

A photograph of a desert landscape. In the foreground, there are several low-lying shrubs with bright yellow and purple flowers. The ground is sandy and covered with small, dry plants. In the background, there are rolling hills and mountains under a clear blue sky.

Managing biodiversity of the Greater Fish River Canyon Landscape

A tool for sustainable land management

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Mendes improved the final document.

Summary

A biodiversity zonation for the Ai-Ais Hotsprings Game Park completed in 2011 was extended to include the Greater Fish River Canyon Landscape. Plants were used as indicators in this conservation planning study, because of the comparatively good information base, their importance for ecological processes and their ready use as indicators at a landscape level.

The field surveys supporting this study proved extremely fruitful in that

- they generated new distribution data,
- thereby improved the mapping base;
- they found more evidence for the Succulent Karoo – Nama Karoo biome transitional status and
- lead to the discovery of new plant species!

The extended mapping generated 32 landscape units in the study area, broadly divided into mountains, plains, rivers and inselbergs. A transparent process using endemism, rarity and conservation status of plant species as indicators was employed to prioritise the landscape units in terms of biodiversity importance. This is a relative assessment to help prioritising, but does not mean that those of lower ranking are not important for biodiversity conservation.

The mountain units in the west and south of the study area (southern Huns and Namus mountains) are those of highest conservation importance in the study area. The plains in the winter rain influenced Succulent Karoo Biome (Dreigrat plains and Succulent Karoo sand plains), as well as mountains towards the east along the Orange and Fish rivers also emerged as being of high conservation importance.

Detailed descriptions of the landscape units provide information on resource use, threats and management guidelines. Please use it and—wisely!



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Not only plants are of interest in the mountainous terrain of the Greater Fish River Canyon Landscape – here a rock monitor on the foothills of the Klein Karas mountains.

Background

Namplace is a project funded jointly by the Global Environment Facility and the Namibian government and addresses the need for integrated land management of protected areas and their surroundings. The Greater Fish River Canyon Landscape is the pilot area in southern Namibia. Establishing a biodiversity baseline and using this to zone the landscape for different land uses is a fundamental step to achieve wise management of natural resources.

In this context Namplace commissioned a biodiversity zonation of the planning domain of the Greater Fish River Canyon Landscape (GFRCL) in southern Namibia. This study is a continuation of the biodiversity zonation for the Ai-Ais Hotsprings Game Park (AHGP) which was completed for the Ministry of Environment and Tourism in 2011 (Burke 2011). A similar approach and methodology are followed in this study.

The study area

The study area covers about 11500 km², somewhat less than half the size of the Sperrgebiet National Park to the west. It is positioned at the interface of three major Southern African biomes, the Succulent Karoo, Nama Karoo and Desert biomes.

The climate is arid and mean annual rainfall ranges between 0 and 100 mm, increasing along a south-west to north-east gradient. Both, summer- and winter rains can occur. Mean annual temperatures range between 16 and 20°C increasing along a west-east gradient (Mendelsohn et al. 2002). However, these broad bioclimatic gradients are locally modified by the mountainous terrain in the study area. The higher reaches likely receive more rainfall and temperatures are more moderate here. Occasional fog influences the western part of the study area and the south-eastern corner borders one of the hottest areas measured in Namibia.

The topography is very rugged and altitudes range from less than 100 m at the deeply incised Orange River to 1654m (amsl) at the Namuskluft peak. The underlying geology is fascinating and ranges from the oldest rocks in Namibia to recent Quaternary sediments. In large parts of the study area some 600 to 550 million year old sedimentary rocks of the Nama Group are exposed. But there are also gneisses, granites and other metasedimentary rocks of the Namaqua Metamorphic Complex and the Gariep Group, as well as sedimentary rocks and volcanic intrusions of the much younger Karoo Group (Swart 2008).

In summary, this is an area of high diversity in landscapes and climatic extremes.



How to use this report

The information contained in this document can be used in many different ways.

Land use planning

This biodiversity- and resulting IUCN-based zonation provides a data-based prioritisation to recognise landscape units of particular importance for biodiversity in this area. Those of highest importance deserve more protection than others and should ideally be utilised for conservation. The map of biodiversity importance (Fig. 4) indicates where these are positioned in the Greater Fish River Canyon Landscape. The map with the IUCN classification shows how current land use has been integrated with the biodiversity zonation (Fig. 5).

Management

Overall management objectives should be linked to land use planning. The rating of biodiversity importance and IUCN conservation category for each landscape unit (Fig. 5) give some direction here. The descriptions of the individual landscape units (pp. 19-89) provide detailed guidelines for management actions that apply to a particular unit.

Environmental assessments

This landscape-level biodiversity assessment can direct more detailed Environmental Impact Assessments where these are required. For example, areas zoned of high and medium biodiversity importance have to include biodiversity specialist studies in the field undertaken by adequately trained and experienced specialists during the appropriate season. This should ideally be the case in all areas, but is currently not practiced in Namibia by all professionals or enforced by the authorities. This should be the minimum standard in all areas identified of biodiversity importance and areas managed for conservation and tourism.

Although the information contained in this document can be used to describe the natural environment to be impacted, this information is by no means adequate as a baseline to assess and monitor potential impacts. More detailed studies at the level of the impact area are always needed, irrespective of biodiversity importance.

Research

The detailed descriptions of the landscape units (pp. 19-89) indicate gaps in biodiversity knowledge which help to direct further research. In terms of plant inventories, data gaps are also indicated in Table 7.

General information

Landowners interested in finding out more about plant diversity on their land can glean information from this document. Appendix 1 is a list of species of conservation importance per landscape unit. The table below (Tab. 1) outlines which landscape units belong to a

management area (farm or nature park). By extracting the plant species from the relevant landscape units, landowners will obtain a list of plants of conservation importance likely to occur in their area. There are possibly more (sometimes perhaps less), (1) as the mapping units do not completely coincide with the management units and (2) not all areas have been covered equally in the field. Yet the species lists will give a reasonable approximation and can alert landowners to look out for certain plants.

Table 1. Link between management and mapped landscape units in the GFRCL.

Management unit	Landscape units
Aussenkehr Nature Park	Aussenkehr hills, Gamkab plains, South-east Orange mountains
Canyon Nature Park	Moedhou plains, North-west canyon lands
Einaug	Gawachab plains, Klein Karas mountains
Gabasis	Gawachab plains
Gondwana Canyon Park	Altdorn hills, Canyon slopes, Eastern sand plains, Gawachab plains, Gondwana hills, Holoogberg, North-east canyon lands,
Konkiep Park	Canyon slopes, Konkiep plains, Northern Huns mountains, North-west canyon lands
Naute Game Park	Gwachab plains, Naute plains, Naute inselbergs, Löwen river
Namuskluft	Dreigrat plains, North-east Namus mountains, Western Namus mountains
Trekpoort	Succulent Karoo sand plains, Nudavib mountains
Zebrafontein	North-east Namus mountains, Western Namus mountains, Succulent Karoo sand plains, Zebrafontein plateau



Approach

Plants are used as indicators to evaluate biodiversity importance because:

- They are at the bottom of the food chain and thus form the basis for most other biodiversity, thus supporting important ecological processes.
- Vegetation can be readily used for landscape-level mapping.
- Information on plant distributions in Namibia is electronically available and retrievable, although not complete for the entire country and at a coarser scale than required for this study.

Preparation and field work

Available plant distribution data (at quarter degree square resolution, i.e. 15 minute intervals on a latitude-longitude grid) were requested from the National Botanical Research Institute to guide the planning of the field work. A rapid assessment was necessary since the vegetation season is brief and only two fieldtrips were planned for the entire study area – one in the summer season (March-May) in the eastern study area, and one in winter (August-October) in the western part.

Gaps in plant distribution data in the eastern part of the study area were identified in the following areas (Fig. 1):

- Naute (new addition to National Park) (grid: 2918CC)
- Klein Karas Mountains (grids: 2718AA, 2718AC)
- Northern canyon (grid: 2717BA)
- North-western canyon (grid: 2717BC)
- South-east corner (grid: 2817BD) and
- Orange River near Aussenkehr (grid: 2817CB).

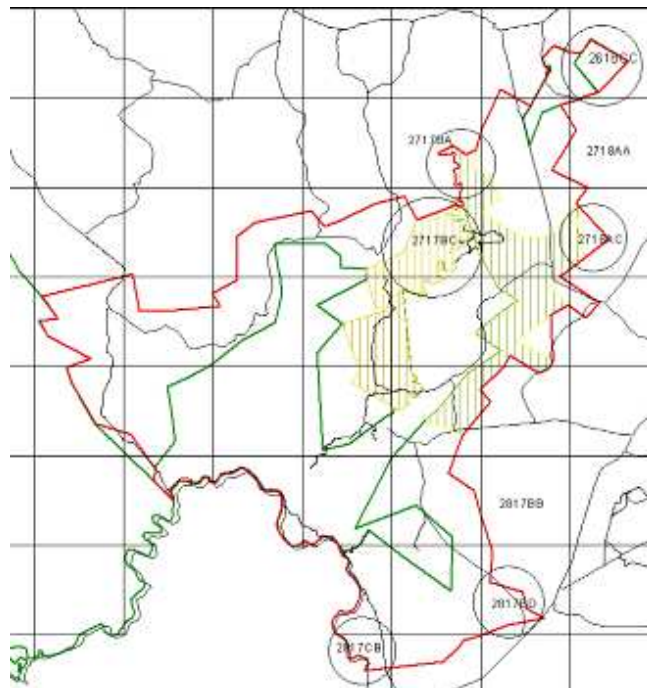


Figure 1. Provisional target areas for summer field survey in the Greater Fish River Canyon Landscape.

The final selection of areas targeted during the summer survey took these data gaps into account, but also included rainfall patterns and representative coverage of all key landscapes. Only one significant rainfall event occurred in the summer season during the period 29-31 March 2013. Also the rains were patchy and ranged between 0 and 54 mm across the eastern part of the study area.

The study was explained to the GFRCL stakeholders at a meeting in Ai-Ais 19 April 2013, and fieldwork commenced immediately after the meeting and extended to 4 May 2013. The fieldwork was undertaken by me and Leevi Nanyeni of the National Botanical Research Institute, with assistance of various GFRCL members in the respective areas.

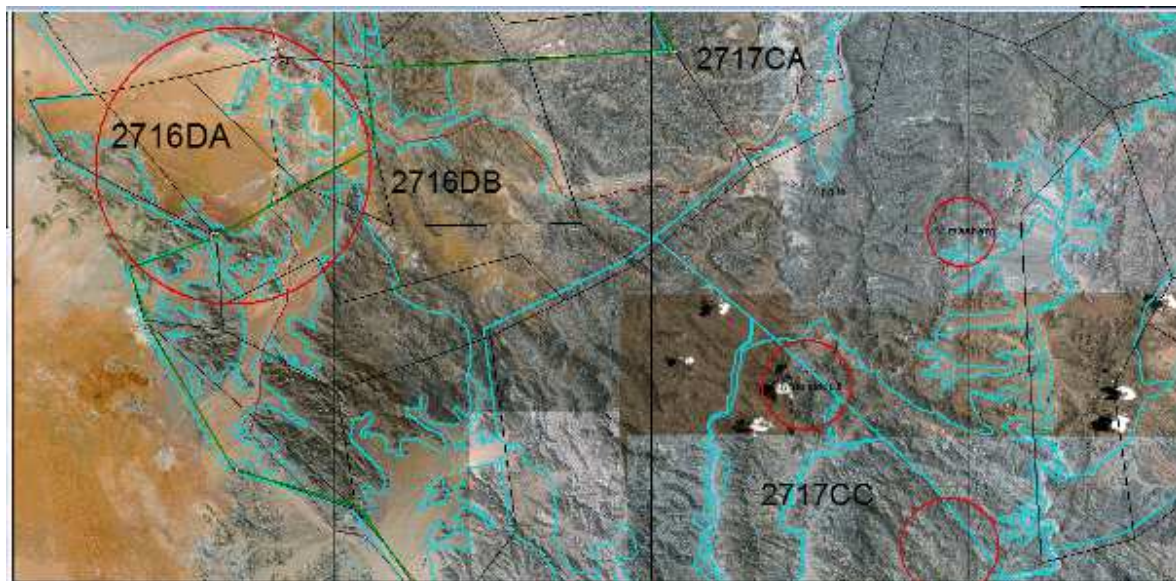


Figure 2. Provisional target areas for winter field survey in the Greater Fish River Canyon Landscape.

The winter survey had a selection of provisional target areas. The final selection, however, followed rainfall patterns and the field survey was largely undertaken in 2716DA, DB and DC, mainly on the farms Zebrafontein and Trekpoort, which had received approximately 35 mm in a rain event in September.

Data processing and analysis

Mapping

A Google image as used for the previous mapping for Ai-Ais Hotsprings Game Park was used to delineate homogenous mapping units. The mapping for the park was incorporated and some adjustments were made in few areas, usually at the boundary with the broader mapping domain. Most mapping took place at 1:100,000 scale. High resolution Google images obtained for Namplace were used to clarify some mapping boundaries where the overview image did not provide sufficient detail. At the scale of the planning domain species-level mapping, even of characteristic plants such as the Karas euphorbia (*Euphorbia gregaria*), was not possible.

Information analysis

The field data collected during 2013 were combined with the data from the previous survey in the AHGP and EIF-supported project along the Orange River. Because of the more extensive coverage of the area, it was now also possible to integrate some plant distribution data of the National Botanical Research Institute's specimen database. Also data from the Karios observatory of the BIOTA project were included (Jurgens et al. 2010), as were data of an inselberg survey in the Klein Karas area (Burke 2001) and various data collected for environmental assessments in the western part of the planning domain. Plant species lists were then compiled for each landscape unit. These species lists cannot be considered complete as repeated surveys over many years and a much larger coverage, particularly of the less accessible areas, is required to achieve this. Also some plant collections from the study area are still awaiting processing at the NBRI and could thus not be included. The species lists, however, serve as relative indicators to provide some means of describing the landscape units and their attributes.

Each landscape unit was named and described by outlining locality, habitat and environmental parameters and key biodiversity components. The conservation importance was rated and resource use and other aspects of biodiversity importance described. Management recommendations and research needs were also provided for each landscape unit. The descriptions of landscape units from the Ai-Ais Hotsprings Game Park biodiversity zonation was included and updated where necessary.

At a particular request of stakeholders, the Rosh Pinah state land was included in the mapping in this revision of the report, because of management issues surrounding the town. This area was previously not included in the Greater Fish River Canyon Landscape. One new mapping unit had to be added – the Obib mountains. Only the eastern-most outliers extend into the mapping domain of the Greater Fish River Canyon Landscape, whereas the majority of these mountains are in the Sperrgebiet. The description of this landscape unit was transferred directly from the biodiversity zonation of the Sperrgebiet (Burke 2006), but not included in the data analysis.

Table 2. Aspects included in the descriptions of the landscape units.

Aspect	Description
Landscape unit	Descriptive name based on geographic landmark
Locality	Geographical position indicated on overview map
Habitat and environmental parameters	Geology, landform, substrate, climate and other main physical environmental parameters
Extent	Surface area covered by landscape unit
Description of vegetation	Growth forms, vegetation cover, key species, diversity
Conservation importance	Conservation importance, based on occurrence of important plant species (protected, endemic, Cites and/or red-listed) and importance for wildlife and ecological functioning ; listing of biota of conservation importance
Resource use and other aspects	Importance of landscape unit for wildlife, other uses, as well as other information related to this mapping unit
Threats	Imminent and possible threats, (e.g. alien plant species, land management, poaching)
Management	Management guidelines, including proposed zoning category
Research needs	Needs regarding biological data (reference to data quality)

Definition of indicators

The recorded plant species were rated based on the criteria endemism, red-list status according to IUCN (Loots 2005), rarity and conservation status in the following manner:

Table 3. Rating of plant species according to level of endemism, red list status, rarity and conservation status.

Category	Description	Rating
Endemism	Southern Namib or southern Karas	3
	Namib Desert or Gariiep Centre of Endemism	2
	Namibia	1
Red list status	Endangered	3
	Vulnerable	2
	Near-threatened	1
Rarity	1-3 qds	3
	4-6 qds	2
	7-10 qds	1
	> 10 qds	0
Protected		1
Cites		1

Rarity is based on the number of recorded distributions in quarter degree squares (1 qds = 15 minute intervals on a longitude-latitude grid). One quarter degree square (qds) is approximately 625 to 650 km² in Namibia, depending on its position in relation to the equator. That means 3 quarter degree squares amount to 1875-2025 km², which is close to the 2000 km² threshold of a plant species' range considered critical by IUCN (2001). The rating used in this assessment is based on these figures. The NBRI's specimens database, published sources (e.g. Loots 2005) and own observations were used to determine the known distribution of plant species.

An additional rating of 1 for protected species (Nature Conservation Ordinance 4 of 1975 and 247 of 1977 or Preservation of Trees and Forest Ordinance of 1952 and Proclamation of the SWA Administration No. 486) or Cites (Convention on International Trade in Endangered Species of Fauna and Flora) species was only added, if the species is not endemic, red-listed or rare as these criteria often overlap. The ratings of plant species which received a ranking of conservation importance were added per biotope resulting in one numerical figure for each landscape unit. Nearly one third (265) out of a total of 879 plant species recorded during this study are species of conservation importance (Appendix 1). The highest ranked species are shown in Table 6. Since the data range of the summed scores was very large (2-301) and dominated by one outstanding highly rated mapping unit, a slightly different algorithm was used than in previous assessments using this methodology (Burke et al. 2008). In this study the mean of all values was determined and used to delimit the three class intervals in the manner indicated in Table 4. A rating of high, medium and fair was applied to prioritise those mapping units of highest importance for biodiversity.

Table 4. Range of values applied for biodiversity importance.

Class interval	Value	Biodiversity importance
Lowest value to mean	< 57	Fair
Mean + mean + 1	57-113	Medium
> mean + mean + 1	> 114	High

Data quality was rated to provide some indication of completeness of the plant species list for each landscape unit. The quality assessment took into account the coverage of the area for each biotope and the nature of the rainy season. "Good", "medium" and "poor" were used in this evaluation. "Poor" data quality usually means a lack of rain in these areas which result in a want of short-lived components of the flora such as herbs and bulbs.

Land use and IUCN zonation

In order to apply IUCN conservation categories, land use in the study area was incorporated (e.g. African Wilderness Restoration 2010). The following IUCN categories apply in the study area:

Table 5. IUCN protected area categories and their definition (Dudley 2008).

Category	Description	Management
Ia	Strict nature reserve – protected for biodiversity and possibly geological features	Human impact, visitation, use and impacts are strictly controlled
Ib	Wilderness area – area retaining natural character without human habitation	Managed to preserve natural condition
II	National park – near natural area set aside to protect large-scale ecological processes	Environmentally compatible activities of educational, cultural, scientific and recreational nature are allowed
VI	Sustainable use area – traditional natural resource management system	Low-level non-industrial use of natural resources

The first three categories applied to all landscape units which were largely managed for conservation. This included the state-protected areas as well as private nature reserves. All landscape units where livestock farming is practised were allocated to category VI – sustainable use area. Large landscape units were divided, if they fall under different management regimes. As a result, some landscape units therefore received two IUCN classes. For smaller landscape units predominant land use determined their allocation.

Shortcomings

Unfortunately many of the most remarkable plant records could not be incorporated in the data analysis, since some identifications are still outstanding. This includes potential new species and new records for Namibia which were sent to various specialists in the particular groups of plants, as well as many collections lodged at the National Botanical Research Institute presently awaiting identification.

The plant inventory at this scale of study is by no means complete and many more surveys, particularly during a good rainy season are required. However, the current inventory is considered sufficiently representative to provide a first approximation.

Unfortunately wildlife data are not available at a comparable scale and/or coverage to be incorporated into the biodiversity assessment. The only reasonably complete animal data at the scale of quarter degree squares are bird atlas data. But birds migrate and range over far greater areas than the landscape-level ecological units mapped here. These data could thus not be incorporated. Wildlife censuses are untaken in some parts of the study area, but again, the scale of mapping is not comparable and since these do not cover the entire planning domain, incorporating only some data would skew the overall assessment.

Table 6. The highest ranked plant species of conservation importance in the GFRCL.

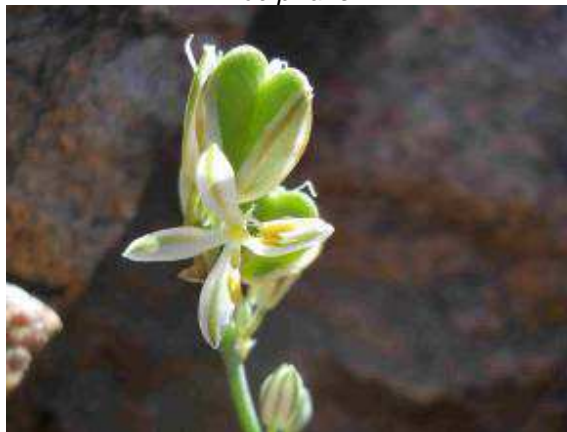
Plant species	Endemism	Red-list	Rarity	Summed rating
<i>Neoluederitzia sericeocarpa</i>	3	3	2	8
<i>Juttadinteria albata</i>	2	2	3	7
<i>Schwantesia loeschiana</i>	3	2	2	7
<i>Aloe pillansii</i>	2	3	1	6
<i>Antimima dolomitica</i>	3	1	2	6
<i>Crassula numaisensis</i>	3		3	6
<i>Elephantorrhiza rangei</i>	3		3	6
<i>Lebeckia dinteri</i>	3		3	6
<i>Monsonia trilobata</i>	3		3	6
<i>Chlorophytum</i> sp.nov.	3		3	6
<i>Ruschia sabulicola</i>	3		3	6



Aloe pillansii



Antimima dolomitica



Chlorophytum sp.nov.



Juttadinteria albata

Biodiversity zonation

The mapping delineated 32 landscape units in the study area. These can be divided into the main landscape categories plains, rivers, mountains and inselbergs. In many cases transitions between these landscape units exist and the boundaries are therefore not always clearly evident in the field. Apart from landforms, other important aspects delineating the mapping units are the prevailing rainfall regime (summer or winter) and in some instances underlying rock types.

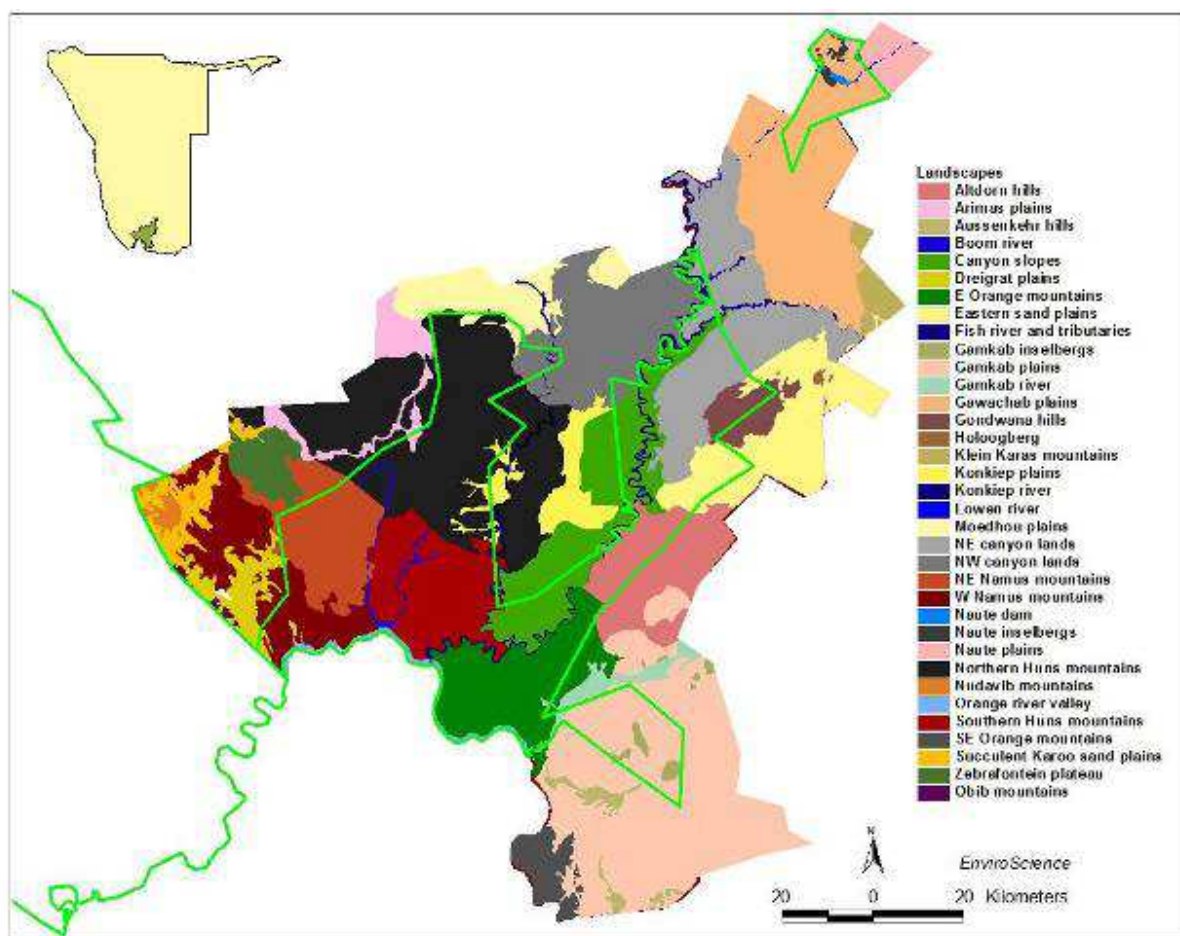


Figure 3. Landscape units in the Greater Fish River Canyon Landscape and boundaries of state-protected areas (bright-green outline).

The western and southern part of the study area is mountainous with plains wedged between these mountains. On the other hand, the eastern and north-eastern part of the study area are covered by extensive plains. The north-central part provides a mosaic of plains and rocky terrain, but unlike in the west and east, these plains are positioned at higher altitude, usually between 1000 and 1400 m amsl. The Fish River Canyon incises deeply into the plateau and rocky terrain in the central-eastern part of the study area resulting in a landscape characterised by deep valleys and steep slopes flanked by plateaus at different elevations.

The largest mapping units were, in descending order Gamkab plains > Northern Huns mountains > Gawachab plains. These collectively cover 35% of the study area.

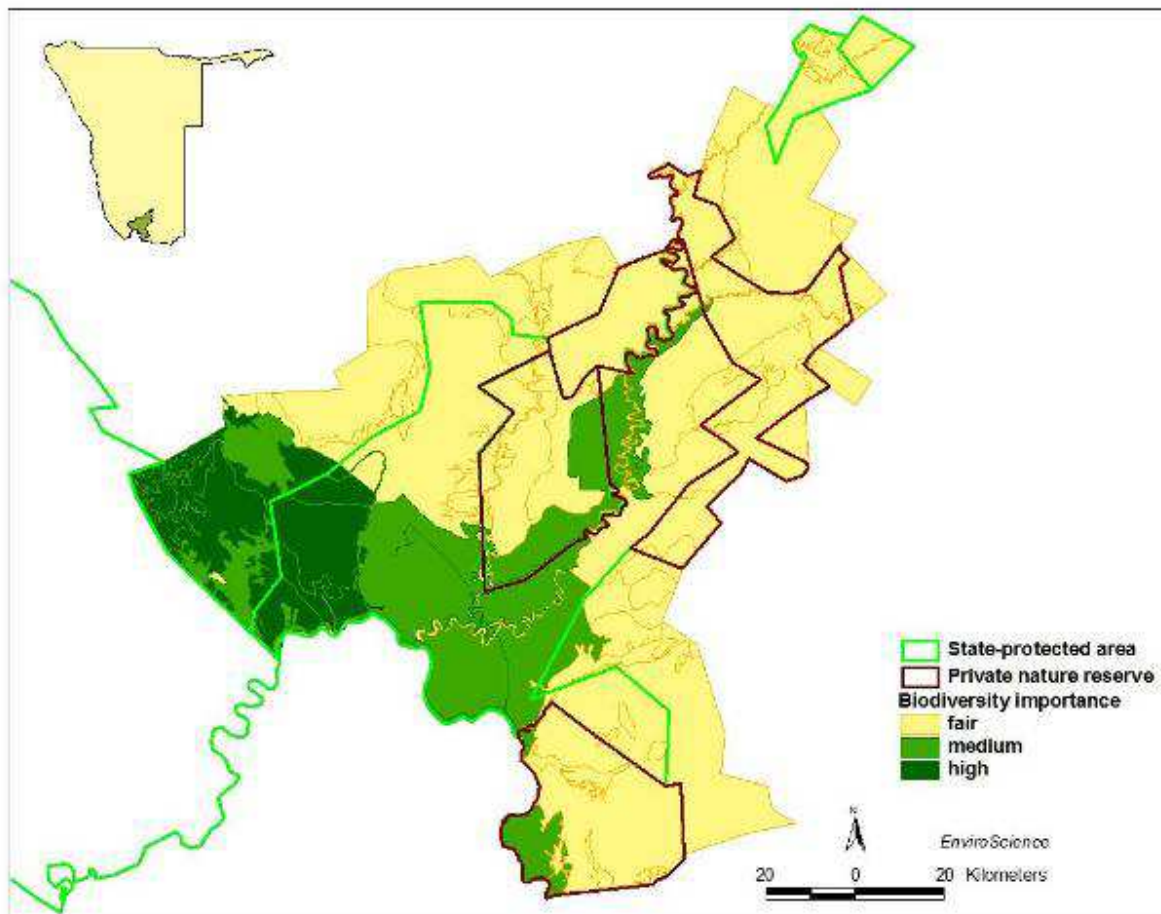


Figure 4. Biodiversity importance in the Greater Fish River Canyon Landscape.

Biodiversity importance in the study area is a relative rating in the context of this landscape. It thereby provides a means of prioritisation, but certainly does not mean that areas indicated of "fair" biodiversity importance do not warrant protection or are not important for biodiversity. This rating reflects plant diversity, - endemism and - rarity, which are widely used indicators in conservation planning (e.g. Pressey et al. 2003; Knapp 2011).

In context of the Greater Fish River Canyon Landscape most of the western succulent karoo section of the study area is classified of "high" conservation importance, the remainder of the winter rainfall influence area of "medium" conservation importance. "Medium" conservation importance also extends north-east along the Fish River and east along the Orange River. This rating clearly indicates the ecological importance of river systems and mountain areas in this arid landscape as well as the overriding influence of winter rainfall.

The majority of the study area is zoned for conservation with different levels of protection. Within this, areas rated "high" in biodiversity importance deserve to be protected as "strict reserves". These are largely the mountains in the south-western part of the study area. But not all areas of "high" and "medium" biodiversity importance could be zoned with adequate protection as some fall into livestock farming areas. This includes the Nudavib mountains, the Dreigrat plains, the Succulent Karoo sand plains and the Zebrafontein plateau in the south-west. Parts of two presently "medium" rated landscape units (Canyon slopes and

southern Huns mountains) were allocated “strict reserve” status, because their inventories are not as complete as the adjoining landscape units and they are expected to receive a higher rating once more data are added.

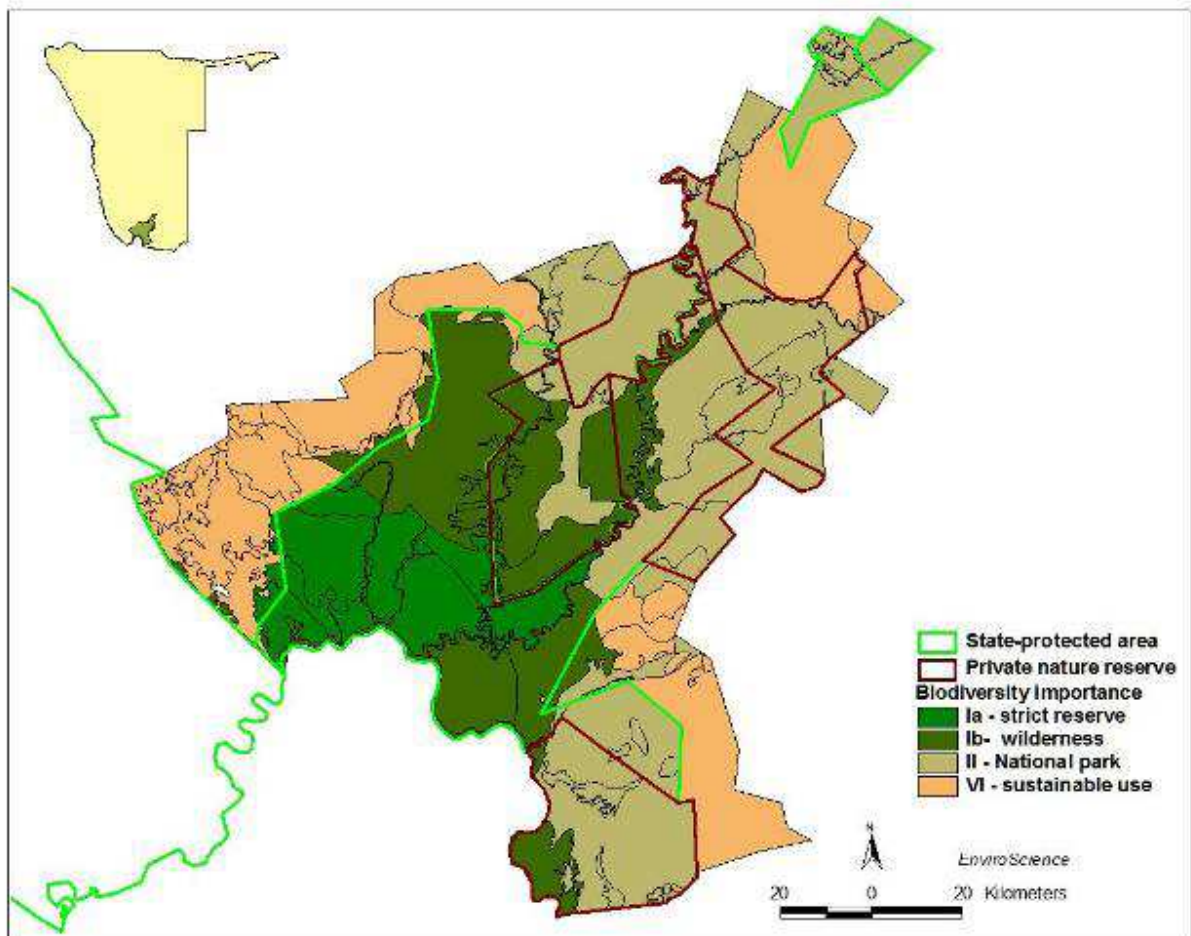


Figure 5. Zoning of the Greater Fish River Canyon Landscape according to IUCN conservation categories.



The plains surrounding Rosh Pinah are of great conservation importance, but heavily utilised.

Key findings

No question – the Ai-Ais Hotsprings Game Park and the adjoining Greater Fish River Canyon Landscape are of tremendous biodiversity importance, in terms of plant species richness only surpassed by the Sperrgebiet National Park in Namibia. Steep altitude gradients, the traversing of a perennial river and the bioclimatic gradient from Succulent to Nama Karoo biome also guarantee that important ecological processes are supported in this landscape.

Improved inventory More intensive surveys, particularly in hitherto poorly collected areas, have generated range extensions (new records of plants in areas where they have not been found previously), turned up new records for Namibia (species known only in South Africa, but now also found in Namibia) and lead to discoveries of several new plant species!

Discovery of new plant species This is certainly most exciting news, as plants are relatively well studied in Namibia and finding new species is not a daily event. Plant material is still with various specialists around the world, but so far four new species haven been found with certainty, and possibly two more may be described.



An exciting quartet – *Chlorophytum* sp.nov. (top left), *Oxalis canaliculata* (top right), *Oxalis hunsbergensis* (bottom left) and *Moraea thermarum* (bottom right).

Three of these new discoveries come from the southern Huns, western Namus mountains and eastern Orange mountains, all from slopes along the Orange River and thus not necessarily inaccessible terrain. *Oxalis hunsbergensis* is not strictly speaking a new discovery, because it had been found before, but because of lack of flowers could not be described. We found it in flower now.

Improvements to previous ecological mapping The better data base enabled me to revise the previous mapping for the Ai-Ais Hotsprings Game Park and resulted in a division of the mountain areas into smaller landscape units. Also some of the boundaries were slightly adjusted.

The Succulent Karoo – Nama Karoo biome boundary The boundary between these two biomes traverses the study area in a north-west-south-easterly direction. The Namus and Huns mountains are a transitional area, which to some extent accounts for their high plant diversity. More field surveys confirmed this, but also lead to the discovery of some succulent karoo vegetation outposts within the Nama Karoo biome. This was the case in the Altdorn hills and the Aussenkehr hills.

Room for improvement

Although this study has improved the biodiversity knowledge base for this area and presented a transparent process for prioritisation, ideally indicators of fauna should also be incorporated in the long-term. Whatever indicators are selected, it is important to obtain relatively even data coverage across the entire study area. Some suggestions for suitable indicators are:

- Wildlife corridors of key species such as mountain zebra.
- Bird nesting records, perhaps of a few representative species of conservation importance.
- Determination of habitat specialists and their respective ranges (e.g. endemic fish or invertebrates).



The landscape units

Table 7. Landscape units, their biodiversity rating, survey period and data quality in the GFRCL.

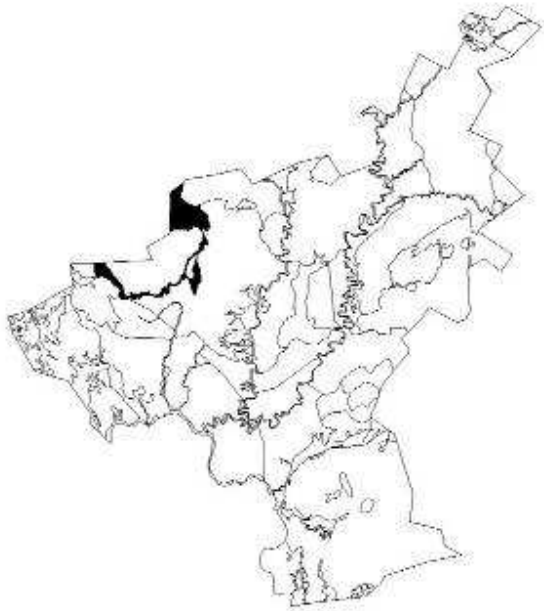
Landscape unit	Biodiversity rating	Survey	Data quality
Altdorn hills and plains	Fair	2013	Good
Arimas plains	Fair	2011,2013	Poor – dry!
Aussenkehr hills	Fair	2013	Good
Canyon slopes	Medium	2011	Good
Dreigrat plains	Medium	2011,2013	Good
Eastern sand plains	Fair	1999, 2011	Good
Eastern Orange mountains	Medium	2012	Poor – dry!
Fish river and tributaries (incl. Gaap, Konkiep)	Fair	2011	Moderate
Gamkab inselbergs	Fair	2011	Good
Gamkab river	Fair	2011	Good
Gamkap plains	Fair	2011,2012	Good
Gawachab plains	Fair	2013	Good
Gondwana hills	Fair	2013	Moderate
Holoogberg	Fair	1999	Good
Klein Karas mountains	Fair	2013	Moderate
Konkiep plains	Fair	2013	Moderate
Lowen river and Naute dam	Fair	2013	Moderate
Moedhou plains	Fair	2011	Poor – dry!
NE canyon lands	Fair	2013	Moderate
NW canyon lands	Fair	2013	Moderate
NE Namus mountains (Nama)	High	2013	Moderate
Obib mountains	High	2006	Moderate
W Namus mountains (Meta)	High	2012,2013	Moderate
Naute inselbergs	Fair	2013	Moderate
Naute plains	Fair	2013	Moderate
Northern Huns mountains	Fair	2011	Poor – coverage
Nudavib mountains	High	1997,1999,2013	Good
Orange River valley (incl. terraces)	Medium	2012	Good
SE Orange mountains	Medium	2013	Moderate
Southern Huns mountains (meta)	Medium	2011, 2012	Poor – coverage
Succulent Karoo plains	High	1997, 2009, 2013	Good
Zebrafontein plateau	Medium	2013	Good

The recent surveys supported by Namplace have raised the data quality of the botanical inventory substantially. Although the 2013 rainy season was overall poor, localised rains fell in some hitherto poorly collected areas and enabled us to improve the inventory. This was particularly true in part of the Gondwana Canyon Park, the Aussenkehr Nature Park, along the Orange River and on the farms Namuskluft, Trekpoort and Zebrafontein.

Landscape units which are still shown as poorly collected had not received any rains during the survey periods. Many of the mountainous areas can only be rated as moderately well collected, because overall coverage of these mapping units is not adequate. These are very difficult to access.

Plains

Arimas plains



Habitat and environmental parameters

Part of the open valley and plains between sections of the Huib Hoch plateau and the Huns mountains, these gravel and alluvial plains are at approximately 1000 m (amsl). The Arimas river traverses these plains. They possibly form a transitional area between the Succulent and Nama Karoo biomes.

Extent 178.4 km², 1.6% of study area.

Description of vegetation The plains support moderately dense dwarf shrubland, while taller shrubs line drainage channels. The Arimas river supports some tress such as camel thorn (*Acacia erioloba*). The succulent shrub *Zygophyllum decumbens* is dominant on the plains, with *Zygophyllum rigidum* locally abundant. *Sisyndite spartea* and *Rhigozum trichotomum* are dominant in drainage lines. In some areas *Brownanthus arenosus* and *B. ciliatus* dominate locally.

Conservation importance **FAIR** Despite the poor rains in this area, some perennial plants of conservation importance were found. These include *Cheiridopsis caroli-schmidtii*, *Euphorbia cibdela*, *Jamesbrittenia bicolor*, *Psilocaulon salicornioides*, *Ruschia odontocalyx*, *Zygophyllum applanatum* and *Z. longicapsulare*.

Resource use and other aspects This area is used for livestock farming.

Threats Possibly overgrazing during drought periods.

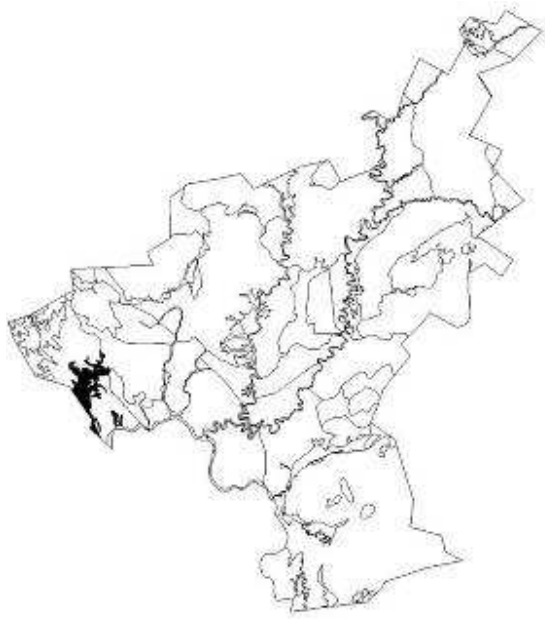
Management No particular management guidelines. IUCN category VI.

Research needs Data quality has been rated poor, since the area was dry during both survey periods.



The Arimas plains support largely deciduous dwarf shrubs, but the short-lived flora was absent during the surveys because of lack of rain. A greater diversity is expected in a good season.

Dreigrat plains



Habitat and environmental parameters

Mostly sandy, these plains are framed by mountains and ridges. They are within the extended coastal influence area along the Orange River and experience occasional fog and strong southerly winds. These plains slope from 450 m amsl at the foot of the Namus Mountains in a south-westerly direction towards the Dreigrat Mountains and the Orange River at 150 m amsl. They fall into the winter rainfall influence area.

Extent 143.5 km², 0.85% of study area.

Description of vegetation Grasses, dwarf and taller shrubs are present, providing sparse perennial plant cover. Drainage lines are more densely vegetated, mainly by tall shrubs. These plains are characterised by the large *Euphorbia gummifera*, accompanied by *Calicorema capitata* and *Brownanthus arenosus*. The tall shrubs *Sisyndite spartea* and *Zygophyllum prismatocarpum* are dominant in drainage lines. Bushman grasses (*Stipagrostis ciliata*), *S. obtusa* and *S. subacaulis* dominate on the more sandy areas. Well over 100 plant have so far been recorded.

Conservation importance **MEDIUM** Astoundingly colourful after rains and species-rich, these plains support a variety of plants of conservation importance. More than one quarter of the recorded species fall into this category. Succulent dwarf shrubs include several *Drosanthemum*, *Eberlanzia*, *Euphorbia*, *Stoeberia* and *Zygophyllum* species, while *Nemesia* and *Trachyandra* species add a colourful short-lived component. Also present are *Aloe dichotoma*, the dwarf succulent *Dracophilus dealbatus* and *Hoodia* species.

Resource use and other aspects These plains are some of the few accessible areas near Rosh Pinah and thus suffer from recreational use and excessive collection of firewood. Tracks made by off-road driving are the most obvious impact, but illegal plant collecting and prospecting and mining activities take their toll on biodiversity. Disturbances from abandoned mines have to date not been rehabilitated.

Threats

- Off-road driving
- Illegal plant collecting
- Firewood collection
- Quarrying, mining and prospecting
- Infrastructure developments

Management

- Investigate and supply alternatives for the use of firewood
- Prohibit off-road driving and implement control measures
- Rigorously enforce Environmental Management Act

- Rehabilitate abandoned mines
- IUCN category: VI

Research needs Field-based red data assessments and monitoring of range-restricted plant species is critical in this landscape unit.



The tall succulent shrub *Euphorbia gummiifera* (foreground) and various *Stipagrostis* grasses characterise the Dreigrat plains.

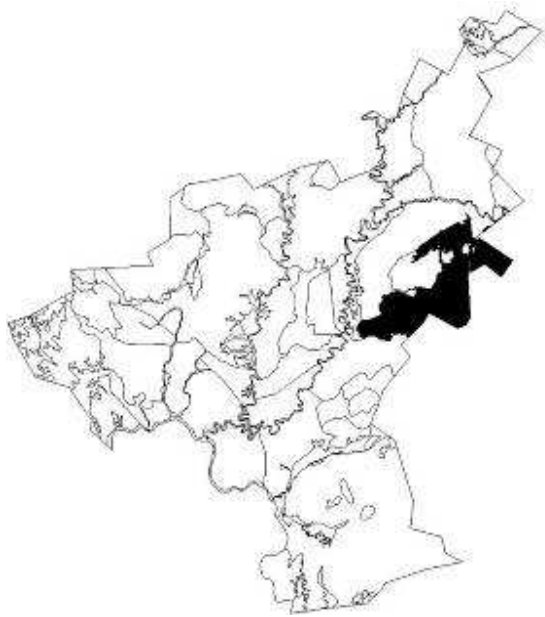


Although far from the coast, fog still provides a fair amount of moisture to plants in this area.



The astounding diversity of these plains becomes apparent during the vegetation season.

Eastern sand plains



Habitat and environmental parameters

The vast expanse of plains, washes and low outcrops in the eastern part of the study area has been combined in this mapping unit. This includes sand as well as gravel and calcrete plains. The plains gently slope to the south-west from an average of 1050 to 450 m (amsl). Temperatures in this part of the study area are on average hotter than elsewhere (maximum temperatures during hottest month 34-36° C).

Extent 586 km², 5% of study area.

Description of vegetation Large sections, particularly the more sandy areas are dominated by grassland, with *Stipagrostis brevifolia*, *S. ciliata*, *S. hochstetteriana* and *S. uniplumis* locally dominant. Vegetation cover here reaches 10-20%. Sections of the gravel plains are locally dominated by the dwarf succulent shrub *Zygophyllum decumbens* and three-thorn (*Rhigozum trichotomum*). In most parts of this mapping unit, however, the tall stem-succulent Karas euphorbia (*Euphorbia gregaria*) is dominant. Isolated quiver trees (*Aloe dichotoma*), in some areas also concentrated, are conspicuous throughout this mapping unit. Dry rivers and washes support some trees and taller shrubs such as *Acacia erioloba*, *A. reficiens*, *Adenolobus garipensis*, *Cadaba aphylla*, *Pappea capensis*, *Parkinsonia africana* and *Sisyndite spartea*. Plant diversity is relatively high for a plain habitat, with just over 100 plant species.

Conservation importance **FAIR** Some 10 % of the recorded plant species are of conservation importance in this landscape unit, such as the endemics *Aloe claviflora*, *Aizoon giessii*, *Blepharis fleckii* and *Caesalpinia merxmullerana*.



A dense cover of perennial grasses, here several *Stipagrostis* species, occurs locally on the eastern sand plains.

Resource use and other aspects The land was used for sheep farming in the past, but is now under management for conservation. Game re-introductions result in thriving wildlife populations, including many animal species that occurred in the area in the past, but had been hunted out (Brown 2006). The grasslands in this mapping unit are of great importance for game.

Threats Mining and prospecting licences cover this area.

Management The entire mapping unit is part of the Gondwana Canyon Park and thus under conservation management.

Research needs Thanks to different data sources, data quality for plants is relatively good, despite the large extent of this mapping unit. Studies at the BIOTA observatory at Karios provided a local inventory of some groups of invertebrates, including some new species and new records for Namibia (Deckert 2010, Mey 2010). However, little is known about invertebrates and particularly small animals in the wider mapping unit.

Gamkab plains



Habitat and environmental parameters

Extensive, gently south-west-sloping plains dissected by a network of drainage lines to the Gamkab River and widely scattered low outcrops characterise this landscape unit. The area descends from approximately 750 m to 150 m (amsl). This is the hottest and driest part of the study area (largely due to being positioned in the rain shadow of the Richtersveld and the Huns mountains) and has by some scientists been characterised as the Lower Orange River Desert Biome outlier (Irish 1994).

Extent 1597 km², 13.9% of study area. This is the largest landscape unit in the study area.

Description of vegetation Most times almost barren, except for the drainage lines and outcrops, annual herbs and grasses can be present in abundance after good rains. Perennial plant cover is no more than 1%, but annual cover can reach 20% locally in good rain years. The tall shrub *Sisymbrium sparteum* is always present, mostly in drainage lines, but the striking succulent creeper *Mesembryanthemum laurifolium* carpets these plains after good rains. The herbs *Myxopappus acutifolius*, *Sesuvium sesuvioides*, *Trianthema parvifolia* and *Zygophyllum simplex* are also present, as are many grasses (*Stipagrostis brevifolia*, *S. ciliata*, *S. namaquensis* and *S. obtusa*). The dwarf shrubs *Calicorema capitata*, *Salsola* sp. and *Zygophyllum decumbens* are locally dominant. Some localised stands of *Euphorbia gregaria* are present. Species diversity hardly reaches 50 plant species.

Conservation importance **FAIR** The southern Namibian endemic *Tetragonia schenkii* grows in some drainage lines and some isolated *Aloe dichotoma* trees and *Ozoroa namaensis* shrubs are present. Nearly 15% of the recorded species are of conservation importance. This area is an important area for wildlife after good rains, as indicated by many antelope spoor.

Resource use and other aspects This is a former livestock farm, and an abandoned quarry is present in this unit.

Threats

- Off-road driving
- The invasive alien wild tobacco (*Nicotiana glauca*) was found near a seepage area.

Management

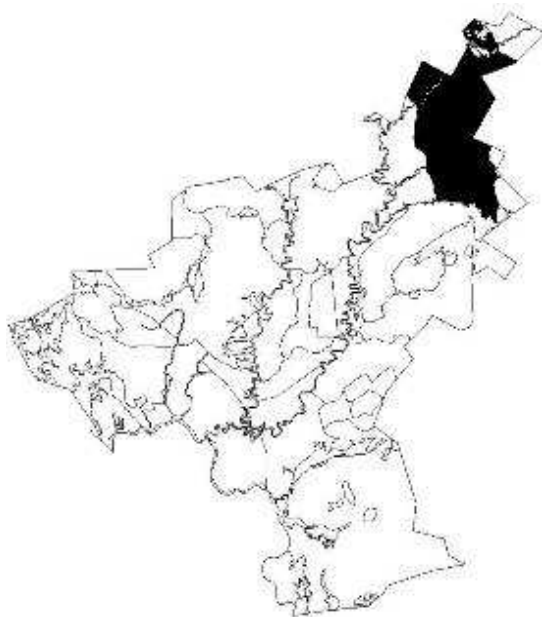
- Prohibit off-road driving and implement effective control measures.
- Eradicate invasive alien plants, where they appear.
- Proposed IUCN category: VI and partly II

Research needs The abandoned quarry indicated on maps of this area may require investigation to assess rehabilitation needs. Data on large wildlife movements would be important to verify animal movement corridors.



After good rains the usually barren Gamkab plains are covered in carpets of succulent creepers (*Mesembryanthemum garusianum*).

Gawachab plains



Habitat and environmental parameters

One of the largest mapping units covering the north-east of the study area, the Gawachab plains comprise plains, drainage lines, shallow dry rivers and low outcrops on sandstones and shales of the Karoo supergroup. The average altitude with a slight tilt towards the Fish River is approximately 750 m (amsl). Gravel covers most of these plains, but there are localised areas with dunes, likely supplied with sand from the Löwen and Fish rivers. This is typical summer rainfall area of the Nama Karoo Biome.

Extent 1006 km², 8.7 % of study area. This is the third-largest mapping unit in the study area.

Description of vegetation Tall- and dwarf shrubland with a low perennial plant cover (no more than 5%) predominates. On most plains the tall stem-succulent Karas euphorbia (*Euphorbia gregaria*) is the dominant plant, replaced by three-thorn (*Rhigozum trichotomum*) in most of the remaining areas. Accompanying the dominant shrubs is a variety of low trees, such as *Acacia mellifera*, *A. reficiens* and *A. hebeclada*, as well as many shrubs and dwarf shrubs (e.g. *Leucosphaera bainesii*, *Phaeoptilum spinosum* and *Zygophyllum decumbens*). *Sisyndite spartea* is dominant in most drainage lines, accompanied by *Adenolobus garipensis*, *Parkinsonia africana*, *Tetragonia schenkii* and the grasses *Stipagrostis brevifolia* and *S. namaquensis*. Plant diversity is surprisingly high for these plains (just over 150 species), but this is possibly linked to the large extent of this mapping unit.

Conservation importance **FAIR** Only 10% of the recorded species are of conservation importance. The succulent *Aloe claviflora* and *Lavrana* species, the endemic shrubs *Haematoxylum dinteri* and *Tetragonia schenkii*, *Hoodia gordonii*, as well as the protected trees *Acacia erioloba*, *Aloe dichotoma*, *Boscia albitrunca*, *Euclea pseudebenus* are some of the species of conservation importance recorded in this landscape unit.

Resource use and other aspects With the exception of plains around Naute dam, most of the land in this mapping unit is used for livestock farming.

Threats

- An assessment of rangeland status was beyond the scope of this study and whether or not overgrazing occurs cannot be stated. However, in this marginal area for livestock farming, there is always a threat of overgrazing.
- The invasive alien tree *Prosopis glandulosa* grows in many drainage lines and dry rivers.
- Hunting and killing of wildlife takes place on some of the farming areas.

Management

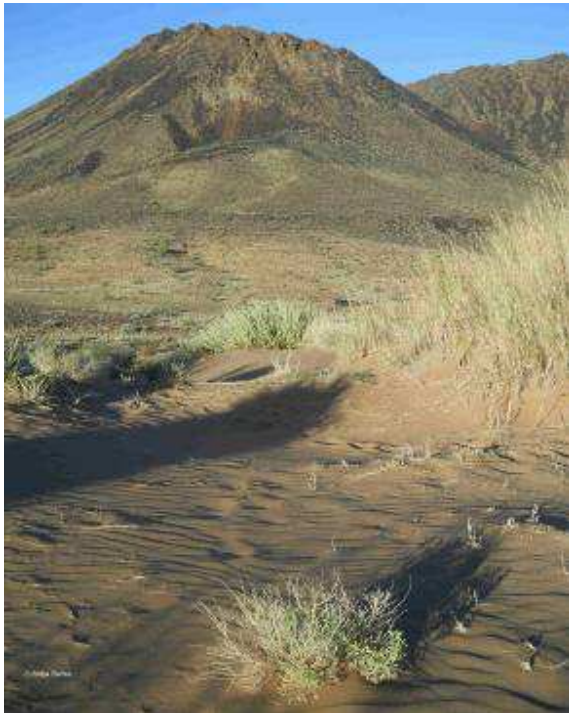
- *Prosopis* control measures should be implemented where feasible, particularly in the Naute Game Reserve.

- Monitoring of wildlife populations, particularly on the farming areas is recommended.
- Proposed IUCN category: VI

Research needs Although this vast area was not covered extensively, available plant data are believed to be representative. There is very little information on wild animals for this mapping unit.



The Karas euphorbia (*Euphorbia gregaria*) and *Stipagrostis brevifolia* are dominant in many parts of the Gawachab plains.

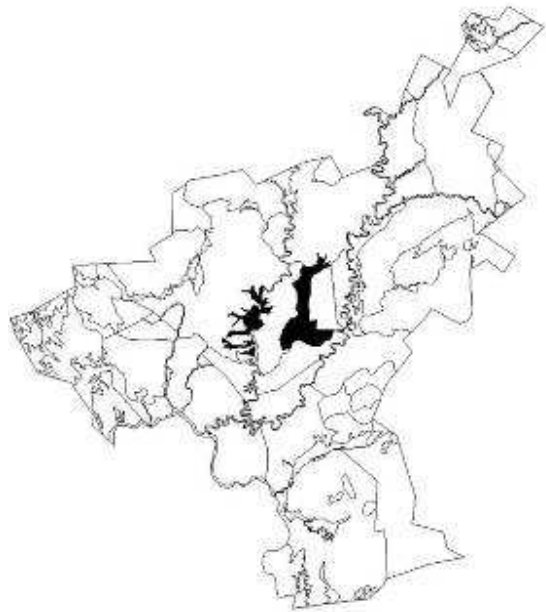


Localised dunes on the Gawachab plains support typical dune vegetation such as *Centropodia glaucum* and *Hermannia gariepina*.



Many *Aloe clavifolia* were dug up in the Holoog area, probably by baboons.

Konkiep plains



Habitat and environmental parameters

The mapping unit “Konkiep plains” comprises two distinct entities separated by the Chumberge, which are part of the “northern Huns mountains”. The eastern section of this mapping unit is a plateau and valley between mountains adjoining the Fish River and the Chumberge, the western section adjoins the Konkiep between the Chumberge and the “northern Huns mountains”. These plains are mostly covered by gravel or colluvium from the adjoining mountain slopes, but some sandy sections are also present. Several dry rivers and drainage lines and low outcrops dissect this landscape unit. These plains are within transitional winter-summer rain area. They slope towards the Konkiep River from about 700 to 450 m amsl.

Extent 241.4 km², 2.1 % of the study area.

Description of vegetation Dwarf shrubland, shrubland and grassland alternate in this mapping unit. Vegetation cover of perennial plants ranges between 5 and 20%. The tall stem-succulent *Euphorbia gregaria* is dominant in most parts, including gravel and sand plains. The dwarf shrub *Petalidium setosum* is locally dominant, particularly in the drainage lines towards the Fish river. Elsewhere, the tall shrub *Sisymbrium sparteae* is dominant in many drainage lines. There are outlier populations of *Ceraria namaquensis* on quartz outcrops. Recorded species richness is presently low (37 species), but not considered complete, as the area has not been covered well nor during a good season.

Conservation importance **FAIR** However, many recorded species (27%) are of conservation importance, such as *Ceraria namaquensis*, many *Euphorbia* species and the stem-succulent *Aloe dichotoma* and several protected trees (e.g. *Acacia erioloba*, *Boscia albitrunca*).

Resource use and other aspects The sections of grasslands in this mapping unit are an important grazing area for wildlife.

Threats None known, as most of this landscape unit is managed for conservation.

Management

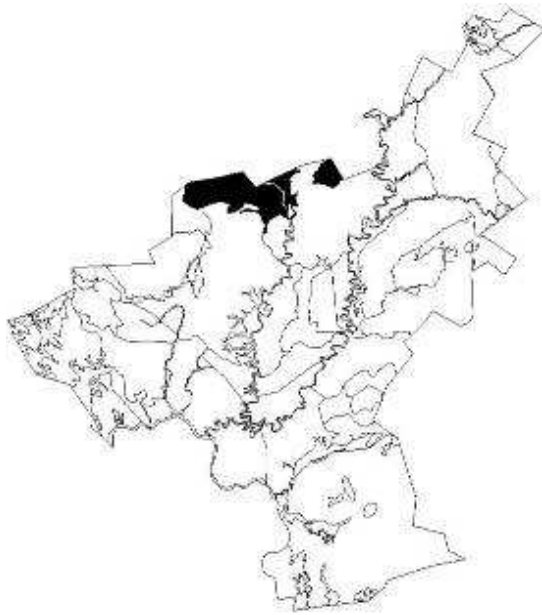
- Proposed IUCN category: II

Research needs Plant data coverage is moderate and should be supplemented during a good season and reviewed once outstanding collections have been incorporated into the NBRI's database. Information on small animals and invertebrates are poor.



Giraffes are doing well in the Konkiep Nature Park, as the Konkiep plains and their imbedded riverbeds appear to provide sufficient browse and fodder.

Moedhou plains



Habitat and environmental parameters

The open plains surrounding the Konkiep River in its upper reaches on the farm Moedhou are included here. The plains are positioned at about 700-750 m (amsl).

Extent 337.8 km², 2.9% of study area.

Description of vegetation The vegetation on the plains is very sparse dwarf shrubland, with perennial vegetation largely concentrated in drainage lines and ephemeral rivers. Here vegetation cover can reach 20%. *Calicorema capitata* is the dominant shrub on the plains, accompanied by *Rhigozum trichotomum* in shallow drainage lines. *Zygophyllum decumbens* is locally dominant or co-dominant. Larger drainage lines and rivers support trees such as *Pappea capensis* and *Euclea pseudebenus* and larger shrubs, for example *Sisyndite spartea* and *Grewia tenax*. Plant species richness is low (just over 50 species).

Conservation importance **FAIR** Although generally not as diverse in plant species as the adjacent mountains, a number of endemics occur in the rivers and drainage lines, such as *Justicia guerkeana*, *Polygala guerichiana*, *Ruellia asperifolia* and *Tetragonia schenkii*.

Resource use and other aspects This landscape unit is used for livestock farming, except the small section which extends into the park.

Threats

- Livestock farming in this very arid area may negatively impact on the vegetation, but this requires longer-term monitoring.

Management

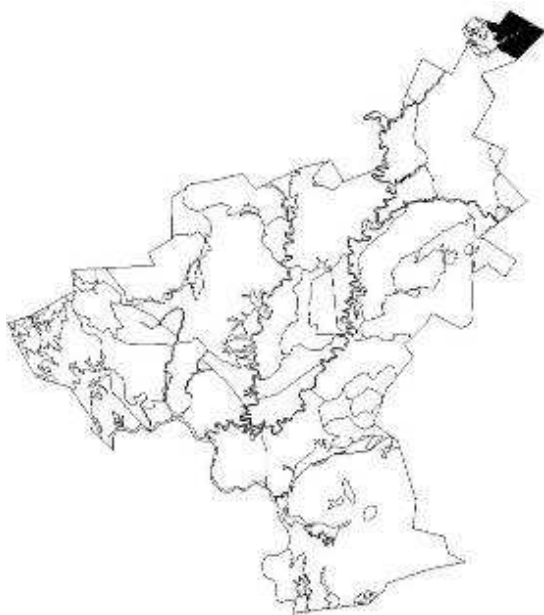
- Proposed IUCN category: VI

Research needs This unit was surveyed during a very dry period and a detailed botanical inventory during a good season is therefore necessary. No animal data were available.



Skirting along the northern extent of the Huns Mountains, the Moedhou plains support a low cover of dwarf shrubs.

Naute plains



Habitat and environmental parameters

Underlain by sandstone and shales, the plains in the northern and eastern part of the Naute Game Reserve are largely level, but dissected by the Löwen river and its shallow tributaries. Gravel and stones provide a surface cover in most areas. At approximately 700 m amsl, they gently slope towards the south. These plains receive summer rainfall.

Extent 121.2 km², 1 % of study area.

Description of vegetation These plains form a mosaic of largely barren areas and areas covered with very sparse dwarf shrubland. Only the washes and the Löwen river support denser and also taller vegetation. Here *Acacia erioloba*, *Adenolobus garipensis*, *Catophractes alexandri*, *Lycium* species, *Parkinsonia africana* and *Tetragonia schenkii* are locally dominant. Not quite 50 plant species have been recorded so far.

Conservation importance **FAIR** Nevertheless some 18% of the species are of conservation importance, for example one endemic herb with a very limited distribution was recorded on these plains (*Geigeria brachycephala*), and many more endemics grow in the drainage lines such as *Indigofera pechuelii*, *Phyllanthus dinteri* and *Tetragonia schenkii*.

Resource use and other aspects Although these plains, most of which are a new addition to the Naute Game Park, comprise former farmland, they appear not to be over-grazed and will be a welcome addition for the parks' wildlife.

Threats Poaching of wildlife has been observed and is likely linked to the agricultural development. The rivers and the dam support many invasive alien plants which are also spreading onto the plains in some areas, particularly along drainage lines. Many more tacks than necessary lead to the water's edge around the dam.

Management

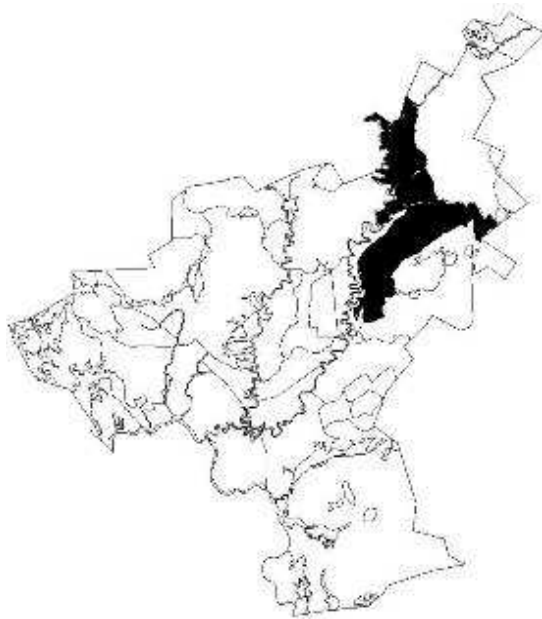
- Near the settlements of the park and agricultural staff, and the recreational areas around the dam, litter and track proliferation will need to be addressed.
- Invasive alien plants, particularly mesquite (*Prosopis* species) will require eradication hand-in-hand with the replacement with indigenous trees, where they provide the only shade.
- Proposed IUCN category: II

Research needs Plant surveys during a good vegetation season are likely to add additional plant species.



The Naute plains support denser perennial vegetation only in drainage lines. The area to the left of the fence is a new addition to the park.

North-east canyon lands



Habitat and environmental parameters A characteristically stepped landscape of dark limestone, sandstone and shales of the Nama Group, adjoining the Fish River provides a mosaic of plains, plateaus and slopes and is dissected by several dry rivers and washes. The steps become steeper and more frequent when the terrain dips from an average of about 750 m (amsl) to the 450 m level of the Fish river. This area receives mainly summer rainfall.

Extent 822.3 km², 7.1 % of study area.

Description of vegetation A sparse cover (perennials not reaching more than 10%) of shrubs is prevalent on the plains. Denser and taller vegetation grows in the dry rivers, and washes. As elsewhere in this part of the study area, the Karas euphorbia (*Euphorbia gregaria*) is dominant in most parts. Three-thorn (*Rhigozum trichotomum*) and *Sisyndite sparteae* are also present throughout this mapping unit. Most diverse are the slopes towards the Fish River, where many additional shrubs, such as *Petalidium setosum*, *Polygala guerichiana*, *Ruellia aspera* and *Zygophyllum* species can be observed. Overall plant species diversity is moderate with just over 80 species.

Conservation importance **FAIR** Nearly 20% of the recorded species are of conservation importance. The endemic shrubs *Haematoxylum dinteri*, *Ruellia aspera* and *Zygophyllum cretaceum* as well as the trees *Aloe dichotoma*, *Maerua schinzii*, *Parkinsonia africana* and several *Euphorbia* species are some of the plants of conservation importance in this landscape unit.

Resource use and other aspects This rugged landscape is well frequented by antelope, mountain zebra and black rhinoceros, indicating good habitat and browse value.

Threats None known at present, as most of the mapping unit is managed for conservation and localised tourism.

Management

- Proposed IUCN category: II

Research needs While large wildlife populations are regularly monitored, data on small animals are absent. The presently "moderate" rated plant data coverage could be improved during a good season.



The alternating plateau and stepped slopes of the north-east canyon lands provide a mix of *Euphorbia gregaria* shrubland, grassland and dwarf shrubland.

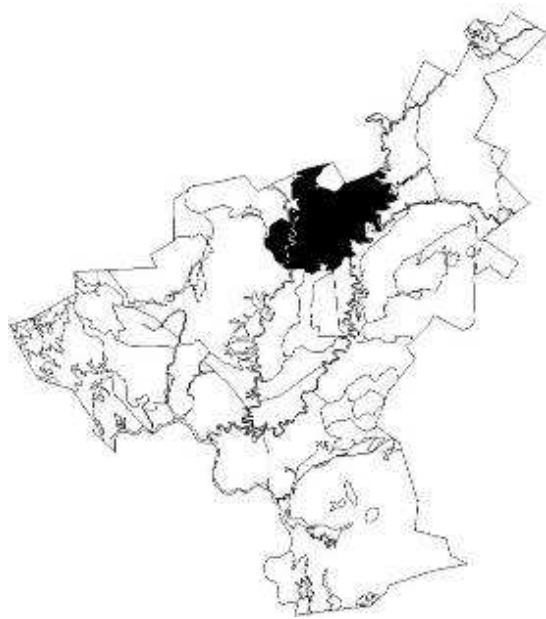


Bloodwood shrubs (*Haematoxylum dinteri*) are an attractive sight when in bloom.



The southern Karas endemic *Haematoxylum dinteri* grows largely on limestone ridges and outcrops.

North-west canyon lands



Habitat and environmental parameters

Similar to the previous mapping unit, the north-west canyon lands are composed of limestone, shale and sandstone of the Nama Group and form a plateau which descends in several stepped layers towards the Fish River. The plateau of the Fischflussrücken is also included here which reaches 800 – 1000 m amsl. Altitudes on the lower part, however range from 500 to 700 m amsl. Summer rains prevail here.

Extent 672.2 km², 7.1% of study area.

Description of vegetation The plateau areas are dominated in most parts by the Karas euphorbia (*Euphorbia gregaria*). *Rhigozum trichotomum* takes over as the dominant plant where *E. gregaria* is absent. The vegetation structure therefore varies between dwarf shrubland and shrubland. Perennial plant cover is low, and hardly reaches 15%. Perennial plant cover can be higher in the kloofs and dry rivers which dissect the rugged terrain. The rivers support tall trees such as camel-thorn (*Acacia erioloba*), sweet-thorn (*Acacia karroo*), *Euclea pseudebenus*, *Pappea capensis* and *Ziziphus mucronata*. A variety of dwarf shrubs grows on the slopes of the various steps, such as *Petalidium setosum*, *Ptychobium biflorum*, *Salsola* species and *Zygophyllum decumbens*. *Zygophyllum rigidum* is locally dominant on the lower plateaus. The grass *Enneapogon scaber* is also associated with most rocky terrain. Plant diversity is comparatively high with just over 100 species.

Conservation importance **FAIR** The Karas endemic bloodwood (*Haematoxylum dinteri*) is associated with limestone and grows in the broken sections of the plateau and the slopes towards the river. Other endemics recorded here are the shrubs *Aspilia eenii*, *Eriocephalus dinteri*, *Petalidium cymbiforme*, *Ruellia aspera* and *Zygophyllum cretaceum*. The protected stem-succulent *Hoodia gordonii* and several *Euphorbia* species also occur. Just of 20% of the total species are of conservation importance. There is possibly a new species of *Oxalis*, which may turn out to be endemic, but this is still awaiting confirmation from specialists.

Resource use and other aspects This mapping unit is entirely in the Canyon Nature Park which is managed for conservation and tourism.

Threats The invasive alien mesquite (*Prosopis glandulosa*) was recorded in one riverbed, and is also found near farmsteads.



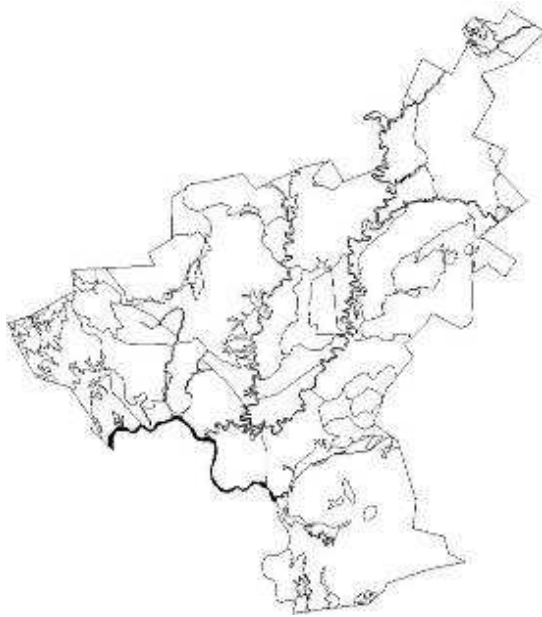
The leaf-succulent *Zygophyllum rigidum* replaces the otherwise ever-present *Euphorbia gregaria* on the lower levels of the steps descending towards the Fish River.

Management

- Control of the invasive *Prosopis glandulosa*, particularly away from human habitations and in riverbeds draining towards the Fish River, is critical to avoid further spread.
- Proposed IUCN category: II

Research needs The plant survey was undertaken during a poor rainy season, and a more complete inventory could be achieved during a good vegetation season. Data quality has thus been rated moderate.

Orange river valley



Habitat and environmental parameters

The permanently flowing Orange River has one of the most extensive catchments in southern Africa and originates in the Lesotho highlands. The wide, open valley of the lower stretches of the river has enabled the coastal influence to intrude much further inland than in adjoining areas. Fog moves in from the west occasionally, reaching the western-most sections of the river, and the strong southerly and south-westerly sea breeze can also be experienced along the western section of the river in the study area. The western part is within the winter rainfall area in Namibia.

Extent 52.5 km², 0.46% of study area.

Description of vegetation This landscape unit comprises the main riverbed, adjoining river banks and terraces.

Reed beds, grass patches, concentrations of sedges and aquatic plants alternate and intermingle along the main river channel, changing according water level and flood impacts. The river banks support stands of riparian woodland and shrubland. These are not continuous, but interrupted where tributaries join the Orange River. Vegetation cover is thus extremely variable, and can reach 100% in dense woodland, sedge, and grass communities, but many areas are also only sparsely vegetated, hardly reaching 5% plant cover. The riverine plant communities are dominated by the tall reeds *Phragmites australis*, occasionally accompanied by *Typha capensis*, various sedges such as *Cyperus*, *Bolboschoenus*, *Schoenoplectus* and *Scirpoides* species and the short grass *Cynodon dactylon*. The riparian woodlands support the tall trees Cape willow (*Salix mucronata*), *Rhus* (*Searsia*) *pendulina*, *Acacia karroo* and *Ziziphus mucronata* and the smaller trees *Euclea pseudebenus* and *Tamarix usneoides*. Shrubs include, amongst others, various *Lycium* species, *Diospyros lycioides*, *Gymnosporia linearis*, *Salsola* species and *Zygophyllum microcarpum*. A variety of herbs grows in the shelter of the woodlands and shrublands, such as *Amaranthus hybridus*, *Cullen obtusifolia*, *Doellia cafra*, *Laggera decumbens*, *Litogyne gariepina* and *Vahlia capensis*. Locally aquatic plants such as *Ludwigia* and *Potamogeton* species form floating mats.

The terraces adjoining the river banks support dwarf shrubland, largely dominated by *Calicorema capitata* on young terraces. Older gravel terraces, particularly those in the west, deserve special attention as they support very diverse dwarf succulent shrubland with many species of conservation importance. Locally dominant are *Eberlanzia sedoides*, *Euphorbia chersina*, *Othonna opima* and *Zygophyllum longicapsulare*. Because of their importance they have been mapped in more detail than possible to depict at the scale of this study (Burke 2012). With over 150 plant species, species richness is high.

Conservation importance **MEDIUM** Although overall rated moderate in the context of this study based on plant species of conservation importance, it needs to be noted that populations of endemics, such as *Amphibolia saginata*, *Hartmanthus pergamentaceus* and

Othonna opima grow on some of the ancient terraces. Some, like *Cephalophyllum herrei* and *Portulacaria pygmaea* are very rare. Many different species of *Crassula*, *Euphorbia*, *Eberlanzia* and *Zygophyllum* further enrich the species diversity of the terraces. Just over 30% of the recorded plants are of conservation importance.

Two near-endemic reptiles – the western sand lizard (*Pedioplanis undata*) and the Namibian worm snake (*Leptotyphlops occidentalis*) have been recorded here (Griffin 2003). The Orange River is also an important habitat for water birds of conservation importance, such as African fish eagle, goliath and purple heron, little bittern, yellow-billed duck and African black duck. Cape Weaver, black and white stork, malachite and lesser double collared sunbird, Namaqua warbler and Cape francolin are also rarer birds that have been recorded in the Orange river valley and surroundings. The lower Orange River is the home of the endemic fish *Barbus hospes* (O’Keeffe et al. 1994).

The river is one of the most important habitats for wildlife in the study area. Due to the permanent river flow it plays a critical role in maintaining ecological functions. However, the river is heavily utilised (see “resource use”).

Resource use and other aspects

- The Orange River is ecologically not in a healthy state due to damming upstream, water abstraction and pollution impacts through fertilisers from irrigation farming and sewage disposal. Irrigation and livestock farming occur even within the boundaries of the national park.
- The gravel banks have been or are currently mined at several places along the river. Where mining has ceased, no attempt of rehabilitation has been made, and where mining is currently active, no progressive rehabilitation is evident.

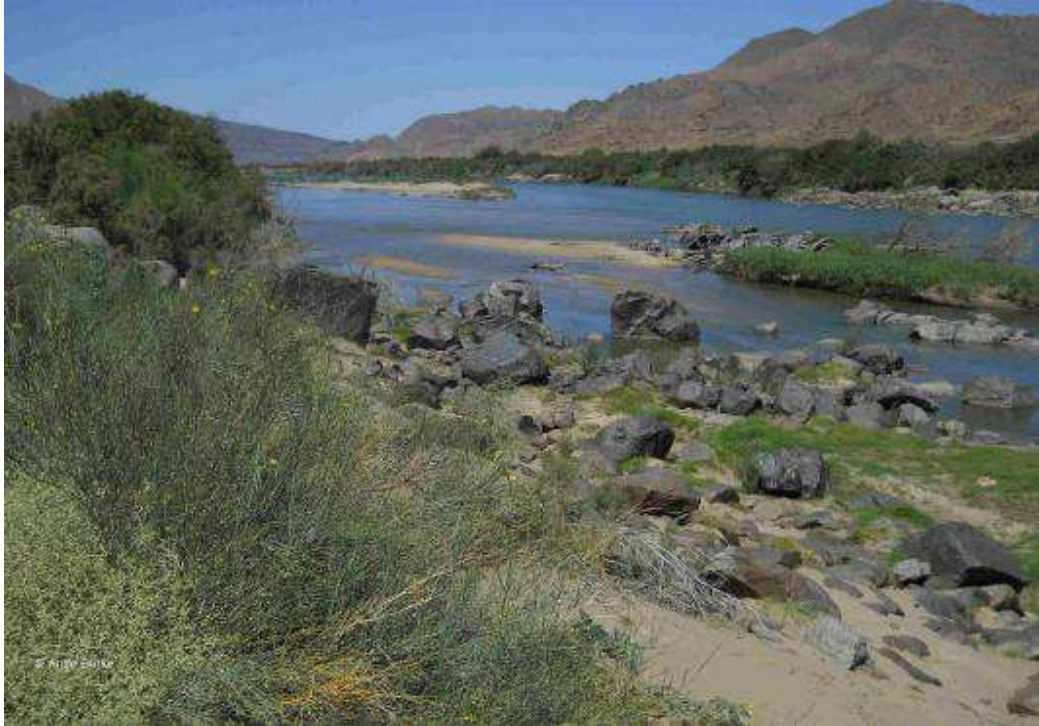
Threats

- Prospecting, mining and quarrying (see above).
- Every invasive alien plant species of concern in the semi-arid and arid parts of Namibia occurs on the banks of the Orange River. Mesquite (*Prosopis* species) has replaced indigenous woodlands along many stretches of the river, often forming impenetrable, monospecific thickets. Castor oil (*Ricinus communis*), Mexican poppy (*Argemone ochroleuca*), wild tobacco (*Nicotiana glauca*) and various thorn apple species (*Datura ferox*, *D. inoxia*) also form, sometimes monospecific, dense stands locally, replacing the indigenous vegetation.
- Irrigation and livestock farming
- Off-road driving
- Illegal plant collecting

Management

- Rigorously implement Environmental Management Act for all prospecting and mining activities and other developments (i.e. undertake environmental assessment and develop management and rehabilitation plans (EMPs)) and regularly check compliance with EMPs.
- Prohibit off-road driving
- Controlling all invasive alien plant species along the Orange River is a formidable task, and not possible without collaboration of all upstream users. Efforts should focus on supporting currently on-going projects in the river basin (e.g. *Prosopis* control) and prevent the further spread of invasives from the river into adjoining habitats. All tributaries to the river are therefore high priority for invasive alien control.
- Proposed IUCN category: Ib

Research needs Although more information on animals is available here than in most other landscape units, more detailed inventories for fauna are desirable. Plant inventory data are relatively good, but field-based Red Data assessments of range-restricted species on the ancient gravel terraces are important. Practical rehabilitation and biodiversity restoration methods have to be developed for disturbed areas.

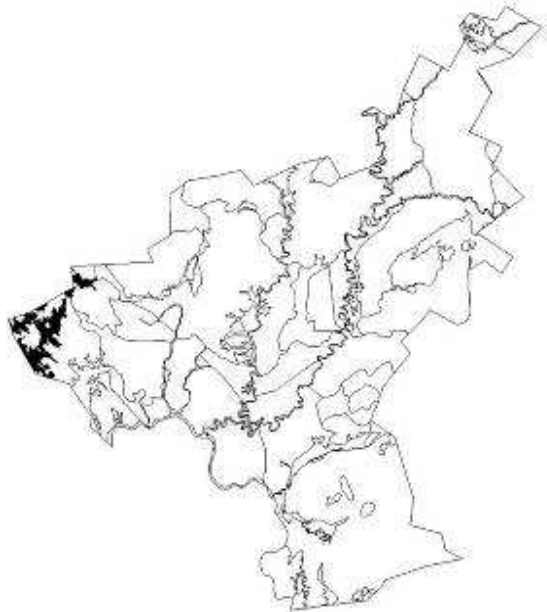


The pretty picture deceives – the Orange River is ecologically one of the least healthy rivers in southern Africa – due to upstream water abstraction, dams and pollution from agriculture, industry and towns.



The ancient Orange River gravel terraces not only contain some diamonds, but also support a specialised flora with many endemics, such the strange and very rare *Portulacaria pygmea* (right).

Succulent karoo sand plains



Habitat and environmental parameters

The largely sandy plains to the west and north of the Namusberge fall within the winter rainfall influence area and are thus part of the Succulent Karoo Biome in Namibia. Shallow drainage lines dissect these south-west sloping plains which descend from about 1000 to 450 m (amsl). Gravel plains and colluvial footslopes occur near the mountains and inselbergs.

Extent 144.1 km², 1.25 % of study area.

Description of vegetation The vegetation is comparatively dense with almost homogenous perennial plant cover between 20-30%. Dwarf succulent shrubs are dominant. Species' dominance varies according to the local area, but *Brownanthus arenosus* is common in most localities. *Aridaria noctiflora*, *Drosanthemum* sp., *Eberlanzia schneideriana*, *Hoodia gordonii*, *Pteronia glabrata*, *Ruschia muelleri*, *Sarcocaulon patersonii* and *Stoeberia beetzii* are other common shrubs on these plains. These are also interspersed with many grasses, such as *Stipagrostis ciliata*, *S. geminifolia*, *S. obtusa* and *S. namaquensis* in washes. The drainage lines occasionally support dense stands of *Euphorbia dregeana*, *Sisyndite spartea* and *Zygophyllum prismatocarpum*. Most remarkable, however, is the great diversity of bulbs and herbs, particularly many daisies, some with a very restricted distribution, such as the bulb *Bulbine namaensis*. Overall, this results in the highest plant diversity encountered on plains in the study area – just over 200 species – equalling the species richness otherwise only recorded in mountains.

Conservation importance **HIGH** Some 27% of recorded plant species are rated of conservation importance. The gravel plains and colluvial footslopes support dwarf succulents, such as *Cheiridopsis robusta*, *Dracophilus dealbatus*, several *Crassula* species, *Ebracteola derenbergiana* and *Lavrana* species, as well as several *Zygophyllum* species. On sand plains the bulbs *Bulbine namaensis* and *B. rhopalophylla*, *Lachenalia giessii* and *pearsonii*, and endemic herbs such as *Crotalaria meyeriana* and *Lessertia eremicola* add to the species of conservation importance.

Resource use and other aspects Most of the mapping unit is used for livestock farming. Although there are presently no obvious indicators of overgrazing, subtle changes in vegetation can only be detected by more detailed rangeland assessments and whether overgrazing is a concern cannot be determined presently. Locally, the sand plains around Rosh Pinah are heavily impacted by vehicle and foot traffic, collection of firewood, littering and pollution. A new mine is in discussion at present which would be situated in the succulent karoo plains.

Threats

- Livestock farming
- Mining and exploration
- Off-road driving
- Locally littering, pollution and firewood collection

Management

- Proposed IUCN category: VI, but should be managed for conservation category Ib

Research needs Local biodiversity inventories for the initial impact assessment of the Skorpion Mine generated some information on small fauna, but also indicated the need for more detailed inventories. Plant inventories are relatively good, but due to the on-going threats, detailed mapping of sensitive areas within this landscape unit to protect critical plant populations is important.



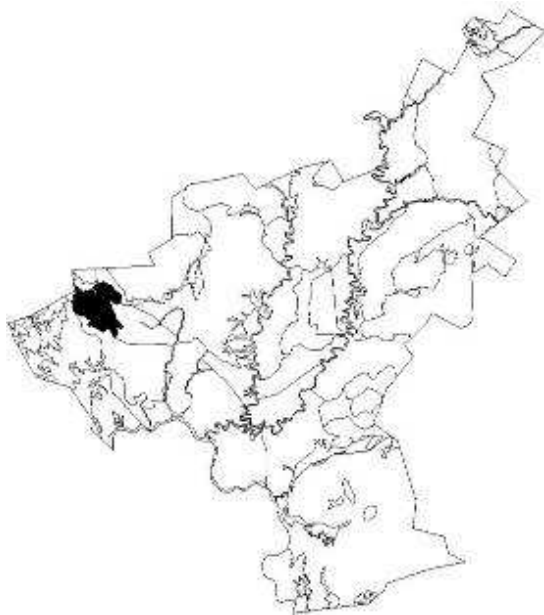
Stunning during the vegetation season in winter, the succulent karoo plains to the north of Rosh Pinah show good plant cover all year round, including the rare succulent below.



Ebracteola derenbergiana

© Antje Burke

Zebrafontein plateau



Habitat and environmental parameters

Undulating plains, broken up by shallow, dry rivers and low ridges comprise this mapping unit. They are positioned at approximately 1300 m amsl, with peaks reaching over 1500 m amsl. The plains ascent gently towards the south and west onto the “back” of the Namus mountains. Winter and summer rains can fall in this area. The underlying geology is complex and sedimentary rock of the Nama Group as well as metasedimentary rock types of the Namaqua complex are present.

Extent 144.5 km², 1.26 % of study area.

Description of vegetation Mostly covered by sparse dwarf shrubland usually not exceeding 15% cover, the drainage lines, dry rivers and some of the ridges support occasional trees and taller shrubs. The vegetation is overall dominated by the dwarf shrubs *Pteronia rangei* and *Zygophyllum decumbens*, with *Eberlanzia* species locally co-dominant. Patches of grassland, composed of *Stipagrostis ciliata* and *S. obtusa* prevail locally where sand has accumulated. Taller shrubs and trees in drainage lines include *Acacia karoo*, *Euclea pseudebenus* and *Sisyndite sparteae*. The intermingling of Succulent and Nama Karoo species has resulted in comparatively high plant diversity, with just over 120 plant species. Many species of conservation importance occur. A gradual change towards more succulent karoo species, such as *Drosanthemum* and *Eberlanzia* species can clearly be seen towards the west and south on the plateau.



Conservation importance **MEDIUM** Nearly one quarter of the plant species recorded are of conservation importance which resulted in a “medium” rating. This includes the range-restricted *Indigofera merxmuelieri*, many different *Euphorbia* and *Zygophyllum* species, the endemic *Euclea asperima* as well as *Aloe dichotoma*, *A. clavifolia* and *Cotyledon orbiculata* on some ridges. *Hoodia* and *Lavrania* species are also present.

Resource use and other aspects This mapping unit is used for livestock farming.

Threats Livestock farming has likely left its marks, as indicated by proliferation of weedy species near livestock concentration points. Whether this has also affected the overall vegetation requires longer-term monitoring.

Management

- The Mexican poppy (*Argemone ochroleuca*) was recorded in some dry rivers and should be eradicated to avoid further infestation.
- Proposed IUCN category: VI

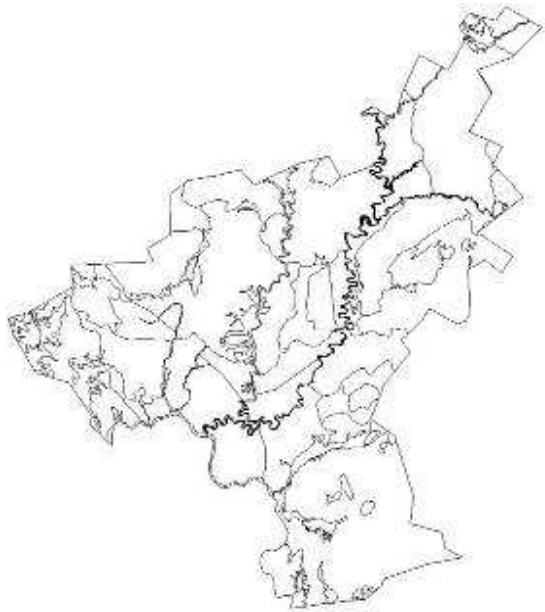
Research needs Fauna data are needed; this includes larger as well as small wildlife, as mountain zebra activity is clearly evident, and at the interface of the Succulent and Nama Karoo biomes high diversity and endemism is expected amongst the invertebrate fauna.



The fan lily (*Boophone disticha* - foreground) grows occasionally on the undulating plains of the Zebrafontein plateau.

Rivers

Fish river and tributaries



Habitat and environmental parameters

This mapping unit includes the Fish, Konkiep and Gaap rivers, as well as some of their tributaries. In the study area they largely flow through mountainous terrain and are thus characterised by a narrowly winding course in most places. Flow regimes differ, with the Fish river receiving the largest water input. The Fish river flows on a moderate to steep gradient in the study area from 750 to 100 m amsl.

Extent 106 km², 0.92 % of study area.

The Fish River is the largest ephemeral river in Namibia with an enormous catchment originating in the central highlands. The last approximately 120 km before the confluence with the Orange River are part of the study area. The river cuts deeply into the bedrock forming the famous Fish River Canyon. The width of the riverbed varies, and is in places up to 1 km wide, sometimes interrupted by buttes (erosion remnants). The riverbed is mostly sandy and framed by gravel banks and adjoined by steep slopes. Access is only possible along sizeable tributaries. There are usually some areas which retain surface water all year round. The Konkiep is a large river which flows into the Fish 20 km upstream of the Fish and Orange River confluence. The Konkiep's riverbed is largely composed of boulders and gravel, with less sandy stretches than the Fish River. Permanent seepage areas also occur in the lower Konkiep. The Gaap river flows through the sedimentary canyon lands, with steep slopes only in the final 4 km section before the river joins the Fish river from the east.

Description of vegetation Although this mapping unit traverses a large part of the study area, the vegetation along these river courses is fairly similar. Patches of riparian woodland, and relatively well vegetated river banks of varying width alternate along the main channel of the Fish River. The woodlands support tall trees and dense thickets, the river banks more open, sparse shrubland. Gravel beds are the key feature in the Konkiep River, with only localised patches of woodland and isolated dunes. Vegetation changes occur frequently associated with flooding, and vegetation communities near the main river channels are usually of short-lived nature.

The woodland patches in the Fish River are largely composed of sweet-thorn (*Acacia karroo*), tamarisk (*Tamarix usneoides*) and false ebony (*Euclea pseudebenus*). The invasive alien mesquite (*Prosopis glandulosa*) is present near the camp at /Ai-/Ais and has spread downstream and into tributaries. Large stands of the tall shrubs *Tetragonia schenkii* and *Sisymbrium spartea* grow on the gravel banks and in dune areas, both in the Fish and the Konkiep Rivers, accompanied by a variety of herbs and grasses. Areas with permanent water support a variety of sedges and grasses. *Acacia erioloba* is the most prominent tree in the Gaap river. Plant diversity is moderate, with just over 80 species.

Conservation importance **FAIR** Although the number of plant species of conservation importance is lower than recorded in the mountains, some 12% of the recorded species are of conservation importance. This includes several (proposed) protected trees such as *Acacia erioloba*, *Euclea pseudebenus* and *Maerua schinzii*, and endemic plants like *Psilocaulon salicornioides*, *Senecio hermannii*, *Salsola arborea* and *Tetragonia schenkii* occur here. However, one of the rarest plants recorded in the study area, the shrub *Neoluederitzia sericeocarpa* occurs in this mapping unit.

Many reptiles, including the near-endemic Namibian dwarf gecko (*Lygodactylus bradfieldi*), rough scaled gecko (*Pachydactylus rugosus*) and the western sand lizard (*Pedioplanis undata*) occur in the Fish River area (Griffin 2003).

The (in Namibia) rare African black duck (*Anas sparsa*) has been recorded in the lower Fish River.

Resource use and other aspects These rivers are extremely important habitats for wildlife and essential for the ecological functioning of ecosystems through the provision of water, nutrient cycling and purification processes. The water in these river systems is the most reliable and thus important water source for wildlife in this section of the study area, away from the Orange River. This, together with a higher structural diversity in vegetation is likely to support a greater array of small wildlife, than the plains and mountain areas.



Gravel banks in the Fish River are occasionally densely vegetated, largely with *Tetragonia schenkii* and *Sisymbrium spartea*.

Threats

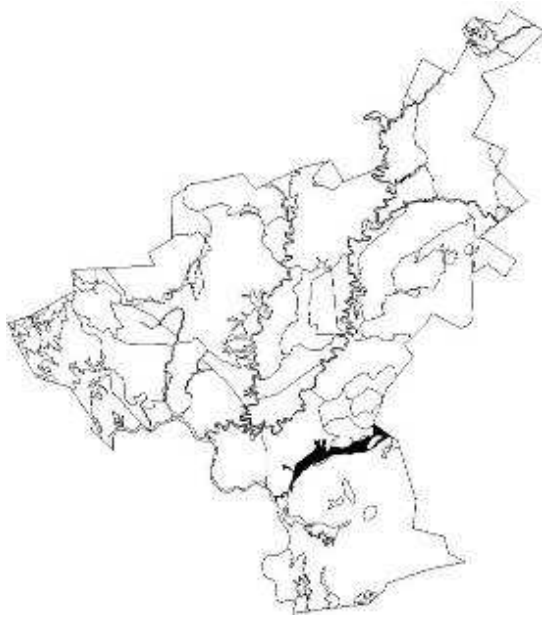
- A major dam (Neckartal) is being built on the Fish river upstream of the study area. This will affect the flood regime, but the potential impacts on biodiversity and ecological functioning of the river are unknown at present.
- All dryland invasive aliens in Namibia likely occur in the Fish river and its tributaries. Mexican poppy (*Argemone ochroleuca*), thorn apple (*Datura inoxia*) and mesquite (*Prosopis glandulosa*) were recorded, but wild tobacco (*Nicotiana glauca*) and castor oil (*Ricinus communis*) are also expected to occur, as they were recorded in adjoining landscape units. Infestations are, however, localised.
- A group of approximately 30 feral horses is present in the Fish River area which could become a threat to indigenous wildlife and vegetation through interbreeding and competition for resources.
- Groundwater is abstracted for the camps at Hobas and /Ai-/Ais, and appropriate sewage treatment at the camps is not always functioning. This could result in water pollution.
- Further tourism developments are planned for both, the Fish and the Konkiep Rivers, according to the Ai-Ais Richtersveld Transfrontier Park joint management zoning. This could infringe on a "strict nature reserve" and "wilderness" status for the lower Konkiep river which the area can presently maintain due to difficult access. Low density development along the lower Fish River could be considered after a rigorous environmental assessment, including a comprehensive biodiversity inventory.

Management

- Ensure environmental impacts of upstream dam development are addressed.
- Better environmental management of tourism developments by joining the "eco awards" initiative.
- Control of invasive aliens (e.g. investigate feasibility of bio-control for *Prosopis*) and monitor occurrence of invasive alien plant species around potential new tourism developments.
- Removal of feral horses.
- Proposed IUCN category: Ib

Research needs Biodiversity inventories for the lower sections of the Fish and Konkiep Rivers are lacking. The aquatic ecosystems in the rivers are poorly studied.

Gamkap river



Habitat and environmental parameters

Very different from the other rivers, the Gamkab River is the collective, final channel of an extensive network of smaller drainage lines on the open plains in the south-east of the study area. The river connects with the Orange River approximately 35 km upstream of the Fish River confluence. This is one of the driest and hottest areas in the study area, and the river flows only rarely.

Extent 90.97 km², 0.79% of study area.

Description of vegetation The shallow riverbed and associated banks support sparse, but tall shrubland. Seepage areas occur in the lower reaches, but open water is only present after good rains. Sedges and short grasses occur around these seepage areas. *Tetragonia schenkii* is the dominant plant in most parts of the riverbed, accompanied by *Sisymbrium spartea*. Very few other plants are usually present, but after good rains carpets with the low succulent creeper *Mesembryanthemum garusianum* and *M. longipapillosum* appear. Several other herbs, such as *Myxopappus acutifolius*, *Helichrysum gariepium*, *Sesuvium sesuvioides*, *Tribulus cristatus* and *Zygophyllum simplex* can then be observed. The southern-most section of the river also supports *Mesembryanthemum hypertrophicum*, associated with saline seepage areas. In some places *Scirpoides dioecus* and *Odysea paucinervis* grow around these seepages. Species richness (just over 20 species) is low.

Conservation importance **FAIR** Only one endemic plant species was recorded, *Mesembryanthemum garusianum*.

Resource use and other aspects The seepage areas which are mostly saline (except for short periods after good rains) provide salt licks for animals.

Threats

- Uncontrolled track development
- Infrastructure developments (the track through the Gamkap River requires maintenance)

Management

- Prohibit off-road driving and enforce track discipline
- Proposed IUCN category: II

Research needs Although saline and ephemeral, the aquatic ecosystems related to the river require attention as very narrow-endemic invertebrates are known to occur in these systems.

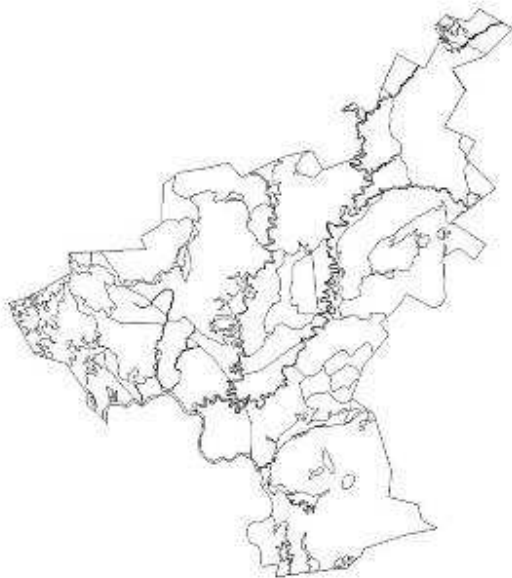


Tall shrubs – mainly *Tetragonia schenkii* (left) and *Sisymbrium spartea* (right) – grow in the main channel of the Gamkab River.



Former seepage areas in the Gamkab basin provide salt licks for animals.

Löwen river



Habitat and environmental parameters

The Löwen river runs along the northern boundary of the study area and finally drains into the Fish river. The flow is interrupted by the Naute dam, which is included in this mapping unit. The river is largely shallow and wide in the study area and contains several permanently wet seepage areas. Within the study area the Löwen river descends gently from 750 to 700 m amsl in a south-westerly direction.

Extent 15.9 km², 0.14% of study area.

Description of vegetation Small patches of riparian woodland alternate with shrubland, extensive open area and patches with reeds and sedges where water is available permanently. In woodland areas camel thorn (*Acacia erioloba*), sweet-thorn (*Acacia karroo*), *Acacia mellifera* and *Euclea pseudebenus* are dominant. Shrubby undergrowth and shrubland sections are largely composed of *Rhigozum trichotomum*, *Boscia foetida*, *Cadaba aphylla* and *Lycium* species. The Naute dam supports wetland vegetation composed of sedges (*Cyperus* and *Juncus* species) and reeds (*Phragmites australis* and *Typha capensis*), but due to the disturbance caused by fluctuating water levels also supports many weedy species, including invasive alien plants such as *Datura innoxia* and *Prosopis glandulosa*. Species diversity is moderate, with just over 80 species.

Conservation importance **FAIR** Some plants of conservation importance, 15% of the recorded species, occur in the river system. This includes (proposed) protected trees such as *Acacia erioloba*, *Boscia albitrunca*, *Euclea pseudebenus*, *Maerua schinzii*, *Rhus* (*Searsia*) *lancea* and *Ziziphus mucronata*, but also some range-restricted herbs such as *Geigeria brachycephala*.

Resource use and other aspects The river and its vegetation are an important source of water, browse and habitat for wildlife. It also provides numerous ecological services such as aquifer recharge and water purification which extend well beyond the river's mapping boundaries.

Threats

- Water pollution near intensively irrigated and fertilised agricultural areas such as southwest of Naute Dam is a concern.
- Water abstraction, if intensified, may also affect the recharge capacity.
- Invasive alien plants have taken a foothold around the dam and are spreading with the flow of water through the river system and to adjoining habitats.

Management

- The Naute dam is unfortunately a prolific source of invasive alien infestation and eradication should be prioritised here.
- Monitoring water abstraction and potential pollution associated with the agricultural activities is critical to avoid negative impacts on the downstream ecosystems.

- Proposed IUCN category: II

Research needs The river system was only accessed at a few places and a more thorough plant inventory would be desirable. No animal data are available.



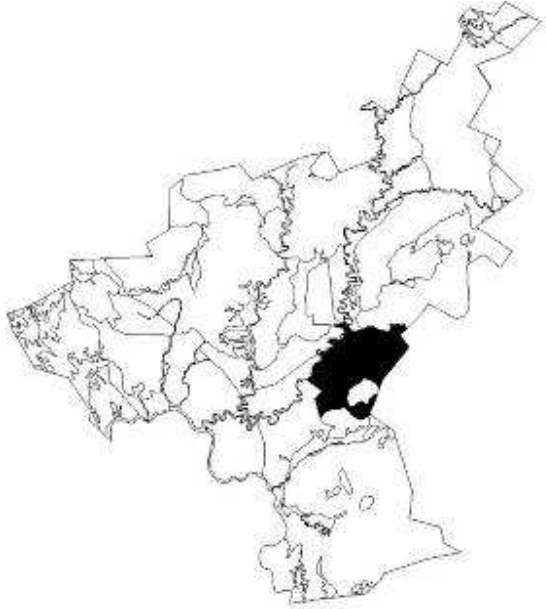
Many stretches of the Löwen River in the Naute Game Park are densely vegetated.



Water flow below the dam creates a permanent wetland in the Löwen River.

Mountains and inselbergs

Altdorn hills and plains



Habitat and environmental parameters

These granite, dolerite and meta-sedimentary hills to the east of the Fish River rise on a north-east upwards sloping plain. Altitudes on the plains range from about 450 m (amsl) near the Fish River to 1000 m in the east of this mapping unit. The hills are higher in the west and can reach a hundred meters or more above the surrounding, but are lower and more scattered towards the east. Several dry rivers drain towards the Fish River and valleys, plains and hills form a diverse mix of subunits. This is mostly summer rainfall area, but occasional winter rains could occur here.

Extent 460.2 km², 4% of study area.

Description of vegetation This landscape-level mapping unit supports different vegetation types associated with the different landforms. It was not possible to differentiate these at the scale of mapping required for the 11500 km² study area. While the dry rivers support trees of up to 4 m height, such as *Acacia erioloba* and *Parkinsonia africana*, the plains and hills are dominated by shrubs and dwarf shrubs. The karas euphorbia (*Euphorbia gregaria*) is dominant in many parts on the plains, otherwise three-thorn (*Rhigozum trichotomum*). *Stipagrostis uniplumis* and other grasses accompany the shrubs on the plains. The grass *Enneapogon scaber* is dominant on many hills. The diversity of rock types and the mosaic-like landscape result in high plant diversity. Just over 170 plant species were recorded in this mapping unit. Of interest were various quartz outcrops which supported vegetation that can be considered outliers of the Succulent Karoo Biome, such as spiny pelargonium (*Pelargonium spinosum*), *Ceraria fruticulosa* and various dwarf succulent *Crassula* and *Euphorbia* species.



Nondescript during the dry season, *Hermannia stricta* cannot be missed when in flower.

Conservation importance **FAIR** Despite the relatively high plant diversity, only 15% of the recorded species are of conservation importance. These are mostly succulent shrubs, such as *Adromischus* and *Crassula* species, *Aloe clavifolia*, *Ruschia* cf. *sabulicola* and *Zygophyllum cretaceum*.



Quartz outcrops in this mapping unit support outposts of succulent karoo vegetation, such as the shrub *Ceraria frutescens* (photo on the right).

Resource use and other aspects The diverse vegetation, with a reasonable contribution of grasses during a good season provides good fodder and grazing for wildlife in this landscape unit. Equally, habitat diversity is high, likely supporting a range of smaller animals and invertebrates. Although formerly used for sheep farming, there are no obvious signs of overgrazing and poor land management.

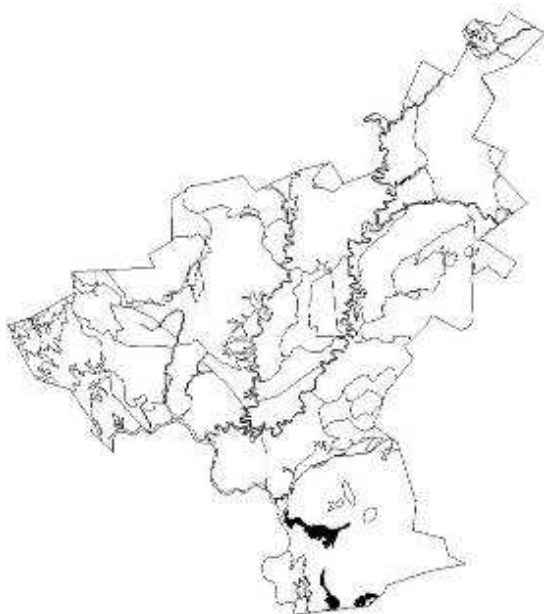
Threats This area is subject to prospecting for minerals and other commodities.

Management

- The currently lax implementation of the Environmental Management Act by the authorities does not guarantee that environmental impacts of such activities will be adequately addressed. Landowners will have to take initiative and ensure that environmental protection is incorporated in potential prospecting activities and appropriate measures are implemented.
- As being part of a private nature reserve, continue regular wildlife surveys.
- Proposed IUCN category: II

Research needs Information on plants and larger wildlife is reasonably good, but all other taxa require more detailed inventories.

Aussenkehr hills



Habitat and environmental parameters A band of granite ridges and hills, coarsely following the course of the Orange River, but at approximately 10 km distance to the east, snakes through the south-eastern-most part of the study area near Aussenkehr. Although only few of these hills reach 100 m above the surrounding, they are prominent landmarks, situated in the driest part of the study area and the boulders and granite colluvium provide diverse microhabitats. This is bioclimatically likely a transitional areas, as it is far enough east to be part of the summer rainfall regime, but still close to the Richtersveld area to receive occasional winter rains.

Extent 81.5 km², 0.71% of study area.

Description of vegetation Although seemingly barren, the Aussenkehr hills support a surprisingly diverse mix of plants, with over 80 species recorded, dominated by the ever-present dwarf shrub *Calicorema capitata* in this area. Plant cover is low and overall hardly reaches 1 m height, stem succulents excepted. Quiver trees (*Aloe dichotoma*) and *Ceraria namaquensis* grow occasionally on these slopes. Both, *Commiphora capensis* and *C. namaensis* occur, as well as *Euphorbia gregaria*. Some slopes facing the Orange River support succulents such as *Crassula sericea*, *Othonna lasiocarpa* and *Ruschia* species.

Conservation importance **FAIR** Nearly one quarter of the recorded plant species are of conservation importance. In addition to those mentioned above, this includes the succulent shrubs *Euphorbia cibdela*, *E. gariepina* and *Zygophyllum cretaceum*.



A large *Ozoroa namaensis* surprises in the central section of the Aussenkehr Nature Park.

Resource use and other aspects Now part of a private nature reserve, this arid area never successfully supported livestock farming.

Threats Open access to this unfenced area has resulted in uncontrolled off-road driving, and possibly also poaching.

Management

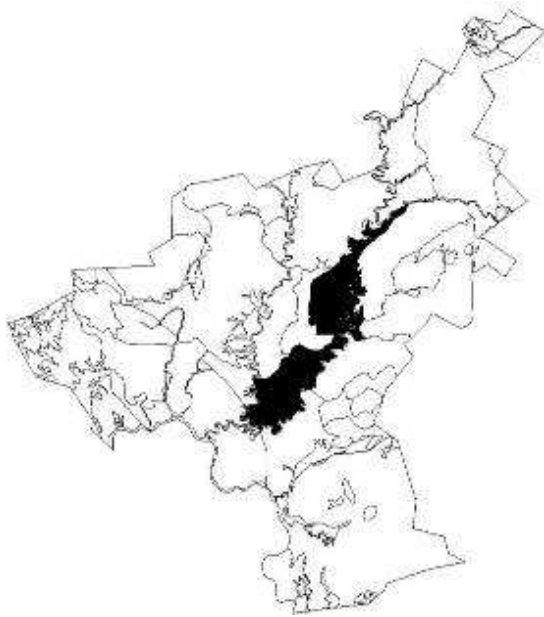
- The recent appointment of a ranger to the Aussenkehr Nature Park may help to curb off-road driving and illegal hunting.
- Proposed IUCN category: II

Research needs Although rain showers triggered the emergence of some annual plants, these were patchy and most of the area was dry during the survey. Plant surveys during a good season are therefore required. Data on animals are sparse.



Granite koppies in the south-east of the Aussenkehr Nature Park contribute to much greater plant diversity than expected in this arid area.

Canyon slopes



Habitat and environmental parameters The landscape unit “canyon slopes” comprises the sedimentary and meta-sedimentary rock types adjoining the Fish River in its southern reaches to the west, and partly east. In the upper reaches they are largely composed of limestone, shale and other sedimentary rocks of the Nama Group, in the southern reaches they are wedged between the granites and gneisses of the Altdorn hills and the southern Huns Mountains. Here they form no clearly distinct landscape unit but grade into the mountainous areas adjoining this mapping unit. The underlying geology is complex, as the Fish River has incised into the Nama Group, as well as the even deeper lying Namaqua Metamorphic Complex. Different rock types are thus exposed in close proximity such as black limestone, quartzite and schist as well as granites and gneissic rocks and dolerite. This is a transitional area between winter and summer rainfall.

Extent 667.3 km², 5.8 % of study area.

Description of vegetation Although during the dry season appearing almost barren, the canyon slopes are remarkably diverse in plant life, given the harsh climatic conditions. Low perennial shrubs form a patchy and low plant cover, except in channels on these slopes, where plant cover can reach 10%. Smaller riverbeds draining into the Fish River are included in this landscape unit and these provide a home to taller shrubs such as *Boscia foetida* and *Sisyndite spartea*, and trees such as *Pappea capensis* and *Parkinsonia africana*. On slopes the tall *Euphorbia gregaria* is conspicuous, along with *Ceraria namaquensis* and *Euphorbia virosa* which are locally co-dominant. The low shrubs *Calicorema capitata*, *Petalidium setosum* and *Zygophyllum cretaceum* are other frequent plant species. After the good rains of 2011 the succulent creeper *Mesembryanthemum garusianum*, the grass *Stipagrostis anomala* and the ground cover *Tribulus cristatus* were also frequent on many slopes. Plant diversity is high – just over 100 were recorded so far.

Conservation importance **MEDIUM** Many range-restricted plant species occur in this mapping unit which contributes to their high conservation value. This includes Namibian endemics such as *Calicorema squarrosa*, *Dauresia alliariifolia*, *Euphorbia cibdela*, *Monsonia deserticola* and *Senecio hermannii*. The protected *Aloe dichotoma* and, towards the south, also *Aloe garipensis* grow on the canyon slopes. Three Gariep endemic *Commiphora* occur: *C. capensis*, *C. cervifolia* and *C. namaensis*. Protected *Crassula* species grow on slopes in the south-western portion of this landscape unit. Overall 27% of the recorded species are listed of conservation importance.

The canyon slopes are also home to near-endemic reptiles, such as the Namibian dwarf gecko (*Lygodactylus bradfieldi*), rough scaled gecko (*Pachydactylus rugosus rugosus*) and the western sand lizard (*Pedioplanis undata*) (Griffin 2003).

Resource use and other aspects The spectacular canyon scenery provides not only the main tourist attraction in the Ai-Ais Hotsprings Game Park, but is also the stage for a challenging 3 to 5-day hiking trail. The impacts of these activities on biodiversity could not be assessed in detail, but no wide-ranging disturbances such as litter carried downstream, or excessive soil compaction and erosion could be observed. However, the resort at the Hotsprings in /Ai-/Ais is an example of how not to design and develop a facility in a National Park which ideally should set a benchmark for environmentally sound development. The excessive lighting which is on during the entire night creates light pollution, not only obscuring the stars, but also attracting lots of insects which find these lights inescapable death traps. Trails from the camp are not marked and people wander at random on the slopes around the camp, creating numerous paths which lead to erosion in some places and soil compaction in others. Lots of water is wasted while attempting to keep alive pitiable patches of grass. Collisions with wildlife occur along the access roads to the camp.

Threats

- Although no invasive alien plant species were recorded during the brief survey, there are invasive plants in the Fish River which have likely also moved up the lower slopes in some places.
- Impacts related to tourism activities around /Ai-/Ais camp and access roads (wildlife collisions on roads, paths, waste creation)
- Infrastructure developments
- Illegal plant collecting
- Quarrying for road and building material

Management

- Recommended management zoning: IUCN Ia and Ib (wilderness),
- Monitor wildlife incidents on roads, and if necessary, introduce speed bumps in critical areas
- Monitor occurrence of invasive alien plant species around potential tourism and mining developments
- Implement borrow-pit management
- Better environmental management of camps, e.g. by joining the “eco awards” initiative

Research needs Large parts of this mapping unit are very difficult to access and data coverage is therefore poor. The impacts of tourism activities on the canyon slopes need to be better understood, managed and monitored around tourism development nodes.



Senecio hermannii is endemic to the central southern part of the Karas region.

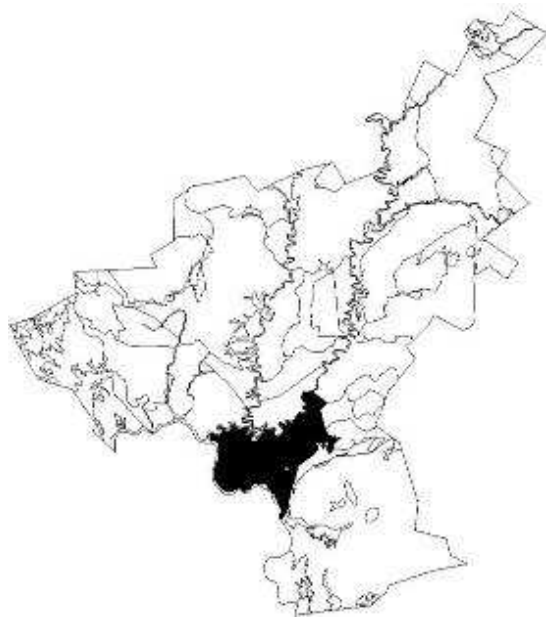


The Namibian endemic *Pegolettia plumosa*.



The canyon slopes near Ai-Ais support diverse vegetation and several endemic plant species.

Eastern Orange Mountains



Habitat and environmental parameters

These mountains between the Gamkab, Fish and Orange rivers in the southern part of the study area are comprised of granite in the south and various metasedimentary rocks in the north of this mapping unit. It is a rugged terrain, dissected only by few dry rivers providing access. The highest peaks rise up to 600 m above the surrounding plains, but most are no more than 400 m. The general altitude ranges between 150 and 750 m amsl. This is a transitional area between the summer and winter rain regimes.

Extent 569.2 km², 4.9%

Description of vegetation Although sparsely covered, the mountain slopes in this mapping unit support diverse vegetation reminiscent of winter and summer rainfall flora. Characteristic are stem succulents such as *Aloe dichotoma*, *Ceraria namaquensis*, *Euphorbia virosa* and *Euphorbia gregaria*, as well as a range of succulent shrubs such as *Zygophyllum species*. Some 130 plant species were recorded.

Conservation importance **MEDIUM** One quarter of the recorded plant species is of conservation importance. All three Gariiep endemic *Commiphora* species occur in these mountains: *Commiphora capensis*, *C. cervifolia* and *C. namaensis* and the Orange River endemic *Jatropha orangeana* is present. In the higher reaches some protected plants such as *Aloe garipensis*, *Conophytum*, *Hoodia* and *Lapidaria* species occur.

Resource use and other aspects Completely within the boundaries of the Ai-Ais Hotsprings Game Park, these mountain areas are an important habitat for the parks' wildlife.

Threats Prospecting, mining and possibly tourism developments.

Management

- Joint management zoning of the Ai-Ais Richtersveld Transfrontier Park suggests low intensity development along the Konkiep and lower Fish River. No plant inventories are available along these sections of the rivers and the adjoining slopes. These are mandatory before any developments can be considered here. Some sections of these mountain areas warrant highest protection status (IUCN Ia), but their exact extent needs to be based on better biodiversity baselines than presently available.
- Proposed IUCN category: Ib

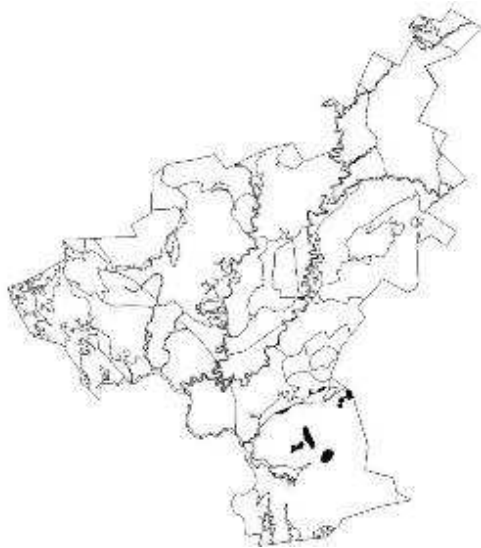
Research needs This mapping unit can only be accessed from the Gamkab river and a short section along the Orange River road. Large parts of this area have thus never been surveyed; those that have, only during dry periods. More biodiversity inventories of all components, including plants, are therefore necessary. Data quality is poor.



Surprisingly well vegetated, the slopes of the eastern Orange mountains support a range of plants of conservation importance, such as the Gariep aloe (*Aloe garipensis*) and *Zygophyllum cretaceum* (below).



Gamkab inselbergs



Habitat and environmental parameters

The inselbergs in the south-east of the study area comprise typical table-top mountains composed of shale and other sedimentary rock types, as well as dolerite outcrops of volcanic origin. The highest peaks are 850 m (amsl), and with this approximately 150 m above the surrounding plains. The inselbergs are surrounded by an extensive network of shallow rivers which drain south-west into the Gamkab River.

Extent 48km², 0.42% of study area.

Description of vegetation The vegetation is very sparse and usually dominated by dwarf shrubs. A reasonable cover of grasses and herbs can be present after good rains. *Euphorbia gregaria* is the dominant perennial plant on the western inselbergs, but *Monechma cleomoides*, *Salsola cryptoptera*, and the perennial grass *Stipagrostis brevifolia* are the dominant plants on the shale inselbergs.

Conservation importance **FAIR** Considering the arid surrounding, these inselbergs are relatively species-rich (just over 100 plant species were recorded) and several plant species of conservation importance grow here. The Namibian endemic *Monsonia deserticola*, the Gariiep endemic *Commiphora namaensis* and the protected *Aloe dichotoma* and *Parkinsonia africana* are some examples. A new plant species, a rare endemic to this area, has also been found here.



And so it is – a new plant species after all! *Oxalis hunsbergensis* is currently being described.

Resource use and other aspects Abandoned quarries and mines are present in this area. Some are within the Ai-Ais Hotsprings Game Park, some are on farms and subjected to livestock grazing.

Threats Off-road driving

Management

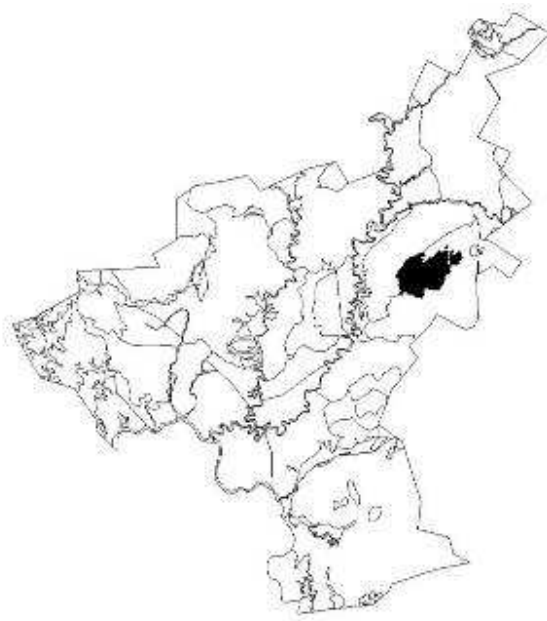
- If access to this area is planned, maintain and clearly demarcate one dedicated access route.
- Prohibit off-road driving and enforce track discipline.
- Proposed IUCN category: II and VI

Research needs Not all inselbergs could be surveyed and particularly higher ones such as Gembokberg deserve attention during a good rainy season.



The shale and sandstone flat-topped inselbergs provide a prominent landmark on the otherwise featureless Gamkab plains.

Gondwana hills



Habitat and environmental parameters

The group of hills and isolated outcrops on the "eastern sand plains" has been combined in this mapping unit. This includes granite outcrops and sandstone and other sedimentary hills. These rise usually no more than 100 m above the plains at about 750 m altitude. Towards the west the sedimentary outcrops join the canyon lands. Bioclimatically these hills are situated in summer rainfall Nama Karoo Biome.

Extent 157.3 km², 1.4% of study area.

Description of vegetation A low cover (hardly exceeding 5%) of dwarf shrub and shrubs can be found on these hills. They include the ever-present *Calicorema capitata* as well as *Dyerophytum africanum*, *Limeum aethiopicum* and *Salsola barbata*. *Euphorbia gariepina* and *E. gregaria* are also locally dominant. The grass *Enneapogon scaber* is also common on these hills, and some trees (*Pappea capensis*) and taller shrubs (*Cadaba aphylla*) can also be found making the vegetation structurally diverse. Recorded species diversity was low, just over 40 species, but is incomplete because of lack of rains.

Conservation importance **FAIR** Some 14% of the currently recorded plants are of conservation importance. Interesting is the co-occurrence of both tall stem-succulent *Euphorbia*, *E. avasmontana* and *E. virosa*. Some endemics were also found such as the shrubs *Petalidium linifolium* and *Solanum rigescentoides*.

Resource use and other aspects Particularly the granite boulders provide diverse habitats for animals.

Threats None presently.

Management

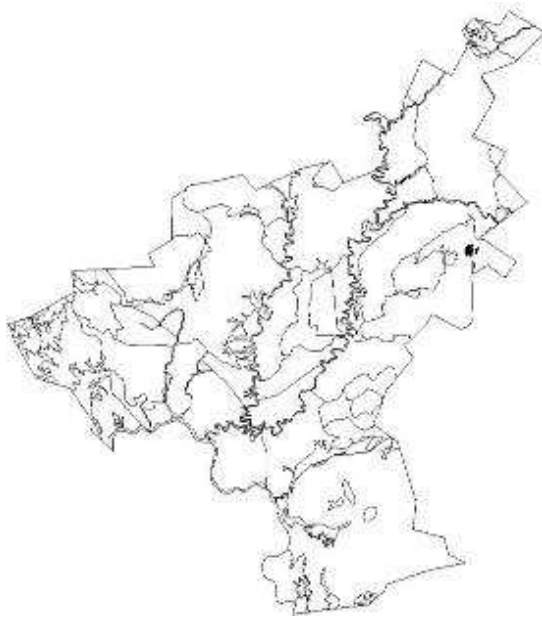
- Proposed IUCN category: II

Research needs This mapping unit was dry during the surveys, and thus few short-lived components of the vegetation could be recorded.



A fair distance from the Orange River, *Aloe garipensis* grows on the Gondwana hills.

Holoogberg



Habitat and environmental parameters

Although geologically part of the "Gondwana hills", the Holoogberg and adjoining hills have been mapped as a separate entity because of their height and isolated position. The typical flat-top mountain rises 210 m above the surrounding plains and is composed of shale and sandstone. The Holoogberg is positioned in largely summer rainfall receiving Nama Karoo Biome.

Extent 7km², 0.06% of study area.

Description of vegetation A low cover of diverse dwarf shrubs (perennial cover not exceeding 15%) clothes the slopes of the mountain, while the top is dominated by a dwarf shrub (*Salsola* sp.), also not exceeding 15% cover. Just over 100 plant species have been recorded. More conspicuous plants on the slopes include the stem-succulents quiver tree (*Aloe dichotoma*) and Nama corkwood (*Commiphora namaensis*) as well as the taller shrubs *Adenolobus garipensis*, leafless wormbush (*Cadaba aphylla*) and red spike-thorn (*Gymnosporia senegalensis*).

Conservation importance **FAIR** Only 8 % of the recorded species are listed of conservation importance. These include the endemic herbs *Aizoon giessii*, *Geigeria pilifera* and *Pegolettia plumosa*, as well as shrubs such as *Indigofera pechuelii* and *Monechma leucoderme*.

Resource use and other aspects The vegetation on the Holoogberg is a source of browse and grazing, particularly when the plains are dry.

Threats None known at present.

Management

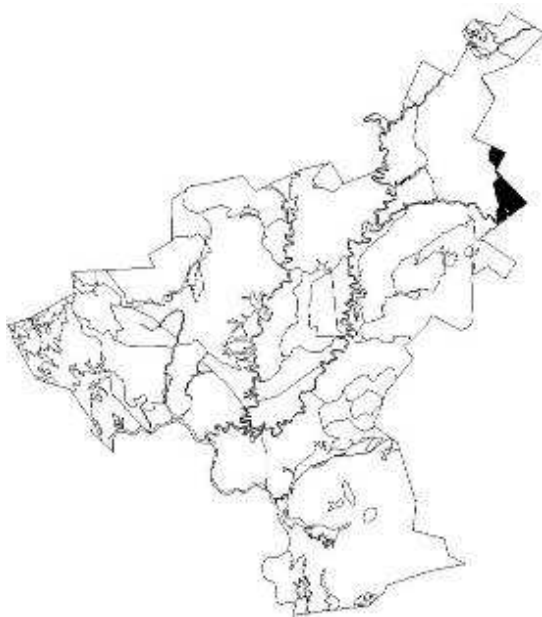
- Proposed IUCN category: II

Research needs There is a lack of animal data for this mountain.



Leading up the slopes of the Holoogberg in several steps, this prominent shale and sandstone mountain dominates the landscape of the eastern sand plains. Once approached more closely it is evident that the vegetation is more prolific than it appears from a distance. These mountains are therefore an important retreat for wildlife during dry periods

Klein Karas mountains



Habitat and environmental parameters

Only marginally extending into the mapping domain, the south-western section of the Klein Karas mountains dominates the landscape over a wide part of the study area. The extensive sandstone and limestone, flat-top mountain massif rises well over 300 m above the plains. In the study area bordered by low foothills, the slopes ascent first gradually and then steeply across several steps towards the plateau of the mountain. The mountains are in summer rainfall area.

Extent 88.6 km², 0.77% of study area.

Description of vegetation The western slopes are covered by a mix of dwarf shrubs and shrubs with a vegetation cover ranging between 5 % on exposed slopes and 25 % in kloofs. The dwarf shrubs *Leucosphaera bainesii*, *Limeum aethiopicum* and *Rhigozum trichotomum* and *Zygophyllum decumbens* are present on most slopes. More conspicuous, although not necessarily common, are taller shrubs such as *Cadaba aphylla*, *Ehretia alba*, *Grewia tenax* and *Phaeoptilum spinosum*. With just over 160 species, plant species richness is relatively high and supplemented by many different bulbs.

Conservation importance **FAIR** Amongst the 12% of plants of conservation importance are the endemic herb *Geigeria brachycephala*, the succulent shrub *Zygophyllum cretaceum* and the shrubs *Aspilia eenii*, *Barleria lanceolata* and *Indigofera pechuelii*. Many (proposed) protected trees also grow on these slopes, such as *Maerua schinzii*, *Pappea capensis* and *Parkinsonia africana*.

Resource use and other aspects The diverse vegetation always provides some browse and grazing, particularly when the plains are dry or overgrazed.

Threats

- Hunting and trapping of wildlife occurs on some of the farming areas. Whether or not with serious consequences for wildlife populations is not known.

Management

- Monitoring of wildlife populations
- Proposed IUCN category: VI

Research needs Apart from this once-off survey, there no other plant data. Data on wildlife numbers are absent.

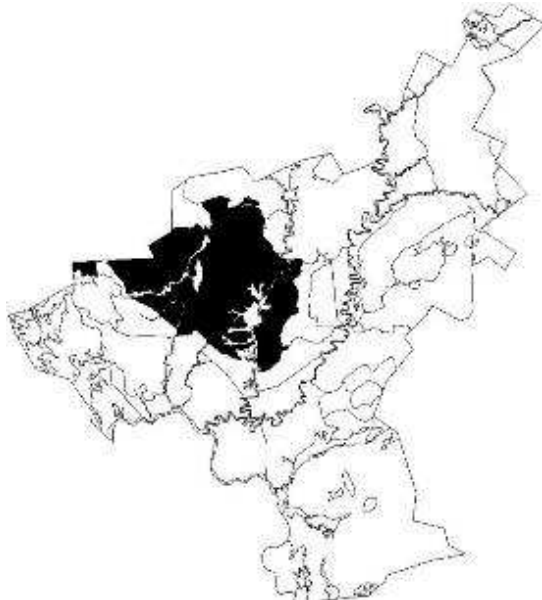


The foothills adjoining the Klein Karas mountains display a diversity of rock types and therefore support a rich plant life.



Several steps of steep slopes have to be conquered to reach the top of the Klein Karas mountains on their western side.

Northern Huns mountains



Habitat and environmental parameters

These mountains are formed by limestone, sandstone and shale of the Nama Group deposited in a typical layered fashion. The limestones are the southern-most extension of the Huib Hoch plateau. Various drainage lines have scoured impressive gorges into these largely dark rocks. Water draining towards the Konkiep River has dissected the former plateau resulting in a very irregular outline along its eastern margin. Altitudes on the plateau reach up to nearly 1600 m (amsl) at their highest peaks, but 1300 m (amsl) is the average, providing an elevation of over 300 m above the adjoining plains. Summer rains likely prevail here, but winter rains occur occasionally.

Extent 1457.5 km², 12.7% of study area. This is the second-largest landscape unit.

Description of vegetation The perennial vegetation is patchy and often concentrated in depressions, gorges and drainage lines, and along the various steps that are created by the different horizontally layered rock types at erosion faces. After good rains, grasses add a fair amount of biomass and form a more even plant cover. Dwarf leaf-succulent shrubs comprise the bulk of the vegetation, growing hardly taller than 30 cm. But trees and taller shrubs are prominent in the gorges and rivers. Overall, perennial plant cover hardly reaches 5%, but in rivers and sheltered places, and after good rains it can reach 15–20%. *Zygophyllum decumbens* is the dominant plant on many parts of the northern plateau, accompanied by the grass *Stipagrostis anomala*. Dominant plant species may change towards the south-west and south-east, but these areas could not be accessed. Plant species richness totals 100, with some 23 of conservation importance.

Conservation importance **FAIR** Various plant species of restricted range are associated with these rocky habitats. Of particular note are populations of the southern Namib endemic shrub *Caesalpinia merxmullerana* which only occurs in the Huns Mountains and some sections of the Huib Hoch plateau. Other endemic plants of the south found here are *Jamesbrittenia primuliflora*, *Petalidium cymbiforme*, *Ruellia aspera* and *Senecio giessii*. The protected quiver tree (*Aloe dichotoma*), and the Gariiep endemics *Commiphora namaensis* and *Pelargonium spinosum* are other striking plants of note.

The Huns mountains are a home to the endemic desert mountain adder (*Bitis xeropaga*) (Griffin 2003).

Resource use and other aspects Many plants provide food and shelter for wildlife, particularly in the gorges. This landscape unit includes one of the most significant archaeological sites in southern Africa – the Apollo 11 cave – and many other archaeological sites of interest are found in this area (Wendt 1976; Masson 2006).

Threats

- Looting and vandalising of heritage sites

- Prospecting and mining

Management

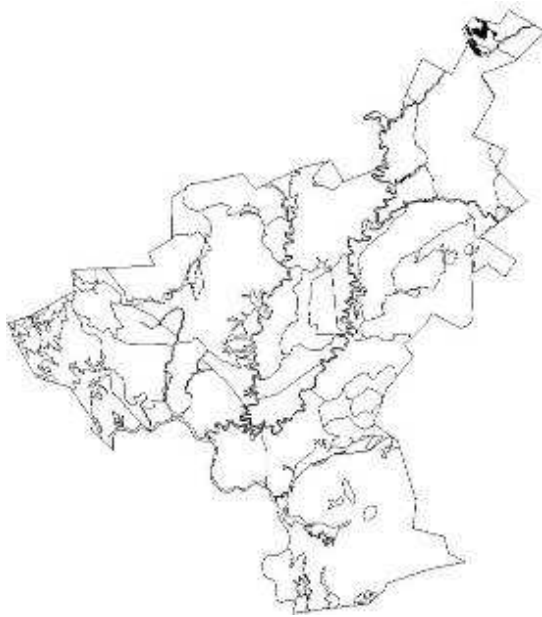
- The Apollo 11 cave archaeological site need to be better protected, but at the same time also made accessible to people genuinely interested in this site.
- Proposed IUCN category: II

Research needs The description of the landscape unit is based on only few observations in the north. The vegetation is expected to change towards the south-west and south-east.



Steep canyons slice through the limestone and shale layers of the northern Huns mountains. A great variety of plants grow here, including the in-bloom striking *Pelargonium spinosum* (foreground).

Naute inselbergs



Habitat and environmental parameters

Outcrops of sedimentary rocks of the Karoo Supergroup and younger dolerite intrusions in the western section of the Naute Game Reserve form a prominent group of inselbergs. They rise up to 170 m above the surrounding plains which are at 700 m amsl altitude. This is summer rainfall area.

Extent 24 km², 0.21 % of study area.

Description of vegetation The slopes of these inselbergs are sparsely covered with perennial plants, but during the rainy season plant cover can reach 20 %. Dwarf shrubs are dominant, but occasional trees and larger shrubs also grow on these slopes. Dominant dwarf shrubs are *Monechma genistifolium* and *Rhigozum trichotomum*. Trees such as *Acacia mellifera*, *Boscia albitrunca*, *Pappea capensis* and *Parkinsonia africana* occur as well. *Aloe dichotoma* grows on some of the inselbergs. The grass *Enneapogon scaber* is very frequent. Plant diversity is moderate and reaches almost 90 species.

Conservation importance **FAIR** The shrub *Elephantorrhiza rangei* is one of the most range-restricted species in the study area and is recorded on these inselbergs. Overall 12% of the recorded species are of conservation importance and include *Aloe dichotoma*, *Commiphora namaensis*, *Zygophyllum cretaceum* and several *Euphorbia*.

Resource use and other aspects The inselberg vegetation is important for wildlife during dry periods when the resources on the plains are exhausted.

Threats None known.

Management

- Proposed IUCN category: II

Research needs No small fauna data are available.

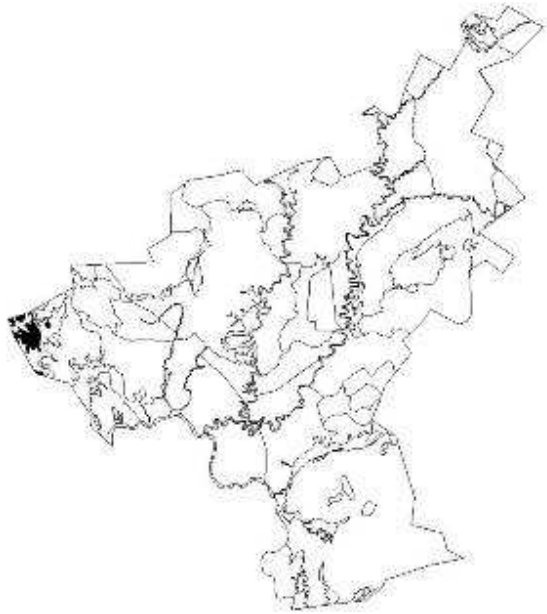


Hiding between the rocks, possibly new plant species, such as this *Oxalis* (left), and a large fig (*Ficus cordata*) surprise on the Naute inselbergs.



With large heart-shaped leaves, the bulb *Eriospermum roseum* could hardly be overlooked on the Naute inselbergs.

Nudavib mountains



Habitat and environmental parameters

These mountains and associated inselbergs are positioned in the north-western corner of the study area and adjoin the Sperrgebiet. The underlying geology is complex here and comprises metasediments of the Orange River Group, the Namaqua Metamorphic Complex and sedimentary rock of the Nama Group (Swart 2008). The highest mountains rise approximately 200 m above the surrounding plains. They clearly fall into the winter rainfall influence area.

Extent 50.6 km², 0.44% of study area.

Description of vegetation The vegetation is typical of the Succulent Karoo Biome and is dominated by dwarf and low succulent shrubs, mostly of the vygie family (Mesembryanthemaceae). Perennial plant cover is high for an arid area and ranges between 15 and 30%. Gorges and some section of these mountains support stands of taller shrubs, such as *Ceraria namaquensis*, *Euphorbia dregeana*, *Euryops namibensis* and *Zygophyllum prismatocarpum*. With over 200 plant species, diversity is high and is it difficult to discern dominant plants, but several *Eberlanzia* species occur frequently.

Conservation importance **HIGH** There is a remarkably high portion of species of conservation importance (37%) which results in this mapping unit being classified as of "high" conservation importance. Most of these are succulents. They include many *Crassula*, *Eberlanzia*, *Euphorbia*, *Pelargonium* and *Zygophyllum* species as well as several *Amphibolia*, *Antimima*, *Astridia*, *Conophytum* and *Tylecodon* species. Of particular note is a population of the rare *Aloe pearsonii* and *Pachypodium namaquanum*, and some unusual *Pelargonium* species which are still awaiting identification.

Resource use and other aspects This diverse vegetation with many endemic and range-restricted plants likely also supports a endemic invertebrates (e.g. Marais 1997). The area is used for livestock farming.

Threats

- Illegal plant collecting is likely happening, as many sought-after collector's items occur on these relatively accessible mountains.
- Livestock farming occurs mainly on the plains, but small stock also moves into the mountains occasionally. Whether this has impacted the vegetation negatively requires longer-term observations.

Management

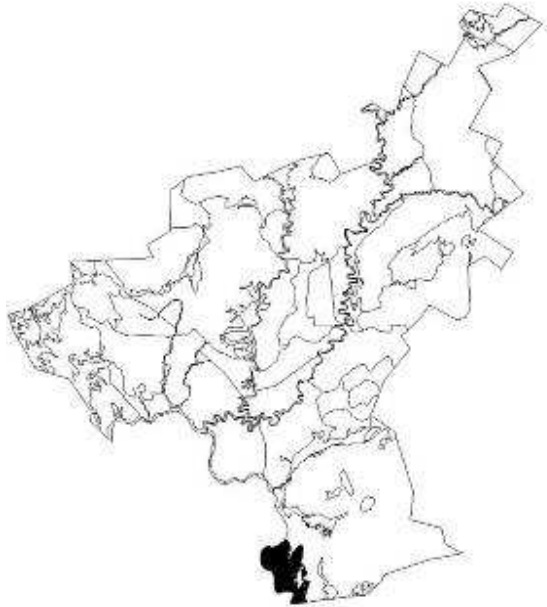
- The remarkable diversity of these mountains with many special plant species sought after by collectors deserves special protection.
- Proposed IUCN category: VI, but Ib should be strived for, at least for selected areas.

Research needs Data quality for plants is good, but all other biodiversity deserves inventories, particularly invertebrates and reptiles. Populations of red-listed and range-restricted plant species should be monitored.



The tall shrub *Ceraria namaquensis* prefers the warmer north- and west-facing slopes in the Succulent Karoo biome, here in the Nudavib Mountains on the farm Trekpoort.

South-east Orange mountains



Habitat and environmental parameters

The southern-most mountains near the Orange river are composed of gneisses of the Haib Group. Although at about 500-800 m (amsl) substantially lower, they can be considered an extension of the Richtersveld's Rosyntjieberg massif, where peaks exceed 1000 m. This W-E trending mountain chain may trap rainclouds more frequently and some of the highest rainfall – 200-300 mm – in the Richtersveld is expected here (Williamson 2000), possibly also influencing the Namibian side. Summer and winter rains could fall in this area.

Extent 147.4 km², 1.28% of study area.

Description of vegetation A sparse cover of dwarf shrubs and shrubs clothes these mountain slopes, hardly reaching 10% cover. Frequent dwarf shrubs are *Anticharis scoparia*, *Aptosimum viscosum*, *Monechma cleomoides* and *Zygophyllum cretaceum*, while the taller shrubs *Adenolobus garipensis*, *Boscia foetida*, *Ehretia alba* and the stem-succulent quiver tree (*Aloe dichotoma*), *Ceraria namaquensis*, the two Gariep-endemic *Commiphora* – *C. cervifolia* and *C. namaensis* – and *Ozoroa namaensis* are more conspicuous. The succulent shrub *Ceraria frutescens* is also present indicating the link to succulent karroo vegetation. Just over 100 plant species were recoded, nearly 30% of these of conservation importance.

Conservation importance **MEDIUM** These include endemic plant such as the two *Commiphora* mentioned above, *Jatropha orangeana*, *Ceraria namaquensis*, *Aloe garipensis* and several *Crassula* and *Euphorbia* species. The new species *Oxalis canaliculata* also grows on these mountain slopes as well as the very rare dwarf succulent *Schwantesia loeschiana*.

Resource use and other aspects Although positioned in the private Aussenkehr Nature Park, there are livestock farming activities along the river and goats also browse along the lower slopes of the mountains.





And again – the Orange River mountains turn up new species – here *Oxalis canaliculata*, presently being described and otherwise only known from Springbokvlakte in the Richtersveld.



Apart from the new discovery, the south-eastern Orange mountains drab-looking slopes support surprisingly diverse vegetation.

Threats

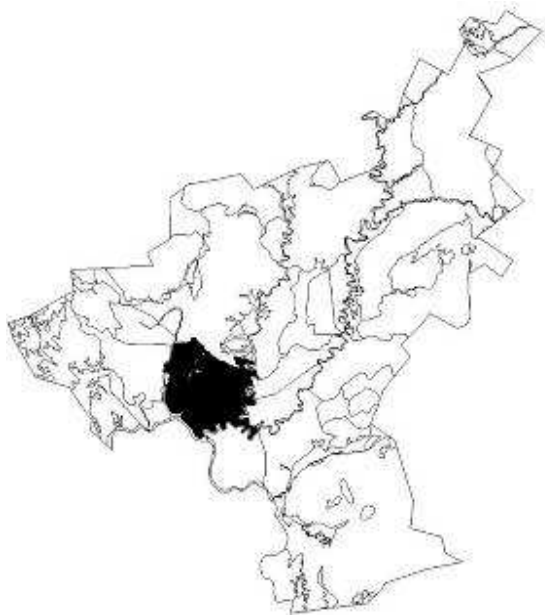
- These mountains are relatively accessible and may well be frequented by succulent collectors.
- They are subject to prospecting and mining licences, and as abandoned mines indicate, prospecting activities may well resume again.
- Livestock farming takes place along the river with concomitant activities such as collection of wood for fuel.

Management

- As for the Orange River valley, stringent implementation of the Environmental Management Act is crucial to prevent unnecessary damage.
- Proposed IUCN category: Ib

Research needs As the discovery of a new plant species indicates, these mountains certainly deserve more thorough plant surveys. Fauna data do not exist.

Southern Huns mountains



Habitat and environmental parameters

The southern part of the Huns mountains are composed largely of metasedimentary rocks of various age classes. This includes the oldest rocks in Namibia (Vioolsdrift Granite Suite) which predominate along the Orange River and in the southern part of this landscape unit as well as various metasedimentary rock types of the Namaqua Complex. This is one of the most rugged terrains in Namibia and is only accessible in few places. It falls into a winter-summer rainfall transitional area.

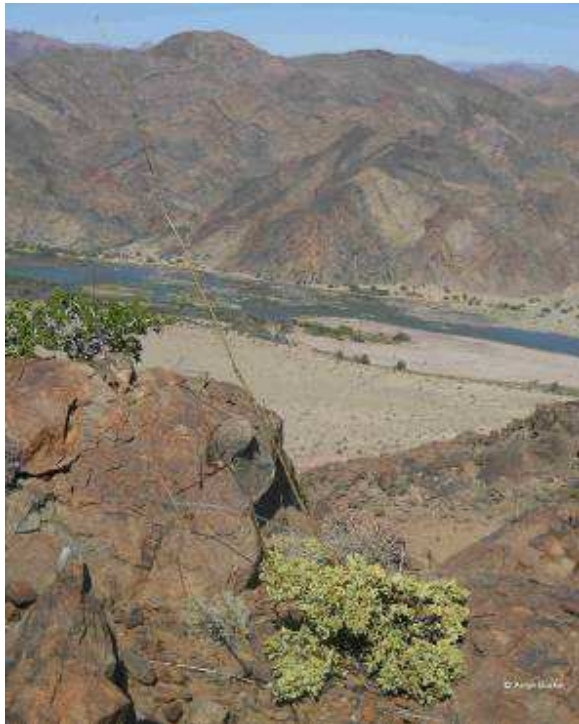
Extent 518.7 km², 4.5% of study area.

Description of vegetation At first sight the mountain slopes may look bare, but closer inspection reveals a reasonable perennial plant cover of succulent, evergreen and deciduous shrubs, particularly in kloofs and drainage lines. Here plant cover can reach 30%, while more exposed slopes barely reach 5% perennial plant cover. Plant cover is patchy and dwarf shrubs are the largest component of the vegetation accompanied by tall shrubs and even occasional trees in drainage lines and kloofs. The vegetation is widely scattered and diverse and it is therefore difficult to name the dominant species. Leaf succulents predominate represented by several *Zygophyllum* species. Dwarf shrubs include several *Hermannia* and *Monechma* species. Taller shrubs and trees include *Gymnosporia* and *Lycium* species, *Ozoroa concolor*, *Rhus* (*Searsia*) *populifolia* and *Zygophyllum prismatocarpum*. During the rainy season a colourful and diverse mix of herbs and bulbs emerge. Recorded species richness is only just over 100 plant species, but this is not a good reflection of the total diversity.

Conservation importance **MEDIUM** Some 32% of the recorded plants are of conservation importance. These are mostly succulents and include several *Conophytum*, *Crassula*, *Euphorbia*, *Pelargonium* and *Zygophyllum* species. Short-lived components of conservation importance are a newly discovered *Chlorophytum* species, the rare *Ornithogalum decusmontium* and some southern Namib endemic herbs such as *Nemesia williamsonii* and *Senecio giessii*. The unusual, range-restricted *Portulacaria armiana* occurs as well as halfmens (*Pachypodium namaquanum*).

With regard to endemic fauna, the desert mountain adder (*Bitis xeropaga*) occurs in the Huns mountains (Griffin 2003). The elusive grey rhebok (*Pelea capreolus*) – an antelope of rocky and mountain habitat in South Africa – is supposed to have its northern-most distribution in the Huns Mountains.

Resource use and other aspects Although completely within the Ai-Ais Hotsprings Game Park, the southern part of the area is subject to prospecting and mining licences.



With the antenna-like long, flexible central stem, the Gariep endemic *Portulacaria armiana* is an unusual plant growing in the southern Huns mountains.

Threats

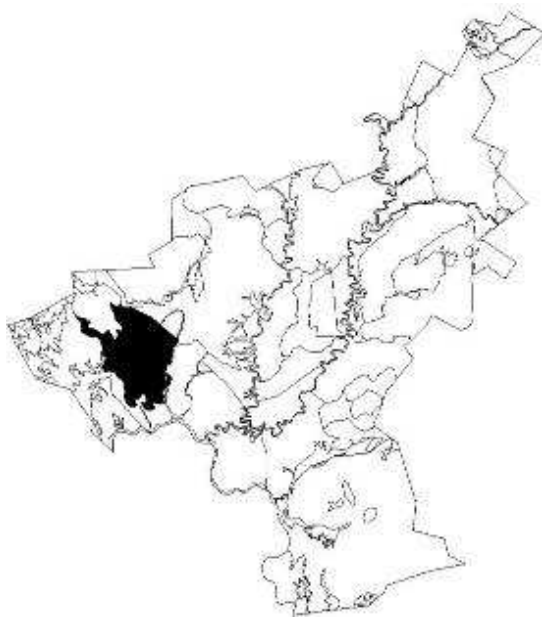
- Quarrying, prospecting and mining
- Illegal plant collecting

Management

- These mountains harbour many extremely rare plants and deserve to be excluded from prospecting and mining licensing.
- Where developments take place, stringent implementation of the Environmental Management Act is called for.
- Proposed IUCN category: Ia

Research needs Only the more accessible part of the mountain terrain along the Orange River has been surveyed, and much more data collecting is required. Animal data are poor for this mapping unit.

North-eastern Namus mountains



Habitat and environmental parameters

This section of the Namus mountains is composed of limestone, shales and sandstone of the Nama Group and has therefore been mapped as a separate landscape unit. They are higher than the western section, with the Namuskluft peak at 1654 m (amsl) presenting the highest mountain in the study area. However, the boundary between the Nama sedimentary rocks and Namaqua metamorphic rock types is not as neat in the field as shown on the map, since these formations often overlie each other and one or the other outcrops locally. This mapping unit is in a transitional winter-summer rainfall area.

Extent 452.9 km², 3.93% of study area.

Description of vegetation The vegetation is clearly transitional between Nama and Succulent Karoo Biome and consists largely of succulent dwarf shrubs, but with a large component of *Pteronia* and *Zygophyllum* species which are not restricted to the Succulent Karoo. *Zygophyllum decumbens* is dominant on many slopes, accompanied by *Pteronia rangei*. Perennial plant cover is low, ranging between 5 and 15 % and most plants hardly reach 0.5m height. Due to the complex geology and the winter-summer rain transition, well over 200 plant species have been recorded, making this the third-most diverse mapping unit, after the western Namus and Nudavib mountains.

Conservation importance **HIGH** Linked to the high plant diversity is also a large portion of species of conservation importance (31%). These include several *Antimima*, *Crassula*, *Eberlanzia*, *Euphorbia* and *Zygophyllum* species. The Namibian endemic low shrub *Indigofera merxmuelieri* is also frequent in this mapping unit. Worth mentioning are also populations of the disjunct distributed tall shrub *Euclea asperrima*, a Namibian endemic from the Naukluft and southern Namib area.

Resource use and other aspects The majority of these mountains fall into the park, but the northern section is subjected to livestock farming. The diverse vegetation is important for wildlife and livestock.

Threats Illegal plant collecting could well be a threat, as many sought-after plants occur. Whether livestock farming poses a threat requires more observations.

Management

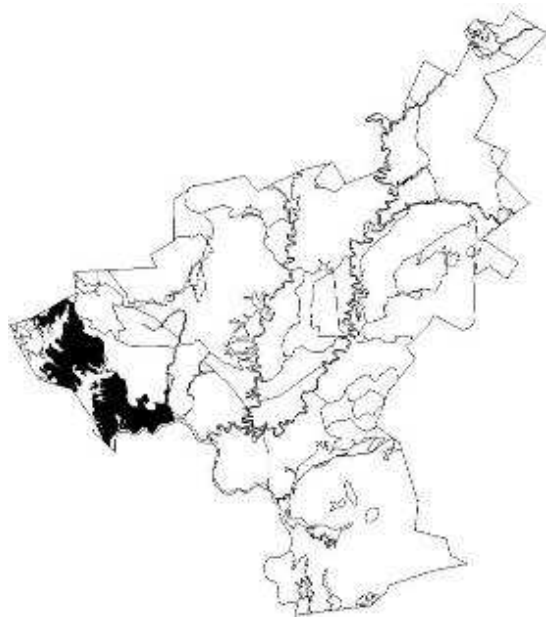
- The invasive alien *Argemone ochroleuca* was observed in some riverbeds. As infestation levels are presently low, it is well worth to eradicate these and curb their spread.
- Proposed IUCN category: Ia for part in park, VI on farming area

Research needs Despite the high plant diversity recorded, most of these mountains are inaccessible and data quality is therefore only moderate. No animal data were available at the scale of this survey.



The dark limestone of the Nama group supports a mix of Succulent Karoo and Nama Karoo plants – here quiver tree (*Aloe dichotoma*) which extends well beyond the Succulent Karoo boundary, and the southern bushman candle (*Sarcocaulon patersonii*) (foreground) which grows mainly in the Succulent Karoo biome.

Western Namus mountains



Habitat and environmental parameters

The western section of the Namus mountains is composed largely of metasedimentary rocks of various age classes. This includes the oldest rocks in Namibia (Vioolsdrift Granite Suite) and gneisses of the Haib Group, as well as various metasedimentary rock types of the Gariep and Namaqua Complex. This is one of the most rugged terrains in Namibia and the interior part is almost inaccessible. The highest peak is 1654 m (amsl). The majority falls into the winter rainfall influence area, but summer rains are also more likely towards the north-east in this mapping unit.

Extent 489 km², 4.25% of study area.

Description of vegetation At first sight the mountain slopes may look bare, but closer inspection reveals a reasonable perennial plant cover of succulent, evergreen and deciduous shrubs, particularly on gentler slopes, in kloofs and drainage lines. Here plant cover can reach 30%, while more exposed slopes barely reach 5% perennial plant cover. Nevertheless, perennial plant cover is patchy and often denser in channels and on south- and south-west facing slopes which are cooler. Dwarf shrubs are the largest component of the vegetation accompanied by tall shrubs and even occasional trees in drainage lines and kloofs. The vegetation is extremely diverse and it is therefore difficult to name the dominant species. Leaf succulents predominate represented by several *Drosanthemum* and *Eberlanzia* species, *Ruschia* and several *Stoeberia* species. A great diversity of *Crassula* and *Pelargonium* species adds to the spectrum. Taller shrubs and trees include *Euphorbia dregeana*, *Ozoroa concolor*, *Rhus (Searsia) populifolia* and *Zygophyllum prismatocarpum*. During the rainy season a colourful and diverse mixtures of herbs and bulbs emerge. With well over 300 plant species, species richness is by far the highest recorded in a landscape unit in the GFRCL.

Conservation importance **HIGH** The extremely high plant diversity in these mountains also results in the highest number of plant species of conservation importance recorded in a landscape unit in this study. Some 36% of the recorded species are of conservation importance. These are mostly succulents and include several *Amphibolia*, *Antimima*, *Astridia*, *Conophytum*, *Crassula*, *Eberlanzia*, *Euphorbia*, *Pelargonium*, *Ruschia* and *Zygophyllum* species. Of particular importance are the endangered giant quiver tree (*Aloe pillansii*), the rare *Juttadinteria albata* which has been found on some of the footslopes near Dreigratberg, and some of the largest populations of the rare *Aloe pearsonii* in Namibia. The range-restricted *Portulacaria armiana* as well as halfmens (*Pachypodium namaquanum*) also deserve to be mentioned.

And if all of this is not sufficient to highlight the mountains' importance for biodiversity, two new bulb species have been found by us during the surveys on these mountains – a new *Chlorophytum* and *Moraea* species, the former only known from here, the new *Moraea* only from one more locality in the Sperrgebiet.

Resource use and other aspects Most of the area is subject to prospecting and mining licences. Prospecting activities currently take place near the old Lorelei copper mine and, without MET's consent, a road has been built up the mountain slopes, very close to critical plant populations, such as halfmens (*Pachypodium namaquanum*). No Environmental Management Plan exists for these activities in the park.

Threats

- Quarrying, prospecting and mining
- Illegal plant collecting

Management

- These mountains are true wilderness areas with tremendous known plant diversity and many extremely rare species. They deserve to be excluded from prospecting and mining licensing for good.
- Where developments are taking place, stringent implementation of the Environmental Management Act is critical.
- Proposed IUCN category: Ia

Research needs Most of the mountain terrain has not been surveyed, and almost every foray into unknown terrain seems to turn up new plant species. More survey work is therefore required, preferably before prospecting and mining activities access unknown areas. Field-based Red Data assessments and monitoring of critical plant populations (e.g. *Aloe pillansii* and *Pachypodium namaquanum*) are called for.



Halfmens (*Pachypodium namaquanum*) in the western Namus mountains.



The diversity of plants of conservation importance on the slopes of the Western Namus mountains is mind-boggling. The largest populations of the rare *Aloe pearsonii* grow here (top photo), as well as such iconic plants as halfmens (*Pachypodium namaquanum*), botterboom (*Tylecodon paniculatus*) (foreground right) and the branched quiver tree (*Aloe ramosissima*) (centre).

Obib mountains

(adapted from Burke 2006)

Habitat and environmental parameters A small section of the eastern part of the Obib Mountains extends from the Sperrgebiet into the Greater Fish River Canyon Landscape. In the northern section of the Obib Mountains, the highest peaks rise approximately 300 m above the surrounding plains. Schist and quartzite of the Gariep Complex, interspersed by quartz veins, are the main rock types. Rainfall at nearby Rosh Pinah has been recorded to provide an annual mean of 54 mm. Fog, moving up the Orange River, however, is an important additional moisture source. Windy conditions are expected all year round, but the broken-up nature of the mountains is expected to provide many sheltered places.

Description of vegetation The vegetation consists largely of leaf and stem succulents. For example *Euphorbia cibdela*, *Euphorbia dregeana* and *Euphorbia gummifera* are common and many other species are locally dominant such as *Aloe ramosissima*, *Aloe pearsonii*, *Aridaria noctiflora*, *Berkheya canescens*, *Ceraria fruticulosa*, *Drosanthemum luederitzii*, *Lampranthus hoerleinianus*, *Othonna opima*, *Pelargonium spinosum* and *Ruschia muelleri*. Most show an average height of 30 cm, but in sheltered places and valleys, average plant height can reach 1.5 m. Plant cover is extremely variable and ranges from 1% on exposed, dry slopes to 20% in valleys and sheltered places and those receiving run-off. Plant diversity is with over 450 species extremely high.



Although looking rather barren during the dry season, the schist slopes of the Obib mountains support a range of plant species of conservation importance.

Conservation importance **HIGH** These mountains are of extremely high conservation importance because of the presence of many range-restricted and protected species. Many succulents of the genera *Aloe*, *Amphibolia*, *Anacampseros*, *Antimima*, *Astridia*, *Cephalophyllum*, *Conophytum*, *Crassula*, *Eberlanzia*, *Hartmanthus*, *Hoodia*, *Juttadinteria*, *Lavrana*, *Psammophora*, *Ruschia*, *Stapelia*, *Stoeberia*, *Tromotriche* and *Tylecodon* occur which are all protected. In addition, there are also many southern Namib endemics, such as *Androcymbium exiguum*, *Arctotis frutescens*, *Berkheya schinzii*, *Brownanthus arenosus*, *Cynanchum meyeri*, *Eriocephalus klinghardtensis*, *Mesembryanthemum barklyi*, *Mesembryanthemum pellitum* and *Senecio giessii*.

Resource use and other aspects These mountains provide an important retreat and food source for wildlife. Obib Fountain is an important natural freshwater source for animals.

Threats

- Mining and exploration
- Off-road driving
- Locally littering, pollution and firewood collection

Management

- Demarcate some areas for recreational use and enforce track discipline and waste management
- All other areas should be demarcated out of bounds
- Proposed IUCN category: Ib

Research needs Field-based assessments of critical plant species for red-listing are required.



Firewood collecting and recreational use are threats to the biodiversity around Rosh Pinah.

References

- African Wilderness Restoration (2010) Canyon Nature Park - report on vegetation survey and analysis. Internal report, 36 pp.
- Brown, C. (2006) Historic distribution of large mammals in the Greater Fish River Canyon Complex, southern Namibia, and recommendations for re-introductions. Adapted from report in the Gondwana Canyon Park, Feb. 2000.
- Burke, A. (2001a). Determinants of inselberg floras in arid Nama Karoo landscapes. *Journal of Biogeography* 28: 1211-1220.
- Burke, A., Kyläkorpi, L., Rydgren, B. & Schneeweiss, R. (2008) Testing a Scandinavian biodiversity assessment tool in an African desert environment, *Environmental Management* 42: 698-706.
- Burke, A. (2006) The Sperrgebiet – Managing its biodiversity. EnviroScience & Namibia Nature Foundation.
- Burke, A. (2011) Managing biodiversity in the /Ai-/Ais Hotsprings Game Park. Strengthening the Protected Area Network Project and Ministry of Environment & Tourism, Windhoek, Namibia, 48 pp.
- Deckert, J. (2010) Karios - Millipedes, termites, true bugs. In: Jurgens, N., Haarmeyer, D.H., Luther-Mosebach, J., Dengler, J., Finckh, M. & Schmiedel, U. (eds.) *Biodiversity in southern Africa 1: Patterns at a local scale*. Pp. 468-469. Klaus Hess, Gottingen & Windhoek.
- Dudley, N. (2008) Guidelines for applying protected area management categories. IUCN, Gland, Switzerland.
- Griffin, M. (2003) Annotated checklist and provisional conservation status of Namibian reptiles. *Namibia Scientific Society*, Windhoek, 168 pp.
- Irish, J. (1994). The biomes of Namibia, as determined by objective categorisation. *Navorsinge van die Nasionale Museum Bloemfontein* 10: 549-592.
- IUCN (2001). IUCN Red list categories and criteria: version 3.1. IUCN Species survival commission. Gland, Switzerland and Cambridge, U.K., 33 pp.
- Jürgens N., Haarmeyer D.A., Luther-Mosebach J., Dengler J., Finckh M. & Schmiedel U. (eds.) (2010). *Biodiversity in southern Africa. 1: Patterns at the local scale – the BIOTA Observatories*. Klaus Hess Publishers, Göttingen & Windhoek, 801 pp.
- Knapp, S. (2011) Rarity, species richness, and the threat of extinction-are plants the same as animals? *PLoS Biology* 9 (5), art. no. e1001067.
- Loots, S. (2005). *Red Data Book of Namibian Plants*. Southern African Botanical Diversity Network Report No. 38. SABONET, Pretoria and Windhoek, 124 pp.
- Masson, J. (2006) Apollo 11 cave in southwest Namibia. *The South African Archaeological Bulletin* Vol. 61, No. 183, Jun., 2006: 76-89.
- Mendelsohn, J., Jarvis, A., Roberts, C. & Robertson, T. (2002). *Atlas of Namibia*. David Philip Publishers, Cape Town, 200 pp.
- Mey, W. (2010) Karios - Butterflies and moths. In: Jürgens, N., Haarmeyer, D.H., Luther-Mosebach, J., Dengler, J., Finckh, M. & Schmiedel, U. (eds.) *Biodiversity in southern Africa 1: Patterns at a local scale*. Pp. 470-471. Klaus Hess, Gottingen & Windhoek.
- O'Keeffe, J., Palmer, R., Avis, T. & Skelton, P. 1994. *Lower Orange River Baseline Study*. Namdeb Diamond Corporation, Oranjemund, 67 pp.
- Pressey, R.L., Cowling, R.M. & Rouget, M. (2003). Formulating conservation targets for biodiversity pattern and process in the Cape Floristic Region, South Africa. *Biological Conservation* 112: 99-127.
- Swart, R. (2008) An earth science review of the Orange-Fish River basin, Namibia. Report produced for the Ephemeral River Basin in Southern Africa (ERB) Project, Desert Research Foundation of Namibia, Windhoek, 46 pp.

- Wendt, W.E. (1976) 'Art mobilier' from the Apollo 11 cave, South West Africa: Africa's oldest dated works of art. *South African Archaeological Bulletin* 31: 5-11.
- Williamson, G. (2000). *Richtersveld - the enchanted wilderness*. Umdaus Press, Hatfield, South Africa, 258 pp.

Appendix 1.

Plant species of conservation importance, their rating and occurrence in different landscape units of the Greater Fish River Canyon Landscape.

[Insert GFRCL-Biodiversity zonation-App1.pdf]