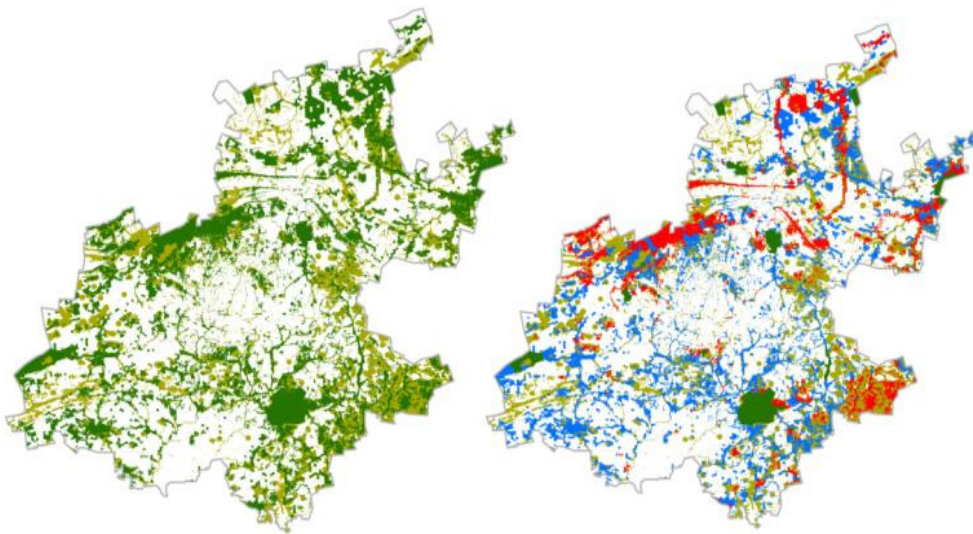


2011

Gauteng Conservation Plan Version 3.3 (C-Plan 3.3)



**agriculture and
rural development**

Department: Agriculture and Rural Development
GAUTENG PROVINCE

Directorate Nature Conservation

Technological Services

Technical Report
Gauteng Conservation Plan Version 3.3 (C-Plan 3.3)
October 2011 revised December 2013

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Contributions by C-Plan 3 Team

CONTENTS

| | | |
|---------|--|---|
| 1. | Introduction | 1 |
| 2. | Background | 1 |
| 3. | Main purpose of C-Plan 3.3 | 1 |
| 4. | Improvements of C-Plan 3.3 | 2 |
| 5. | C-Plan 3 Team | 3 |
| 6. | Software used | 3 |
| 7. | Projection | 4 |
| 7.1. | Projection Coordinate System | 4 |
| 7.2. | Information on Albers from ArcGIS 9.3 help file | 4 |
| 8. | Raster GIS layers for habitat modelling | 4 |
| 8.1. | Land cover classes | 5 |
| 8.2. | Pristine land cover classes | 6 |
| 8.2.1. | Cultivated land | 6 |
| 8.2.2. | Cultivated Land excluding Wetlands | 6 |
| 8.2.3. | Cultivated Land excluding built-up, mines and other excluded areas | 6 |
| 8.2.4. | Final Cultivated Land | 6 |
| 8.2.5. | Primary Grassland | 7 |
| 8.2.6. | Primary Grassland and Natural Bare Rock | 7 |
| 8.2.7. | Primary Wooded Grassland | 7 |
| 8.2.8. | Primary Woodland | 7 |
| 8.2.9. | Primary Vegetation | 7 |
| 8.2.10. | Primary Vegetation and Bare Natural Rock | 7 |
| 8.2.11. | GDARD & Metropolitan Wetlands and DWAF Rivers | 7 |
| 8.2.12. | GTI land cover 2009 Wetlands | 7 |
| 8.2.13. | Final Wet Areas (150m buffer) | 8 |
| 9. | Layers for Biodiversity Features | 8 |

| | | |
|-------------|--|-----------|
| 9.1. | Plants (Michele Pfab) | 8 |
| 9.1.1. | Confirmed locations (Buffered) | 11 |
| 9.1.2. | Habitat- and meta-population models | 11 |
| 9.2. | Bird Habitat Models (Dr Craig Whittington-Jones) | 15 |
| 9.2.1. | Species included in C-Plan 3 | 15 |
| 9.2.1.1. | African Finfoot (<i>Podica senegalensis</i>) | 15 |
| 9.2.1.2. | African Marsh-Harrier (<i>Circus ranivorus</i>) | 16 |
| 9.2.1.3. | African Grass-Owl (<i>Tyto capensis</i>) | 17 |
| 9.2.1.4. | Blue Crane (<i>Anthropoides paradiseus</i>) | 19 |
| 9.2.1.5. | Blue Korhaan (<i>Eupodotis caerulescens</i>) | 20 |
| 9.2.1.6. | Cape Vulture (<i>Gyps coprotheres</i>) | 21 |
| 9.2.1.7. | Half-collared Kingfisher (<i>Alcedo semitorquata</i>) | 22 |
| 9.2.1.8. | Melodious Lark (<i>Mirafra cheniana</i>) | 23 |
| 9.2.1.9. | Secretarybird (<i>Sagittarius serpentarius</i>) | 23 |
| 9.2.1.10. | White-bellied Korhaan (<i>Eupodotis senegalensis</i>) | 25 |
| 9.2.1.11. | White-backed Night-Heron (<i>Gorsachius leuconotus</i>) | 25 |
| 9.2.2. | Species excluded from C-Plan 3 | 26 |
| 9.3. | Invertebrates (Ian Engelbrecht) | 27 |
| 9.3.1. | Butterflies | 27 |
| 9.3.1.1. | Highveld blue butterfly (<i>Lepidochrysops praeterita</i>) | 27 |
| 9.3.1.2. | Heidelberg Copper Butterfly (<i>Chrysoritis aureus</i>) | 29 |
| 9.3.1.3. | Roodepoort Copper Butterfly (<i>Aloeides dentatis dentatis</i>) | 30 |
| 9.3.2. | Beetles | 31 |
| 9.3.2.1. | Stobbia's fruit chafer beetle (<i>Ichneustoma stobbiai</i>) | 31 |
| 9.3.3. | Invertebrates excluded from C-Plan 3 | 31 |
| 9.4. | Mammals (Lihle Dumalisile) | 32 |
| 9.4.1. | Species included in C-Plan 3 | 32 |
| 9.4.1.1. | Juliana's golden mole (Bronberg sub-population) (<i>Neamblysomus julianae</i>) | 32 |
| 9.4.1.2. | Southern African hedgehog (<i>Atelerix frontalis</i>) | 34 |
| 9.4.1.3. | Spotted-necked otter (<i>Lutra maculicollis</i>) | 34 |
| 9.4.1.4. | White tailed mouse (<i>Mystromys albicaudatus</i>) | 36 |
| 9.4.1.5. | Rusty pipistrelle/bat (<i>Pipistrellus rusticus</i>) | 36 |
| 9.4.1.6. | Blasius's/Peak-saddle horseshoe bat (<i>Rhinolophus blasii</i>) | 37 |
| 9.4.1.7. | Darling's horseshoe bat (<i>Rhinolophus darlingi</i>) | 37 |
| 9.4.1.8. | Geffroy's horseshoe bat (<i>Rhinolophus clivosus</i>) | 37 |
| 9.4.1.9. | Hildebrandt's horseshoe bat (<i>Rhinolophus hildebrandtii</i>) | 37 |
| 9.4.1.10. | Scheiber's long-fingered bat (<i>Miniopterus schreibersii</i>) | 37 |
| 9.4.1.11. | Temminck's hairy bat (<i>Myotis tricolor</i>) | 38 |
| 9.4.1.12. | Welwitsch's hairy bat (<i>Myotis welwitschii</i>) | 38 |
| 9.4.2. | Species excluded from C-Plan 3 | 39 |
| 9.5. | Fish – Maloney's Eye sub-catchment (Siyabonga Buthelezi) | 39 |
| 9.6. | Herpetofauna (Gavin Masterson) | 40 |
| 9.6.1. | Species included in C-Plan 3 | 40 |
| 9.6.2. | Species excluded from C-Plan 3 | 40 |
| 9.7. | Pan clusters | 41 |
| 9.7.1. | Pans within near-pristine quaternary catchments | 41 |
| 9.7.2. | Good quality Pans | 41 |
| 9.8. | Near-pristine Quaternary Catchment | 43 |
| 9.9. | Bioclimatic zones | 43 |
| 9.9.1. | Preparation of input for MARXAN analyses | 43 |
| 9.9.2. | MARXAN analyses (Dr S Holness - sholness@nmmu.ac.za) | 45 |
| 9.9.2.1. | Shapefiles: | 45 |
| 9.9.2.2. | Original data: | 46 |
| 9.9.2.3. | Analysis method: | 46 |
| 9.9.2.4. | Evaluation: | 47 |
| 9.9.2.5. | Recommendation for inclusion in CPLAN 3: | 48 |

| | | |
|--------------|--|-----------|
| 9.9.2.6. | Layers and fields: | 48 |
| 9.9.3. | Final decision on bioclimate zone layer | 49 |
| 9.10. | Carbon sequestration: Woodland (Mesic / Scarp) | 49 |
| 9.11. | Primary Vegetation | 50 |
| 9.11.1. | Vegetation modelling | 50 |
| 9.11.2. | Finalizing Primary Vegetation layer | 52 |
| 10. | Creating input files for C-Plan 3 | 53 |
| 10.1. | Planning Unit File | 53 |
| 10.1.1. | Excluded Areas | 53 |
| 10.1.2. | Protected Areas | 54 |
| 10.1.3. | Available Areas | 55 |
| 10.1.3.1. | Build an Initial Planning Unit (PU) File | 56 |
| 10.1.3.2. | Erase Excluded Areas from the Initial PU | 56 |
| 10.1.3.3. | Create fields for the Initial PU | 56 |
| 10.1.3.4. | Erase Protected Areas from the Initial PU | 56 |
| 10.1.4. | Final Planning Unit File | 57 |
| 10.1.4.1. | Combine Excluded Areas, Protected Areas and the Initial PU | 57 |
| 10.1.4.2. | Remove smaller than the minimum size polygons and slivers | 57 |
| 10.2. | Biodiversity Feature File (BDF): | 58 |
| 10.2.1. | Fields needed for BDF | 58 |
| 10.2.2. | Numbering system for BDFs | 59 |
| 10.2.3. | Vulnerability (sensitivity) values | 60 |
| 10.2.4. | Creating the BDF table | 60 |
| 10.3. | Site-by-Feature File (SBF) / PU versus BDF File | 60 |
| 10.3.1. | ArcView: Tabulate areas | 60 |
| 10.3.2. | ArcMap: Tabulate areas | 60 |
| 10.4. | Building DBF and SBF in CLUZ | 61 |
| 10.5. | Cost / Threat Layer | 63 |
| 10.6. | C-Plan Database | 64 |
| 10.6.1. | Build C-Plan database | 64 |
| 10.6.2. | Import the Vulnerability Score | 64 |
| 11. | Critical Biodiversity Areas (CBAs) | 65 |
| 11.1. | Set up C-Plan Database in ArcView | 65 |
| 11.2. | Method for analysis | 65 |
| 11.3. | Discussion | 66 |
| 12. | C-Plan Version 3.3 | 68 |
| 12.1. | Background | 68 |
| 12.2. | Statistics for C-Plan 3.3 | 69 |
| 13. | Ecological Support Areas (ESAs) | 70 |
| 13.1. | Method to create ESAs | 70 |
| 13.1.1. | Dolomite | 70 |
| 13.1.2. | Rivers | 71 |
| 13.1.3. | Wetlands | 71 |
| 13.1.3.1. | Pans | 71 |
| a. | Good quality pans | 71 |
| b. | Transformed pans: | 71 |
| 13.1.3.2. | Other Wetlands | 71 |
| 13.1.4. | Corridors | 72 |
| 13.1.5. | Ridges | 73 |
| 13.1.6. | Metropolitan low cost areas | 74 |
| 13.1.6.1. | Original data | 74 |

| | |
|---|----|
| 13.1.6.2. Data compilation method..... | 74 |
| 13.1.6.3. Recommendation for inclusion in CPLAN 3:..... | 74 |
| 13.2. Final Ecological Support Areas | 75 |
| 14. Conclusion | 75 |
| 15. Acknowledgements | 76 |
| 16. References to GIS Tools used | 78 |
| 17. List of Spatial Data used | 79 |

Abbreviations

| | |
|---------|--|
| BDF: | Biodiversity Feature |
| C-Plan: | Gauteng Conservation Plan |
| CBA: | Critical Biodiversity Area |
| CLUZ: | Conservation Land-Use Zoning software |
| DEA: | Department of Environmental Affairs |
| EIA: | Environmental Impact Assessment |
| ESA: | Ecological Support Area |
| GIS: | Geographic Information System |
| GDARD: | Gauteng Department Agriculture and Rural Development |
| GTI: | GeoTerra Image (GTI) Pty Ltd |
| GPS: | Global Positioning System |
| ISCW: | Institute for Soil, Climate and Water |
| IUCN: | International Union for Conservation of Nature |
| LC: | Least Concern |
| LC09: | Land cover 2009 dataset developed by GTI |
| NT: | Near Threatened |
| OL: | Orange List |
| OLC: | Orange List Confirmed (Location) |
| NDA: | National Department of Agriculture |
| PA: | Protected Area |
| PQ4 | Priority Quaternary Catchment |
| PU: | Planning Unit (same as the term “planning site” previously used in C-Plan 1 and 2) |
| QDS: | Quarter Degree Square |
| RL: | Red Listed (Data) |
| RLC: | Red List Confirmed (Location) |
| RSA: | Republic of South Africa |
| SANBI: | South African National Biodiversity Institute |
| SBF: | Site-by-Feature |
| V: | Vulnerable |

1. Introduction

Gauteng Nature Conservation (hereafter Conservation), a component of the Gauteng Department of Agriculture and Rural Development (GDARD) produced the Gauteng Conservation Plan Version 3 (C-Plan 3) in December 2010. The conservation plan was edited on three occasions since then: C-Plan 3.1 was released in July 2011 after it became apparent that some areas were not desirable in Critical Biodiversity Areas (CBAs hereafter). Not all areas were addressed in the first round of editing, so this was done during September 2011 resulting in C-Plan Version 3.2. It was soon released however, that some CBAs became separated by the removal of undesirable areas causing some attributes not to be completely reflective of that CBAs any longer. C-Plan 3.3 became available in October 2011 after this issue was addressed. References to C-Plan 3 in this document will naturally refer to version 3.3 as well where relevant.

2. Background

Conservation planning was started in Gauteng in the year 2000 and the aim was to revise C-Plan at least every 5 years. C-Plan Version 1 was produced in 2001 and was followed by version 2 in 2005. Version 2 was refined in 2007 and was named Version 2.1. The small size of the province made it feasible to conduct an extensive biodiversity survey, named BGAP, which aimed to provide the information on spatial occurrence of biodiversity necessary for rigorous conservation planning. C-Plan 3 represents priority areas for biodiversity conservation in the Gauteng province.

C-Plan 3 is based on the systematic conservation protocol developed by Margules & Pressey (2000) and is based on the principles of complementarity, efficiency, defensibility and flexibility, irreplaceability, retention, persistence and accountability. Systematic conservation planning is an iterative process. Knowledge of the distribution of biodiversity, the status of species, approaches for dealing with aspects such as climate change, methods of data analysis, and the nature of threats to biodiversity within a planning region are constantly changing, especially in the Gauteng province which is developing at an extremely rapid rate. This requires that the conservation plan be treated as a living document with periodic review and updates.

The GIS software tool, C-Plan, developed in Australia was used for data analysis in all versions of the Gauteng Conservation Plan, and the name was adopted for the product, which has been known within the department and by its stakeholders as C-Plan since. The products have been the basis of the decision support process to the EIA process in the department, and together with a standardized set of decision making guidelines have allowed for consistent, scientifically justified and defensible recommendations on development applications submitted to GDARD.

3. Main purpose of C-Plan 3.3

The main purposes of C-Plan 3.3 are:

- to serve as the primary decision support tool for the biodiversity component of the Environmental Impact Assessment (EIA) process;
- to inform protected area expansion and biodiversity stewardship programmes in the province;
- to serve as a basis for development of Bioregional Plans in municipalities within the province.

C-Plan 3.3 will be a valuable tool to ensure adequate, timely and fair service delivery to clients of GDARD, and will be critical in ensuring adequate protection of biodiversity and the environment in Gauteng Province.

4. Improvements of C-Plan 3.3

Substantial improvements have been made in C-Plan 3.3, including the following:

- The Gauteng boundary has changed since C-Plan 2 and all data had to be updated to include the Merafong municipality. Some data i.e. ridges and koppies, wetlands were obtained from North West Parks Board and were further updated by GDARD.
- The department has obtained an up to date (2009), high quality, fine scale land cover dataset produced by GeoTerra Image (GTI) for the province. This dataset was used in species habitat modeling in addition with other spatial data for Gauteng.
- Transformed areas to be avoided were created newly from GTI 2009 land cover and other updated datasets i.e. QuickBird imagery available to assist in establishing C-Plan 3.2 areas.
- The conservation status of several species has been revised allowing for more credible decision making on which species are included in the plan. The frog layer and all but one snake species were consequently dropped from C-Plan 3.2.
- Most of the existing input layers have undergone substantial revision and improvement i.e.:
 - Better distribution of confirmed global positions system (GPS hereafter) readings for species from continued fieldwork carried out by GDARD staff and some GPS location data received from external stakeholders.
 - All species habitat models were re-created based on new land cover 2009 data developed by GTI and other relevant data.
 - Wetland data were improved greatly by integrating fine-scale wetland data from Ekurhuleni and some of Johannesburg Metropolitan Councils, and digitized data from Quickbird 2004/05 satellite imagery by GDARD.
- New input layers include wooded areas for carbon sequestration, unique fish species catchment (Maloney's Eye), bioclimatic zones, primary vegetation, pristine quaternary catchments (in C-Plan 2 included in ecological processes layer).
- Climate change considerations have been identified for inclusion. Corridors for climate change and species migration were completely re-created based on the updated land cover 2009 and spatial data for ridges and wetlands maintained by GDARD.
- Existing protected areas in the province have been re-evaluated for inclusion as contributing to targets.
- The planning units have been completely re-created. They are now based on 100 ha hexagonal shapes (previously 100 ha square grids).
- The final product includes Critical Biodiversity Areas (CBAs) and Ecological Support Areas (ESAs) to be in line with municipal Bioregional Plans. CBAs contain irreplaceable, important and protected areas (terms used in C-Plan 2) and ESAs contain buffered wetlands, buffered rivers, ridges within 1500m of CBAs, dolomite, corridors and low cost metropolitan areas (from Dr Holness).
- C-Plan version 3.3 came about to properly bring C-Plan in line with municipal Bioregional Plans by reclassifying agricultural areas within CBAs rather as ESAs. Many transformed areas found since releasing C-Plan 3 were removed too. See the paragraph on C-Plan 3.3 later in this document for more information.

Important considerations in the development of the revised conservation plan, which did not exist during the production of previous versions, are the strategic support required by the protected area expansion and biodiversity stewardship programmes within GDARD, and the requirement for production of Bioregional Plans by the municipalities. These considerations influenced the technical aspects of the project in particular the identification of CBAs and ESAs as well as a public review of the technicalities of the conservation plan used to identify CBAs.

SANBI has appointed bioregional planning consultants to assist provinces and municipalities to develop conservation plans and Bioregional Plans. These consultants provided technical assistance, GIS

assistance in creating the bioclimatic zone layer, and supplied spatial data for Ekurhuleni and Johannesburg municipalities to expedite the publication of Bioregional Plans, particularly for municipalities responsible for grassland conservation. Funding for this initiative was provided to the SANBI Grasslands Programme by WWF.

5. C-Plan 3 Team

| Person(s) | Responsibility |
|--|--|
| Michele Pfab (SANBI) | Project leader 2000-2009 and continued to advise after she left GDARD in 2009. Also responsible for plant layers, vegetation, planning, technical advise, final analyses |
| Dr Stephen Holness and Andrew Skowno | Bioregional planning consultants |
| Pieta Compaan (GDARD) | GIS, planning, protected areas, abiotic layers including wetlands, habitat modeling, ecological support areas, final analyses, final product, technical report |
| Siyabonga Buthelezi, Vukosi Ndlophu, Tebogo Nkadimeng, Piet Muller (GDARD) | Aquatics |
| Dr Craig Whittington-Jones (GDARD) | Birds |
| Ian Engelbrecht (GDARD) | Invertebrates |
| Gavin Masterson (GDARD) | Herpetofauna |
| Lorraine Mills (GDARD) | Plants |
| Lihle Dimalisile (GDARD) | Mammals |
| Steven Nevhutalu (GDARD) | Coordination, Bioregional planning |

6. Software used

C-Plan 3 was created with the help of a large variety of GIS and Microsoft Office software packages including the following:

- ESRI family of GIS products (ArcEditor 9.3.1, Spatial Analyst, ModelBuilder, ArcView 3.2).
- GIS tools such as Tools for Graphics and Shapes Extension for ArcGIS version 1.1.85, ET GeoWizards version 9.9 for ArcGIS 9.2 and above, Hawth's Analysis Tools version 3.27, XTools Pro for ArcGIS desktop version 6.1.0 Free Tools, Polygon-to-Point Extension for ArcView 3.x.
- MS Office (Excel 2003) – creating dbf tables as Excel 2007 removed this function.
- CLUZ, an ArcView GIS interface that allows users to design protected area networks and conservation landscapes. It can be used for on-screen planning and also acts as a link for the MARXAN conservation planning software. It is currently being developed at DICE and is funded by the British Government through their Darwin Initiative for the Survival of Species.
- MARXAN (used by Dr S Holness to finalize the bioclimatic zones input layer for C-Plan 3) has been developed by researchers at The Ecology Centre of the University of Queensland. It has been designed to produce efficient solutions to the problem of selecting portfolios of planning units that meet a suite of biodiversity targets.
- The software called C-Plan version 3.4 (ArcView linked C-plan Decision Support System) developed by New South Wales National Parks and Wildlife Services in Australia (to execute C-Plan 3 final analyses with).

7. Projection

All files were created in Albers (to enable easy area calculations) and the end result for C-Plan 3 was re-projected to geographic format for distribution.

7.1. Projection Coordinate System

Projected Coordinate System: WGS_1984_Albers

Projection: Albers
False_Easting: 0.00000000
False_Northing: 0.00000000
Central_Meridian: 24.00000000
Standard_Parallel_1: -18.00000000
Standard_Parallel_2: -32.00000000
Latitude_Of_Origin: 0.00000000
Linear Unit: Meter

Geographic Coordinate System: GCS_WGS_1984

Datum: D_WGS_1984
Prime Meridian: 0
Angular Unit: Degree

7.2. Information on Albers from ArcGIS 9.3 help file

Shape: Shape along the standard parallels is accurate and minimally distorted in the region between the standard parallels and those regions just beyond. The 90° angles between meridians and parallels are preserved, but because the scale along the lines of longitude does not match the scale along the lines of latitude, the final projection is not conformal.

Area: All areas are proportional to the same areas on the earth.

Direction: Locally true along the standard parallels.

Distance: Distances are most accurate in the middle latitudes. Along parallels, scale is reduced between the standard parallels and increased beyond them. Along meridians, scale follows an opposite pattern.

Limitations

Best results for regions predominantly east–west in orientation and located in the middle latitudes. Total range in latitude from north to south should not exceed 30–35°. No limitations on the east–west range.

Uses and applications

As it is usually used for small regions or countries but not for continents, it was regarded to be the appropriate projection for developing C-Plan 3.

8. Raster GIS layers for habitat modelling

Various raster layers were created from environmental parameters such as altitude, aspect, slope (all derived from a mosaiced SRTM 90m DEM received from DWAF, 2009), land cover, geology, soil, landtypes, ridges and wetlands and rivers. More information on how these layers were created is available in the document called Environmental Parameters created for habitat modelling for C-Plan 3 compiled by Pieta Compaan, 2010.

New land cover used in habitat models was created by GeoTerralimage (GTI) Pty Ltd in 2009 from a combination of single date SPOT5 10m resolution satellite imagery, acquired during both 2009 and 2008,

and 50cm resolution aerial photography acquired in 2009. The 2009 aerial photography covered the main urban centres of Pretoria and Johannesburg. All the digital aerial photography and the SPOT5 imagery was ortho-rectified using a combination of aerial photography and cadastre as the primary geographical reference, and a 20m DEM for terrain height.

This document does not contain information on methodology followed by GTI to develop land cover 2009. Full Copyright and Intellectual Property Rights of the digital land-cover data resides with GTI and the digital land-cover data and accompanying report are distributed under license by GTI.

8.1. Land cover classes

The classes of land cover 2009 developed by GTI in Table 1 were included and reclassified to values in the field "Gridcode" below. The original land cover codes are displayed in the field "LC09 No". The "Tenure C-Plan 3" field contains the term "Available" if the land cover was considered in habitat models or in the planning units (PUs) for C-Plan 3 site database. If the land cover was transformed or unsuitable, the land cover was reclassified to a gridcode 9999 and "Excluded" for conservation purposes (ignored by C-Plan 3 analysis). Cultivated land and old lands may still harbor suitable habitat for most faunal species as it is long grass, therefore it was classied as "Available" in PUs. Cultivated land, however was considered a threat (explained later in this document) with a certain value and steered away from in the final C-Plan 3 analysis, preferring natural areas in selecting CBAs. Primary vegetation is only an issue for plants and invertebrates whose foodplants are the herbs and forbs that disappear after cultivation.

Table 1: Reclassification of GTI land cover 2009 for C-Plan 3 species habitat modelling

| Gridcode | LC09 No. | Name | Tenure C-Plan 3 |
|----------|----------|--|-----------------|
| 1 | 1 | Dense Trees / Bush | Available |
| 2 | 2 | Woodland / Open Bush | Available |
| 3 | 3 | Wooded Grassland | Available |
| 4 | 4 | Grassland | Available |
| 7 | 7 | Natural Bare Rock | Available |
| 8 | 8 | Rocky Grass Matrix | Available |
| 11 | 11 | Urban Woodland | Available |
| 12 | 12 | Urban Grass | Available |
| 13 | 13 | Natural Water | Available |
| 14 | 14 | Man-made Water | Available |
| 15 | 15 | Wetland (non pan) | Available |
| 16 | 16 | Wetland Pans | Available |
| 24 | 24 | Smallholdings: Dense Trees / Bush | Available |
| 25 | 25 | Smallholdings: Woodland / Open Bush | Available |
| 26 | 26 | Smallholdings: Wooded Grassland | Available |
| 27 | 27 | Smallholdings: Grassland | Available |
| 500 | | All cultivated land including old lands to create primary vegetation | |
| 551 | | Cultivated Crops (17), Pasture (18), Cultivated Other (19), Smallholdings: Cultivated (29) | Available |
| 561 | | Old Lands: Dense Trees / Bush (30), Old Lands: Woodland / Open Bush (31), Old Lands: Wooded Grassland (32), Old Lands: Grassland (33), Old Lands (topo): Dense Trees / Bush (36), Old Lands (topo): Woodland / Open Bush (37), Old Lands (topo): Wooded Grassland (38), Old Lands (topo): Grassland (39) | Available |
| 9999 | | Degraded (5), Non-Vegetated / Bare(6), Plantation & Woodlot (9), *Urban Trees (10), Intensive Cattle Camps (20), Urban (21), Mines (22), Sports & Recreation Grassland (23), Smallholdings: Degraded (28), Old Lands: Degraded (34), Old Lands: Non-Vegetated / Bare | Excluded |

| Gridcode | LC09 No. | Name | Tenure C-Plan 3 |
|----------|----------|--|-----------------|
| | | (35), Old Lands (topo): Degraded (40), Old Lands (topo): Non-Vegetated / Bare (41) | |

*Urban trees were classified as excluded areas as they were found to be mostly garden and street trees (see images below in Figure 1 – red patches from GT1 land cover 2009). Checks were however done in areas where red/orange listed plants occurred and natural patches were digitized and merged on top of land cover in the reclassified raster.



Figure 1: Urban trees in land cover 2009 draped over Quickbird satellite imagery 2004/05

8.2. Pristine land cover classes

Pristine (untransformed) land cover and other raster layers for plant- and invertebrate habitat were created as follows:

8.2.1. Cultivated land

Created a raster layer including GDARD cultivated areas digitized from 1:50 000 topographical maps and from Quickbird images 04/05 and cultivated areas received from NDA 2007.

Note: Data below were not used because of:

- Scale too rough: Cultivated lands 1994 and Urban Eye 1999
- Mispositioned data: NLC 2000
- Doubtful data: QB landcover 2006 (used only data digitized from QB images)

8.2.2. Cultivated Land excluding Wetlands

Used GDARD digitized wetlands and merged pan, wetland, waterbody with cultivated land in a temporary file. This step was carried out to ensure that wetlands are kept as an intact layer and not disappear as part of cultivated land.

Reclassify wetlands to NoData to ensure that no wetlands are included in cultivated land.

8.2.3. Cultivated Land excluding built-up, mines and other excluded areas

Merged all excluded areas in the land cover 2009 with Cultivated Land excluding Wetlands cultivated land in a temporary file.

```
merge(con([lc09_rcls] == 9999,9999),[cultnowet_pcc])
```

Reclassify class 9999 to NoData to ensure that no excluded areas are included in cultivated land.

8.2.4. Final Cultivated Land

Merged all cultivated land in the land cover 2009 with Cultivated Land excluding Wetlands as well as excluding built-up, mines and other excluded areas in a temporary file.

```
cultfin = merge(con([lc09_rcls] == 551 | [lc09_rcls] == 561,580), [cultfin_pcc])
```

Keep this order to ensure cultivated land as the top raster.

8.2.5. Primary Grassland

Merged final cultivated land with grassland and rocky grassland in the land cover 2009 using a temporary file.

```
merge([cultfin],con([lc09_rcls] == 4 | [lc09_rcls] == 8,104))
```

Keep this order to ensure cultivated land as the top raster.

Reclassify class 580 (cultivated) to NoData to remove it from grassland.

8.2.6. Primary Grassland and Natural Bare Rock

Merged final cultivated land with primary grassland and Bare Rock in the land cover 2009 using a temporary file.

```
merge([cultfin],[primgrass09],con([lc09_rcls] == 7,7))
```

Keep this order to ensure cultivated land as the top raster.

Reclassify class 580 (cultivated) to NoData to remove it and primary grassland and natural bare rock to the same value.

8.2.7. Primary Wooded Grassland

Merged final cultivated land with primary wooded grassland in the land cover 2009 using a temporary file.

```
merge([cultfin],con([lc09_rcls] == 3,103))
```

Keep this order to ensure cultivated land as the top raster.

Reclassify class 580 (cultivated) to NoData to remove it.

8.2.8. Primary Woodland

Merged final cultivated land with primary woodland and Woodland / Open Bush in the land cover 2009 using a temporary file.

```
merge([cultfin],con([lc09_rcls] == 1 | [lc09_rcls] == 2,101))
```

Keep this order to ensure cultivated land as the top raster.

Reclassify class 580 (cultivated) to NoData to remove it.

8.2.9. Primary Vegetation

Merged Primary grassland + Primary wooded grass + Primary woodland.

```
primveg09 = merge(con([primgrass09] == 104,100),con([primwgrass09] == 103,100),con([primwood09] == 101,100))
```

8.2.10. Primary Vegetation and Bare Natural Rock

Merged Primary vegetation + Bare Rock in the land cover 2009.

```
Primvegrok09 = merge(con([primveg09] == 100,107),con([lc09_rcls] == 7,107))
```

8.2.11. GDARD & Metropolitan Wetlands and DWAF Rivers

Several sets of wetlands were rasterized from data digitized over the years based on 1:50000 topocadastral mapsheets and updated extensively between 2005 to 2010 based on QuickBird 2004/05 imagery. Wetland and river data provided by Dr Stephen Holness for Ekurhuleni (very good quality) and Johannesburg metropolitans were also used.

a. Unbuffered wetlands

Classes include pans, wetlands and waterbodies [farm dams, large dams and lakes]

b. Wetlands (including pans) excluding waterbodies

c. Wetlands (including pans) excluding waterbodies buffered by 150m

d. Rivers buffered by 150m

Classes include perennial and non-perennial rivers. These were rasterized separately in different rasters and then merged with perennial rivers as the first layer in order to keep them on top.

e. "Primary" wetlands and rivers buffered by 150m

Buffered wetlands, perennial- and non-perennial rivers minus built-up areas.

```
merge(con([lc09_rcls] == 9999,9999),[wet_pcc150],[rivdwaf150]) – temporary file.
```

Reclassify class 9999 to NoData to remove it and wetlands and rivers to the same value.

File: [wetrvpc150prm].

8.2.12. GTI land cover 2009 Wetlands

Wetlands from GTI land cover 2009 were not used in habitat models as they were found to be over-represented in some areas. After a workshop by the C-Plan Team in June 2010 it was

decided to use only GDARD data as well as data provided by Dr Stephen Holness for Ekurhuleni and Johannesburg metropolitans.

8.2.13. Final Wet Areas (150m buffer)

Wetlands and rivers created in par. 5.2.11

Minus transformed land from land cover 2009 data

Merge(con([wetrvc150prm] == 140,150),con([wetlc150prim] == 1,150))

9. Layers for Biodiversity Features

This section contains detailed information on the biodiversity features, the methodology followed to create the layers, their targets for conservation and the rationale for inclusion into C-Plan 3. Biodiversity targets refers to the estimates of the quantities of biodiversity features that should be conserved in a region and are fundamental to systematic conservation planning (Pfab, *et.al.*, 2011).

9.1. Plants (Michele Pfab)

A ranking scheme (Pfab, 2000) that prioritizes Red and Orange Listed plant species in Gauteng from the most important to the least had been developed within the Directorate of Nature Conservation. This ranking scheme was used to develop a Red Data policy. The essential details of the ranking scheme are briefly described in the following paragraphs (extracted directly from Pfab, 2000 – a few amendments with updated information included by PC Compaan). For more detail, please refer to Pfab & Victor (submitted). All references in the extract below from Pfab, 2000 have been included in the reference list of this document.

Priority ranking of Red Data plant species in Gauteng

Locality information for all Red and Orange Listed plant species occurring in Gauteng has been collected from five sources:

- Transvaal Provincial Administration (TPA) records.
- The Pretoria National Herbarium Computerized Information System (PRECIS).
- Herbaria at the Universities of Witwatersrand and Pretoria.
- Professional and amateur botanists.
- Data recorded in the field by the Technological Services division of the Gauteng Directorate of Nature Conservation.

This information has been collated to form a provincial Red and Orange Listed plant database, comprising an extensive list of all known localities within Gauteng for each Red Data plant species.

Using the Red Data List of Southern African Plants (Hilton-Taylor, 1996), the completed provincial Red and Orange Listed plant database, trade information supplied by TRAFFIC (Trade Records Analysis of Flora and Fauna in Commerce) and general distribution records from general botanical literature (Fabian & Germishuizen, 1997; Retief & Herman, 1997), each species was assessed in terms of eight criteria (Table 2).

- Criterion A considers endemism,
- Criteria B, D and E consider species distributions at decreasing spatial scales,
- Criterion C considers IUCN listings of taxa evaluated at the national (South Africa) level (Pfab & Victor, submitted),
- Criterion F considers the protection of each taxon within conservation areas, and
- Criteria G and H represent the factors of threat that are specifically important within Gauteng.

Due to the problems associated with linear ranking schemes (Given & Norton, 1993), a hierarchical approach to priority setting was adopted, where the most important criterion, endemism (Table 2), was

used for the initial species sorting. Each group was then sorted progressively using the next important criterion. This was continually repeated, each subsequent group being sorted progressively until all the criteria had been used, following the order indicated below and in Table 2, until the final priority list was produced (included in Appendix 1 in the table under Priority Grouping).

- A. Endemism was deemed the most important criterion – in terms of conserving biodiversity, a taxon restricted to southern Africa would be of a higher priority than those occurring elsewhere.
- B. Similarly, in terms of distribution, taxa restricted to Gauteng or to the northern provinces of South Africa (Gauteng, Mpumalanga, Northern and North West provinces, i.e. the former Transvaal province) would be of a higher priority for the Gauteng Directorate of Nature Conservation than those taxa more widely distributed.
- C. Red Data status was based on national (South Africa) evaluations completed under the SABONET Red Listing project according to the new IUCN categories and criteria (IUCN, 2000) and using the RAMAS Red Listing software (Pfab & Victor, submitted). All taxa listed in the threatened categories of Critically Endangered, Endangered and Vulnerable are included as well as those listed as Data Deficient. As it is possible that a Data Deficient taxon may qualify for a threatened category, it is important to follow the precautionary approach and ensure that conservation action is also targeted to these taxa (IUCN, 2000).
- D. Taxa having a narrow distribution within the northern provinces would be of a higher priority than those taxa with a wider distribution in these provinces. Taxa restricted to subregions falling predominantly over Gauteng (central and south, see Retief & Herman 1997 for the positions of the five subregions in [Figure 2](#)) should receive higher priority than those taxa falling into one or more subregions that do not fall over Gauteng (north, east and west, see Retief & Herman 1997).
- E. Similarly, taxa recorded at fewer localities should receive higher priority than those taxa recorded at more localities.
- F. After considering distributions, it was then necessary to sort those taxa with populations protected within conservation areas from those taxa that essentially remain unprotected. Conservation areas include provincial, private and municipal nature reserves as well as the Magaliesberg Protected Natural Environment, the Sterkfontein, Kromdraai, Swartkranz & Environs Cradle of Humankind World Heritage Site, all natural heritage sites and conservancies.
- G. Urbanization is the greatest threat to species in Gauteng (Pfab & Victor, submitted), and therefore constituted the next level of sorting. Urbanization threat to taxa with populations occurring in all major urban areas in the province is expected to be higher than to those taxa with populations occurring in fewer urban areas, with taxa restricted to rural areas being the least threatened. Since most major development and urban expansion is expected in Johannesburg and Pretoria, populations occurring in these areas are considered to be at a higher risk than those occurring in the minor urban areas of Gauteng.
- H. Utilization data (Newton & Chan, 1998) were incorporated into eighth-level sorting. A taxon collected from the wild for either its medicinal, food or for other values (Mander *et al.*, 1997, van Wyk *et al.*, 1997, van Wyk & Gericke, 2000) or advertized for sale on nursery catalogues on Internet sites was considered to be a higher priority than those taxa not collected at all. Taxa related to, i.e. belonging to the same genera as, known medicinals or plants collected and/or traded were assumed to be at a higher risk, due to possible future utilization related to potential genetic and/or collector value of the taxa.

Table 2: Criteria used for the priority setting exercise for the Red Data plant species occurring within Gauteng. Criteria are ranked from the most important to the least, with criteria scores arranged in descending order of importance.

| CRITERION | SCORE |
|---|-------|
| A. <i>Endemic to southern Africa?*</i> | |
| Yes | 1 |
| No | 2 |
| B. <i>Distribution within southern Africa</i> | |
| Gauteng | 1 |
| Gauteng + one other province/country* | 2 |
| Gauteng + two or more other provinces/countries* | 3 |
| C. <i>Red Data status in South Africa</i> (see Pfab and Victor submitted) | |
| Critically Endangered | 1 |
| Endangered | 2 |
| Vulnerable | 3 |
| Data Deficient | 4 |
| D. <i>Distribution within the Northern Provinces</i> (Retief and Herman 1997) | |
| One subregion | 1 |
| Two subregions, two over Gauteng | 2 |
| Two subregions, one over Gauteng | 3 |
| Three subregions, two over Gauteng | 4 |
| Three subregions, one over Gauteng | 5 |
| Four/five subregions | 6 |
| E. <i>Distribution within Gauteng</i> | |
| One recorded locality | 1 |
| 2-4 recorded localities | 2 |
| 5-9 recorded localities | 3 |
| 10 or more recorded localities | 4 |
| F. <i>Occurrence in conservation areas</i> | |
| No recorded localities inside conservation areas | 1 |
| One or more localities inside conservation areas | 2 |
| G. <i>Urbanization threat</i> | |
| Recorded localities in Johannesburg, Pretoria and other large towns | 1 |
| Recorded localities in Johannesburg and Pretoria | 2 |
| Recorded localities in Johannesburg <u>or</u> Pretoria and other large towns | 3 |
| Recorded localities in Johannesburg <u>or</u> Pretoria | 4 |
| Recorded localities in other large towns | 5 |
| Recorded localities outside of urban areas | 6 |
| H. <i>Utilization</i> | |
| Traded/collected/utilized taxon | 1 |
| Potentially traded/collected/utilized taxon | 2 |
| No known or potential trade/collection/utilization | 3 |

*Including former Transvaal province (now includes Gauteng, North West province, Northern province and Mpumalanga), former Cape province, Free State and KwaZulu-Natal and the countries Lesotho, Swaziland, Namibia, Botswana and Zimbabwe.

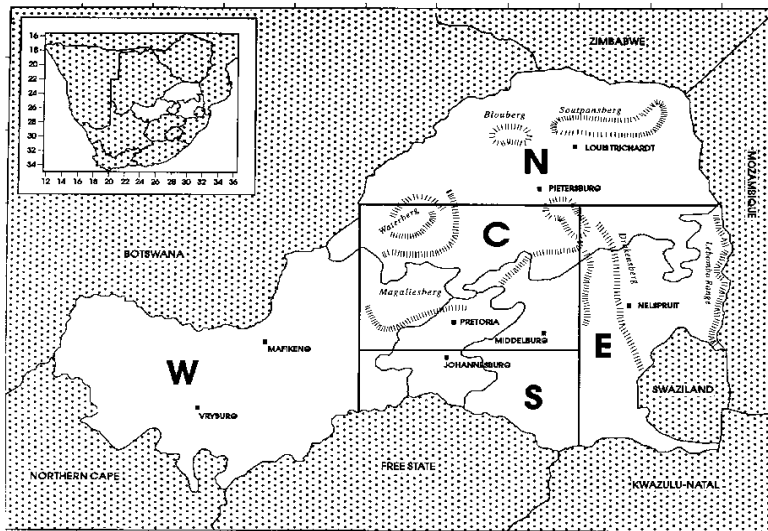


Figure 2: The five subregions of the northern provinces of South Africa (from Retief & Herman, 1997).

The plant layer included buffered confirmed (known) plant species' GPS waypoints to represent Red and Orange Listed plant populations, as well as habitat- and meta-population models. Declining species (Orange Listed plants) are usually widespread and common and were therefore not included in the conservation plan. The conservation targets for these species will be very low and it is highly likely they will be met already in some protected area or other area in the conservation plan.

9.1.1. Confirmed locations (Buffered)

Confirmed (known) GPS locations of Red and Orange Listed plant recorded in the GDARD plant database (7252 records as at the end of November 2010) were buffered according to the priority profile for each species indicated in terms of the scoring of all species against the eight criteria in Table 2 and consequently grouped into group A1, A2, A3 and B. The buffer distance for each group is as follows (more information on the GDARD Red List Plant Species Guidelines can be obtained from Lorraine Mills at Lorraine.Mills@gauteng.gov.za):

- 200m for all populations occurring within the urban edge
- 600m for rural A1 populations
- 500m for rural A2 populations
- 400m for rural A3 populations
- 300m for rural B populations

Appendix 1 illustrates the complete list of Red and Orange Listed plant species included in C-Plan 3 analysis. The conservation target for all confirmed Red- and Orange Listed plants was 100% of the area, except for *Bowiea volubilis* subsp. *volubilis* and *Lithops lesliei* subsp. *lesliei*. The polygons for these two species were converted to centroids and assigned values of the population sizes recorded for each population. The total population size was set as the target.

9.1.2. Habitat- and meta-population models

GDARD wetlands including Ekurhuleni and Johannesburg wetland data received from Dr Stephen Holness (not wetlands from 2009 land cover as mentioned previously) were used for habitat models.

For some of the plant species, habitat models are needed only within their historical distribution, while for others habitat models are needed within their historical distribution as well as their “extent of occurrence” to accommodate metapopulation dynamics. The table below summarizes which species needed habitat models (confined to their historical distributions) and which needed metapopulation models (confined to extent of occurrences).

Table 3: Red- and Orange Listed plant species habitat- and meta-population models.

| Species | Habitat model needed | Metapopulation model needed |
|---|-----------------------------|------------------------------------|
| <i>Adromischus umbraticola</i> subsp. <i>umbraticola</i> | Yes | No |
| <i>Alepidea attenuata</i> | Yes | No |
| <i>Argyrobium campicola</i> | Yes | No |
| <i>Argyrobium megarrhizum</i> | Yes | No |
| <i>Blepharis uniflora</i> | Yes | No |
| <i>Brachycorythis conica</i> subsp. <i>transvaalensis</i> | Yes | Yes |
| <i>Brachystelma discoideum</i> | Yes | Yes |
| <i>Ceropegia decidua</i> subsp. <i>pretoriensis</i> | Yes | Yes |
| <i>Ceropegia turricula</i> | Yes | Yes |
| <i>Cheilanthes deltoidea</i> subsp. nov. Gauteng form | No | Yes |
| <i>Cineraria austrotransvaalensis</i> | Yes | Yes |
| <i>Cineraria longipes</i> | No | Yes |
| <i>Cucumis humifructus</i> | Yes | Yes |
| <i>Delosperma leendertziae</i> | Yes | No |
| <i>Dioscorea sylvatica</i> | Yes | No |
| <i>Encephalartos lanatus</i> | Yes | No |
| <i>Eulophia coddii</i> | Yes | Yes |
| <i>Frithia humilis</i> | Yes | No |
| <i>Gladiolus pole-evansii</i> | Yes | No |
| <i>Gladiolus robertsoniae</i> | Yes | No |
| <i>Gnaphalium nelsonii</i> | Yes | Yes |
| <i>Habenaria barbertoni</i> | Yes | Yes |
| <i>Habenaria bicolor</i> | Yes | Yes |
| <i>Habenaria kraenzliniana</i> | Yes | Yes |
| <i>Habenaria mossii</i> | Yes | Yes |
| <i>Holothrix micrantha</i> | Yes | Yes |
| <i>Holothrix randii</i> | Yes | Yes |
| <i>Khadia beswickii</i> | Yes | No |
| <i>Kniphofia typhoides</i> | Yes | No |
| <i>Lithops lesliei</i> subsp. <i>lesliei</i> var. <i>rubrobrunnea</i> | Yes | No |
| <i>Melolobium subspicatum</i> | Yes | No |
| <i>Prunus africana</i> | Yes | No |
| <i>Searsia gracillima</i> var. <i>gracillima</i> | Yes | No |
| <i>Stenostelma umbelluliferum</i> | Yes | Yes |
| <i>Trachyandra erythrorrhiza</i> | Yes | Yes |

Method followed in creating models

- Overlaid confirmed buffered populations with historical distributions referred to as “RD Farms” or Red Data Farms.
- Modeled habitat is needed for all areas where a confirmed population is absent (see examples below). Model must be based on minimum and maximum values for environmental parameters

measured at the location of confirmed populations. If no populations have been confirmed, then basic habitat models follow literature descriptions (as per habitat model spreadsheet - not included in this document).

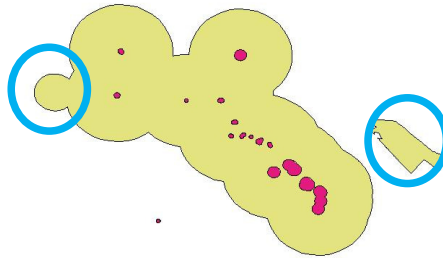


Figure 3: Confirmed buffered populations for *Ceropogia decidua subsp. pretoriensis* (pink) and historical distribution. Blue circles indicate where habitat models are needed (where buffered populations are absent).

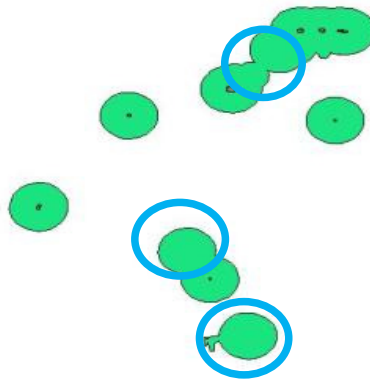


Figure 4: Confirmed buffered populations for *Holothrix randii* and historical distribution (green areas). Blue circles indicate where habitat models are needed (where buffered populations are absent).

- c. When the model results show no habitat in one or more of these areas, do a sensitivity analysis to determine which environmental parameter is responsible for “eradicating” all habitat. Remove this parameter from the model and re-run.
- d. Where a metapopulation model is needed (as per table above), habitat needs to also be modeled within the wider “extent of occurrence” of the species, which is mapped as a minimum convex polygon – the smallest polygon in which no internal angle exceeds 180 degrees and which contains all the sites of occurrence, i.e. including historical distributions and confirmed buffered populations and connecting to neighbouring provinces in which the species also occurs (illustrated in examples below.)

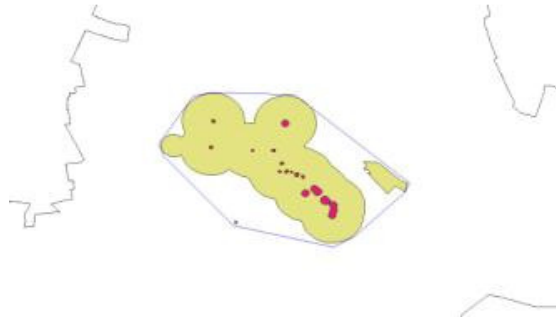


Figure 5: Extent of occurrence (outer polygon) for *Ceropogia decidua* subsp. *pretoriensis* – species is endemic to Gauteng and therefore connectivity with a neighbouring province is not required. Historical distribution plus confirmed buffers all included in extent of occurrence.

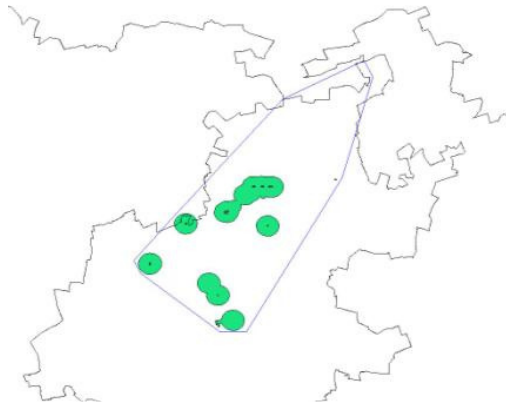


Figure 6: Extent of occurrence (larger transparent polygon) for *Holothrix randii* ... includes historical distribution plus all confirmed buffered populations and linking to Limpopo as species is also recorded in Limpopo.

- e. First Filtering of habitat patches
 - i. Calculate the average area of occupancy for each species (i.e. average area covered by populations of each species, as mapped by confirmed points with a minimal buffer of 50m).
 - ii. Delete habitat patches smaller than this average area of occupancy.
For species for which we do not have any confirmed populations, use the average area of occupancy averaged over all of the species calculated in (i) above.
- f. Create centroids for the remaining habitat patches using the model covering the largest area, i.e. the metapopulation model if there is one.
- g. Calculate the number of centroids for each species. Statistics were analysed by Michele Pfab (at SANBI) to assess these in relation to the species targets to determine whether any further refinement of the model (by filtering out more habitat patches) was desirable.
- h. Final filtering of habitat patches
 - i. Union habitat file with updated excluded areas
 - ii. Remove excluded areas and coinciding parts
 - iii. Do a multipart
 - iv. Remove all fields except ID and hectares
 - v. Recalculate areas and remove any slivers < average size calculated from 1st filter exercise.

- vi. Add unique ID
- vii. Create centroids
- viii. Do a multipart on RD Farm if needed
- ix. Add RD Farm identifier
- x. Do a Spatial join between centroids and RD Farm file
- xi. Do a Spatial join between result and QDS if metapopulation is needed
- xii. Add a field called "Select"
- xiii. Follow instructions from spreadsheet (from M Pfab based on her analysis of statistics above) of number of centroids to select in RD Farms and QDSs
- xiv. Move centroids to centre of biggest patches selected
- xv. Ensure that there are not more than 1 centroid in a planning unit and not more than 1 per 100 ha if they are in a reserve.
- xvi. Remove redundant centroids.

Centroids instead of polygons as created above were used for Red- and Orange Listed plants species' habitat- and metapopulations. [Appendix 1](#) illustrates the complete list of Red and Orange Listed plant species included in C-Plan 3 analysis and their conservation targets. More information on how targets were calculated may be obtained from Michele Pfab at SANBI (M.Pfab@sanbi.org.za).

9.2. Bird Habitat Models (Dr Craig Whittington-Jones)

The following sections explain the rationale, and method followed to create input data for priority Red Listed bird species included in C-Plan 3. References to authors in this section have to be obtained from Dr Craig Whittington-Jones at Craig.Whittington-Jones@gauteng.gov.za.

9.2.1. Species included in C-Plan 3

9.2.1.1. African Finfoot (*Podica senegalensis*)

Rationale for inclusion

IUCN = LC (Ekstrom & Butchart 2004 - BirdLife International Red List Authority); RSA = VU A2c + C1 (Barnes 2000). Main threats include habitat loss.

Raw distribution data sources

GDARD field data, specialist consultants, general public, Tarboton et al. 1987.

Distribution mapping/modeling general

The African Finfoot occurs along clear perennial rivers and streams overhung by shrubs or trees or lined with reeds (Tarboton *et al.* 1987; Barnes & Parker 2000). Only rivers for which this species has been confirmed (either in recent surveys or historically according to Tarboton *et al.* (1987) and Allan (1997)) were mapped.

Distribution mapping/modeling technical

The maximum extent of rivers along which species has been confirmed (i.e. Magalies, Bloubankspruit, Crocodile, Hennops, Elands and Wilge) or was known to occur historically (i.e. Pienaar's, Hennops, Skeerpoort and Vaal) were selected. For the Vaal River, remaining suitable stretches of habitat were identified by van der Westhuizen Coetzer *et al.* (2005). A buffer including the riparian zone and 100m (outside the urban edge) OR the riparian zone and 32m (inside the urban edge) was adopted as per the Aquatic Unit's requirement for safe-guarding water quality.

The Pienaar's upstream (south) of Roodeplaat, the Sesmyspruit (tributary of the Hennops) upstream (east) of Rietvlei Nature Reserve and the Bronkhorstspruit River (tributary of the Wilge) from the dam south were excluded from the model as these are stretches are considered unsuitable.

Targets

20 breeding pairs; 100% of modeled suitable habitat.

Target motivation

For Vulnerable species listed under the IUCN Red List Criteria of B, C or D Pfab et al. (2010) recommend that all populations must be conserved in situ.

The African Finfoot is inconspicuous and may be more widespread than records suggest (Barnes & Parker 2000), but Tarboton (1997) nevertheless estimated that fewer than 20 pairs remained in Gauteng. Gauteng's proportional share (based on relative extent of national range falling within the province i.e. approximately 4.8%) of the estimated 500-1000 individuals remaining regionally (Parker & Barnes 2000) is approximately 10-20 breeding pairs.

Densities of one pair/1.5-2.2km have been reported for rivers in Zimbabwe and Kenya respectively (Irwin 1981 in Allan 1997; Urban et al. 1986). While densities are expected to vary among rivers, as a very rough estimate, approximately 30-44km of suitable riverine habitat would be required to support 20 pairs. However, due to the linear connectivity of their habitat, impacts such as reduced water flow through over-extraction and damming, destruction of riparian vegetation with associated reduction in water quality due to siltation and increased salt loads (Barnes & Parker 2000) have consequences not only at the point of impact, but downstream too. Consequently, the full extent of suitable modeled habitat along each identified river (except the Vaal) needs to be conserved if the integrity of this species' habitat is to be maintained. The Vaal River is highly impacted and thus only those remnant patches of suitable habitat identified by van der Westhuizen Coetzer et al. (2005) were included in the model and hence the target.

9.2.1.2. African Marsh-Harrier (*Circus ranivorus*)

Rationale for inclusion

IUCN = LC (Ekstrom & Butchart 2004 - BirdLife International Red List Authority); RSA = VU A1c + A2bc + C1 (Cohen 2000 - Percy Fitzpatrick Institute of African Ornithology). Main threats include habitat loss and degradation.

Raw distribution data sources

GDARD field data, Coordinated Waterbird Count (CWAC) database.

Distribution mapping/modeling general

The African Marsh-Harrier occurs widely, but patchily within the province and is typically associated with large wetlands on which it is dependant for breeding. Wetlands (including those too small for breeding), watercourses and to a lesser extent adjacent grassland areas may be used for foraging. Aquatic habitat for which the species has been confirmed was "buffered" with 350m of terrestrial habitat both to protect the wetland resource and to provide for the persistence of prey species. Semlitsch & Bodie (2003) recommend retaining 350m of terrestrial habitat around wetlands and rivers as a life zone for reptiles and amphibians and this "buffer" was adopted in the absence of equivalent data for the African Marsh-Harrier's primary prey i.e. small mammals.

Distribution mapping/modeling technical

Observations within the 2007 urban edge were excluded. The full extent of each discrete wetland associated with each remaining observation (e.g. Rietpan) was selected. For rivers, the river shapefile was unioned with ridges shapefile and ridge-associated sections were excluded (the African Marsh-Harrier was not recorded foraging on ridges during BGAP surveys). For remaining river sections the main channel and only those tributaries with confirmed observations were retained. The extent of the main channel retained depended on the proximity to the urban edge and provincial boundary (both considered "barriers") and the proximity to confirmed observations (this last proximity threshold was subjective and consideration should be given to using quaternary catchment boundaries, as was subsequently adopted for the African Grass-Owl). Each selected wetland and remaining stream section was then buffered to a distance of 350m with primary grassland and secondary grassland (i.e. include land cover codes 3, 4, 7, 8, 13, 15, 16, 561, 571 and exclude unsuitable land cover codes (i.e. 1, 2, 24, 25, 26, 27, 551, 9999 – see Table 1). Suitable land cover was dissolved and intersected with rivers and wetlands. Remnant habitat patches <100ha were excluded, unless linked directly to a wetland/stream.

Targets

10 breeding pairs @ 1000ha per pair = 10 000ha.

Target motivation

For Vulnerable species listed under the IUCN Red List Criteria of B, C or D Pfab *et al.* (2010) recommend that all populations must be conserved *in situ*. However, conservation of this species within the urban edge is not considered feasible due to poor habitat connectivity and fire-based habitat management requirements.

The size of the Gauteng African Marsh-Harrier population is unknown, but Gauteng's proportional share (based on relative extent of national range falling within Gauteng outside of the 2007 urban edge i.e. approximately 1.9%) of the estimated 3000-5000 pairs remaining regionally (Barnes 2000) is approximately 55-95 breeding pairs. However, in recent years, habitat degradation and fragmentation, particularly in highly industrialized provinces such as Gauteng have led to marked population declines (Cohen 2000) and it is estimated that fewer than 10 pairs of African Marsh-Harrier now remain in the province (Tarboton 1997).

Data on the foraging range requirements of this species is not available, but Tarboton & Allan (1984) found that most Highveld wetlands larger than 100ha supported a breeding pair of African Marsh-Harriers, while Simmons (1997) reports breeding densities of 8 pairs per 1000ha. The density of breeding pairs in Gauteng appears to be considerably lower, probably as a consequence of habitat degradation and poor water quality, and e.g. Marievale Bird Sanctuary (>1000ha) may now only support a single pair. A more realistic estimate for the province at present is therefore 1000ha per pair.

Suggestions that this species may re-colonize rehabilitated wetlands are encouraging (Cohen 2000) and potential therefore exists to increase, though concerted management intervention, the number of pairs than can be supported in the province to a level closer to our proportional responsibility.

9.2.1.3. African Grass-Owl (*Tyto capensis*)

Rationale for inclusion

IUCN = LC (Ekstrom & Butchart 2004 - BirdLife International Red List Authority); RSA = VU A2c + C1 (Barnes 2000). Main threats include habitat loss. In Gauteng, road fatalities contribute to high levels of mortality while early and unplanned fires may compromise breeding success.

Raw distribution data sources

GDARD field data, Transvaal Museum, SAFRING, Birds in Reserves Project (BIRP), specialist consultants, general public (particularly roadkill data from Tahla Ansara-Ross and Paul Jooste). Spatial resolution of bird atlas data is too coarse.

Distribution mapping/modeling general

African Grass-Owl occur widely within the grassland biome in Gauteng. They are dependent on rank vegetation typically associated with wetlands and water courses for roosting and nesting, but forage more widely over adjacent terrestrial grasslands. The quaternary catchment boundaries were used to delimit the extent of aquatic habitat associated with each Grass Owl observation. Adjacent terrestrial foraging habitat up to 1500m (estimated maximum foraging distance based on unpublished roadkill data) around the aquatic habitat was included in the model.

Distribution mapping/modeling technical

Areas within the 2007 urban edge were excluded and quaternary catchments that intersected with remaining confirmed Grass-Owl points were selected. Wetlands (lakes and evaporation ponds were excluded) and streams within the identified quaternary catchments were selected. These wetlands/streams were buffered by 1500m, buffered wetlands and streams were merged and then unsuitable land cover codes (i.e. 1, 2, 24, 25, 26, 551, 9999) were deleted. Primary grassland and secondary grassland (i.e. land cover codes 3, 4, 7, 8, 13, 15, 16, 27, 561, 571. See Table 4.) were retained. The various habitat types were dissolved together and then remnant patches of suitable habitat <100ha were deleted, unless linked directly to a wetland/stream or if simply separated from another patch of suitable habitat by a road. Any centroid derived point (e.g. those for Buffelsdrift Conservancy

and Roodeplaat Nature Reserve from the BIRP database) that did not link to a habitat patch >100ha was excluded from the final shapefile.

Within existing polygons small farms dams were incorporate into the model. This helped to reduce some of the complexity and the habitat around such waterbodies is generally good for owls.

If any polygon extends beyond 1500 from a wetland/stream/river/small dam, please “trim” the excess. This will limit us to the core foraging habitat of this species. If this reduces any patches below 100ha, discuss with scientist.

Targets

150 breeding pairs @ 260ha per pair = 39 000ha.

Target motivation

For Vulnerable species listed under the IUCN Red List Criteria of B, C or D Pfab et al. (2010) recommend that all populations must conserved in situ. However, conservation of this species within the urban edge is not considered feasible due to poor habitat connectivity and fire-based habitat management requirements.

The size of the Gauteng Grass-Owl population is unknown, but Gauteng’s proportional share (based on relative extent of national range falling within Gauteng outside of the 2007 urban edge i.e. approximately 5.9%) of the estimated <5000 Grass-Owls remaining regionally (Barnes 2000) is approximately 150 breeding pairs.

Data on the foraging range requirements of this species is not available, but an interim estimate (Whittington-Jones, 2010) suggests that 130ha may be sufficient for a pair, but that an equivalent area of unoccupied habitat is likely to be required as a refuge for when habitat patches are rendered temporarily unsuitable e.g. as a result of grazing pressure and/or fire which are essential tools in the management of their habitat.

GIS Steps:

- a. Establishing extent of habitat model
 1. Confirmed observations (point records) from the following sources were integrated: GDARD, literature, Nat World, Transvaal Museum
 2. Confirmed records were buffered by 1500m
 3. Quaternary catchments (Q4s) intersecting (select by location) buffered points were extracted
 4. Non-perennial rivers and perennial rivers were buffered by 1500m
 5. GDARD wetlands (including pans & dams) were buffered by 1500m
 6. Buffered rivers and wetlands were merged, dissolved and multi-parted (wet-areas)
 7. Buffered wet-areas were intersected with extracted Q4s (draft extent)
 8. The urban edge 2007 boundary was removed from Gauteng creating a “rural” Gauteng
 9. The draft extent was intersected with “rural” Gauteng creating an extent for this bird
- b. Habitat model
 1. Reclassified required habitat from land cover 2009 using extent above. See Table 4 below.

Table 4: Reclassified land cover 2009 for bird habitat modelling purposes

| Gridcode | Name |
|----------|--------------------|
| 3 | Wooded Grassland |
| 4 | Grassland |
| 7 | Natural Bare Rock |
| 8 | Rocky Grass Matrix |
| 13 | Natural Water |
| 15 | Wetland (non pan) |
| 16 | Wetland Pans |

| Gridcode | Name |
|-------------|--|
| 27 | Smallholdings: Grassland |
| 561 and 571 | All Old Lands (value 571 was later incorporated into value 561 for land cover) |

2. Rasterize exclud areas digitized for C-Plan 3 to value 99999
3. Merge exclud areas raster with habitat raster in a temporary file
merge([excl_area],[ago_hab])
4. Reclassify value 9999 to NoData to remove these from habitat
5. Rasterize wetlands and pans digitized by GDARD using value 15 and 16 respectively (same as land cover values)
6. Merge exclud areas raster with GDARD wetlands raster in a temporary file
merge([excl_area],[wetpan_gdard])
7. Reclassify value 9999 to NoData to remove these from GDARD wetlands [wetpan_gdardf]
8. Merge GDARD wetlands and land cover habitat for grass owl
hab_subfin = merge([wetpan_gdardf],[hab_ext_avail])
9. Reclassify habitat raster to value 1
10. Convert habitat to shapefile (generalize)
11. Calculate areas
12. Select polygons > 100ha and export
13. Select wetland < 100ha from exercise below that did not intersect result in previous step and merge it into result of previous step.
14. Delete all polygons at Buffelsdrift as they were < 100ha.

9.2.1.4. Blue Crane (*Anthropoides paradiseus*)

Rationale for inclusion

IUCN = VU A2bcde + 3bcde (Butchart & Pilgrim 2006 - BirdLife International Red List Authority); RSA = VU A1acde + A2bc (McCann 2000); Near-endemic to South Africa. Main threats include habitat loss, poisoning and powerlines.

Raw distribution data sources

GDARD field data, Coordinated Avifaunal Roadcount (CAR) database

Distribution mapping/modeling general

Blue Cranes roost and breed in wetland areas (though they may also nest away from water) and forage in grassland, pasture, cultivated land and fallow fields (Tarboton *et al.* 1987; pers. obs.). Although they appear to show strong fidelity to breeding territories, very few breeding pairs have been confirmed within Gauteng to date. The average home range of Blue Cranes in KZN was 3.8km² (380ha) (SACWG) and in the absence of equivalent data for Gauteng, the KZN estimates were used as the basis for mapping breeding territories.

A non-breeding flock of about 300 birds routinely over-winters on the border between SE Gauteng and Mpumalanga, though it has yet to be established where these birds breed. For the purposes of the conservation plan, the over-wintering area was defined as the area contained within the shortest continuous imaginary boundary which could be drawn to encompass all the confirmed points for this species in southeast Gauteng and adjacent Mpumalanga. Farms falling within Mpumalanga obviously cannot be included in the Gauteng conservation plan, but it was necessary to use those Blue Crane points falling in the adjacent area of Mpumalanga to draw the initial extent of occurrence polygon. It is critical that any conservation plan for Mpumalanga makes provision for conservation of the remainder of this over-wintering area.

Distribution mapping/modeling technical

Confirmed breeding points (wetlands) within the Modderfontein Conservation Area, the Rhino and Lion Nature Reserve and on the farms De Wagensdrift 417JR, Wolvengat 442 JR and Driefontein 179 IQ and suspected breeding sites (Danielsrust 518 JQ, Brandbach 471 JR, Leeuwfontein 492 JR and Leeuwfontein 288 JS) were buffered with 380ha of suitable terrestrial foraging habitat. A polygon encompassing the over-wintering area was generated.

Targets

9 breeding pairs @ 380ha per pair = 3420ha AND the core over-wintering area of the Blue Cranes in SE Gauteng.

A discrepancy between the area calculated above for targets and GIS calculations in the habitat model was explained as follows by Dr Whittington-Jones:

“The discrepancy between the area of total breeding habitat polygon (6158ha) and the area calculated based on the minimum requirement per breeding pair (i.e. 380ha per pair) is because we digitized more suitable habitat around each confirmed or suspected pair that was strictly required. While it is more “space hungry” to include the larger area (i.e. 6158ha), I believe that there are several good reasons for doing so.

- 1. We have not mapped the foraging movements of the breeding pairs so don't know exactly which areas are important for breeding success*
- 2. There may be between-year differences in the suitability of habitat patches within the range of each pair*
- 3. A good breeding site may support more than one breeding pair in some years*
- 4. If we allow the computer to select only a subset of the mapped breeding area, the area target may be achieved without necessarily including all the confirmed and suspected breeding localities.”*

In conclusion, the target was set at 100% (i.e. 6158ha) of confirmed breeding habitat and 100% (i.e. 9626ha) of overwintering habitat.

Target motivation

For Vulnerable species solely listed under the IUCN Red List Criteria of A or E Pfab *et al.* 2010 recommend that at least 10 000 mature individuals must be conserved *in situ* and thereby avoiding a Vulnerable listing under the C criterion in the event that the species is subject to a decline or extreme fluctuations.

For Blue Cranes, Gauteng's proportional share (based on relative extent of national range falling within Gauteng outside of the 2007 urban edge i.e. approximately 1.5%) of 10 000 mature individuals is 75 breeding pairs. This greatly exceeds the number of pairs estimated for the province by Tarboton (1997) i.e. <20 pairs and only 9 pairs (5 confirmed and 4 suspected) have been recorded for the province to date. However, since breeding cranes are not easily located and it is not known what habitat features distinguish occupied breeding wetlands from those where no breeding takes place it is impossible at this stage to model potential breeding habitat in order to make provision in the conservation plan for sufficient habitat for an additional 66 breeding pairs. The target for breeding pairs is therefore to accommodate the 9 known/suspected pairs at this stage, with the proviso that should any additional pairs be identified, adequate provision must be made for their conservation pending the revision of the conservation plan.

The area utilized routinely by non-breeding flocks (mapped between 2000 and 2010) is comprised of a mosaic of wetlands, natural grassland, pastures, fallow fields and actively cultivated lands and while not obviously unique, may be as critical to the survival of this species (for reasons that are not yet understood) as their traditional breeding wetlands and it seems implausible that c-plan software would be able to “predict” which other areas might provide suitable alternatives. While only areas of natural habitat within the over-wintering area have been selected for inclusion within the conservation plan, a general change in land use from agriculture to urban, industrial or mining would be incompatible with the persistence of this flock.

9.2.1.5. Blue Korhaan (*Eupodotis caerulescens*)

Rationale for inclusion

IUCN = unknown; RSA = NT A2c (Barnes 2000b); Near-endemic to South Africa. Main threats include habitat loss.

Raw distribution data sources

GDARD field data, specialist consultants, general public, Coordinated Avifaunal Roadcount (CAR) database.

Distribution mapping/modeling general

The Blue Korhaan occurs in shortly grazed grassland, pastures, old lands and fallow fields (Tarboton *et al.* 1987), habitat types that occur widely within the province. Yet despite this, confirmed records are few and patchy. While this may simply reflect poor sampling, it may also be a consequence of as yet undetermined habitat limitations. Until this issue is further resolved, modeling of suitable habitat was restricted to those areas with clusters of confirmed Blue Korhaan records. Areas with few isolated records (e.g. Suikerbosrand Nature Reserve) were excluded from the model pending further surveys.

Distribution mapping/modeling technical

Simply buffering confirmed points with 100ha (minimum viable management unit and estimated spatial requirements of a pair) of suitable habitat provided an unsatisfactory model of this species' distribution, artificially fragmenting the landscape and causing large areas of otherwise suitable and conterminous habitat to be excluded. For this reason, the full extent of patches of conterminous habitat around confirmed points falling outside the urban edge were mapped. Artificial barriers such as roads were used to demarcate patch boundaries and all unsuitable habitat including agricultural holdings, actively cultivated fields (i.e. land cover codes 24, 25, 26, 27, 551, 561 & 9999 – see [Table 1](#)), fragments of suitable habitat <100ha and "slivers" of natural habitat (e.g. road verges) were excluded.

Targets

100 breeding pairs @ 100ha per pair = 10 000ha.

Target motivation

For Near-Threatened species, Pfab *et al.* 2010 recommend that at least 10 000 mature individuals must be conserved *in situ*, thereby avoiding a Vulnerable listing under the C criterion in the event that the species is subject to a decline or extreme fluctuations.

For this species, Gauteng's proportional share (based on relative extent of national range falling within Gauteng outside of the 2007 urban edge i.e. approximately 2%) of 10 000 mature individuals is 100 breeding pairs. In optimum habitat, Blue Korhaans occur at a density of 20 birds/10km² or 1 bird per 50ha (Tarboton *et al.* 1987.) thus 100 breeding pairs would require approximately 10 000ha of suitable habitat.

9.2.1.6. Cape Vulture (*Gyps coprotheres*)

Rationale for inclusion

IUCN = VU C1 + 2a(ii) (Butchart & Pilgrim 2006 - BirdLife International Red List Authority); RSA = VU A1acd + A2bcd + C1 + C2b (Anderson 2000 - Northern Cape Nature Conservation); Endemic to southern Africa. Main threats include poisoning (accidental and to obtain parts for muthi purposes), powerlines, food stress during chick rearing and persecution.

Raw distribution data sources

GDARD field data, VULPRO

Distribution mapping/modeling general

The Cape Vulture breeds in the Magaliesberg on the farms Nooitgedacht 471 JQ and Bergsig 569 JQ (the latter lies within the boundaries of the original Nooitgedacht farm) in Gauteng as well as at two other active colonies within the North West Province and forages widely across the two provinces. A core foraging area has been mapped through the tracking of adult birds (K. Wolter, unpublished data).

Distribution mapping/modeling technical

The farms Nooitgedacht 471 JQ and Bergsig 569 JQ.

Targets

One breeding population (minimum of 118 breeding pairs); the full extent of the farms Nooitgedacht 471 JQ and Bergsig 569 JQ.

Target motivation

For Vulnerable species listed under the IUCN Red List Criteria of B, C or D, Pfab *et al.* 2010 recommend that all populations must be conserved *in situ*. The most recent estimate of Cape Vulture breeding population for Gauteng is 118 pairs at a single locality, though the population appears to be expanding.

Given the extensive foraging movements of this species, only the breeding site can feasibly be included in the conservation plan for Gauteng. To limit human disturbance and persecution, the breeding cliffs require a buffer and in the absence of any tested buffer width for this species, the boundaries of the farms Nooitgedacht 471 JQ and Bergsig 569 JQ are considered achievable and must be deemed adequate until demonstrated otherwise.

Threats to foraging birds are addressed through implementation of mitigation measures on all new electricity infrastructure (enforced through the EIA legislation), while the establishment of supplementary feeding sites (i.e. vulture restaurants) seeks to address the threats posed by food stress (and to a more limited extent poisoning).

9.2.1.7. Half-collared Kingfisher (*Alcedo semitorquata*)

Rationale for inclusion

UCN = LC (Ekstrom & Butchart 2004 - BirdLife International Red List Authority); RSA = NT A1 + A2c + B1 + B2bcde + C1 (Allan 2000). Main threats include habitat destruction and degradation.

Raw distribution data sources

GDARD field data, specialist consultants, Tarboton *et al.* 1987.

Distribution mapping/modeling general

The Half-collared Kingfisher occurs along perennial rivers and streams where suitable cover in the form of wooded margins or over-hanging vegetation exists (Tarboton *et al.* 1987) and is widely, but patchily distributed in the province. Only rivers for which the species has been confirmed were mapped.

Distribution mapping/modeling technical

The maximum extent of each river along which the Half-collared Kingfisher has been confirmed (i.e. Magalies, Bloubankspruit, Crocodile, Muldersdrif se Loop, Pienaar's, Elands, Malanspruit, Hennops, Bronkhorstspuit and Wilge) were selected. For the Vaal River, remaining suitable stretches were identified by van der Westhuizen Coetzee *et al.* (2005). The Blesbokspuit which is probably marginal habitat, the Pienaa's River upstream (south) of Roodeplaat, the Sesmyspruit upstream (east) of Rietvlei Nature Reserve and the Bronkhorstspuit River from the dam south were excluded as these stretches were considered unsuitable.

A buffer including the riparian zone and 100m (outside the urban edge) OR the riparian zone and 32m (inside the urban edge) as per the Aquatic Unit's requirement for safe-guarding water quality was adopted.

Targets

240 breeding pairs; 100% of modeled suitable habitat

Target motivation

For Near-Threatened species, Pfab *et al.* 2010 recommend that at least 10 000 mature individuals must be conserved *in situ*, thereby avoiding a Vulnerable listing under the C criterion in the event that the species is subject to a decline or extreme fluctuations.

For this species, Gauteng's proportional share (based on relative extent of national range falling within the province i.e. approximately 4.8%) of 10 000 mature individuals is 240 breeding pairs. Pairs require at least 1km of suitable riverine habitat for breeding (Clancey 1992 in Allan 2000), but densities may be as

low as 1 bird/9km even in prime habitat (Allan 2000). While densities are expected to vary among rivers, as a very rough estimate, approximately 240-2160km of suitable riverine habitat would be required to support 240pairs. Given the poor state of rivers in Gauteng and the dependence of this species on clear, fast-flowing perennial rivers and streams with dense marginal vegetation (Mclean 1993), it is likely that considerable restoration work will be required to meet this target.

Due to the linear connectivity of their habitat, impacts such reduced water flow through over-extraction and damming, destruction of riparian vegetation with associated reduction in water quality will have consequences not only at the point of impact, but downstream too. Consequently, the full extent of suitable modeled habitat along each identified river (except the Vaal) needs to be conserved if the integrity of this species' habitat is to be maintained. The Vaal River is highly impacted and thus only those remnant patches of suitable habitat identified by van der Westhuizen Coetzer *et al.* (2005) were included in the model and hence the target.

9.2.1.8. Melodious Lark (*Mirafra cheniana*)

Rationale for inclusion

IUCN = NT (Stattersfield & Butchart 2004 - BirdLife International Red List Authority); RSA= NT A1c + A2c (Barnes 2000c); Endemic to southern Africa. Main threats include habitat loss and degradation.

Raw distribution data sources

GDARD field data, specialist consultants and general public.

Distribution mapping/modeling general

The Melodious Lark occurs widely in the province and while Tarboton *et al.* (1987) observe that it favours *Cymbopogon-Themeda* and Bankenveld grassland types, it may also occur at high densities in *Hyparrhenia* dominated grasslands (pers obs.). Modeling was limited to delineating the remnant patches of suitable natural habitat where this species has been observed in the last decade.

Distribution mapping/modeling technical

Areas within the 2007 urban edge, small holdings, ridges (no records for this habitat) and unsuitable habitat (i.e. land cover codes 24, 25, 26, 27, 551, 561, 571 & 9999 – see Table 1) were excluded. Conterminous grassland around remaining confirmed points was then selected and habitat fragments smaller than 100ha (minimum viable management unit) were excluded from the final model.

Targets

320 breeding pairs @ 2ha per pair = 640ha.

Target motivation

For Near-Threatened species, Pfab *et al.* 2010 recommend that at least 10 000 mature individuals must be conserved *in situ*, thereby avoiding a Vulnerable listing under the C criterion in the event that the species is subject to a decline or extreme fluctuations.

For this species, Gauteng's proportional share (based on relative extent of national range falling within Gauteng outside of the 2007 urban edge i.e. approximately 6.4%) of 10 000 mature individuals is 640 individuals or 320 breeding pairs. On Suikerbosrand Nature Reserve, Melodious Lark density in suitable habitat ranged from 1-7 birds per ha (C. Whittington-Jones, unpublished data). Assuming the lowest density, 320 breeding pairs would require approximately 640ha of suitable habitat.

9.2.1.9. Secretarybird (*Sagittarius serpentarius*)

Rationale for inclusion

IUCN = LC (Ekstrom & Butchart 2004 - BirdLife International Red List Authority); RSA = NT A1c + A2c (Barnes 2000d). Main threats include habitat degradation and disturbance. In Gauteng collisions with powerlines and entanglement with fences may be important sources of mortality.

Raw distribution data sources

GDARD field data, Coordinated Avifaunal Roadcount (CAR) database

Distribution mapping/modeling general

The Secretarybird occurs in grassland and open woodland (Tarboton *et al.* 1987), habitat types that occur widely within the province. The model was restricted to conterminous patches of natural habitat around confirmed Secretarybird records.

Distribution mapping/modeling technical

In an attempt to restrict the area of modeled habitat to that minimum sub-set of the total available habitat where Secretarybirds were most frequently encountered, area of occupancy polygons were generated to encompass clusters of confirmed Secretarybird records and unsuitable habitat patches were excluded. During the technical review process, however, these regular polygons were criticized as being too artificial in construction and appearance and it was subsequently suggested that each point should instead be buffered by an area equivalent to the territory occupied by a pair of Secretarybirds.

Estimates of territory size vary from 20km² (i.e. 2 000ha) in well managed areas of good habitat such as the Kruger National Park to 230km² (i.e. 23 000ha) elsewhere in the former Transvaal (Steyn 1982). Tarboton & Allan (1984) estimated a density of 0.6 Secretarybird pairs/100km² (i.e. 16 667ha per pair) for the Highveld and Bushveld regions which would be broadly applicable to Gauteng, but presumably includes areas of unsuitable habitat. Since areas of degraded and unsuitable habitat were to be excluded from the conservation plan, an estimate of territory size restricted to good habitat was required for Gauteng.

The square of inter-nest distance may be used to estimate territory size of raptors (Van Zyl 1992). Two Secretarybird pairs nested 5600m apart on Suikerbosrand Nature Reserve in 2005 and a territory size of approximately 3 150ha was estimated for the species in Gauteng. Assuming that territories do not overlap extensively, a territorial bird might therefore be expected to forage up to 2800m around its nest and could potentially be up to 5600m from an adjacent active territory. Few nests were encountered so each confirmed Secretarybird point was buffered by 5600m. While not ideal, this approach ensured that the model included larger patches of suitable habitat in areas where higher concentrations of foraging birds were observed.

All land within the urban edge, agricultural holdings, actively cultivated fields (i.e. land cover codes 24, 25, 26, 27, 551 & 9999 – see Table 1) and habitat fragments <100ha as well as "slivers" of natural habitat (e.g. road verges) were excluded from the buffered points and the final model comprised suitable habitat patches larger than 100ha, but within 5600m of a confirmed record for this species.

Targets

30 breeding pairs @ 3 150ha per pair = 94 500ha.

Target motivation

For Near-Threatened species, Pfab *et al.* 2010 recommend that at least 10 000 mature individuals must be conserved *in situ*, thereby avoiding a Vulnerable listing under the C criterion in the event that the species is subject to a decline or extreme fluctuations.

For this species, Gauteng's proportional share (based on relative extent of national range falling within Gauteng outside of the 2007 urban edge i.e. approximately 1.2%) of 10 000 mature individuals is 60 breeding pairs. However, data from biannual Coordinated Avifaunal Roadcounts (CAR) which target large terrestrial birds produced a highest single count of 11 individual Secretarybirds for the survey network which covers a maximum of 20% of the Gauteng outside of the urban edge. While these data require more careful analysis a more realistic estimate for the province is probably less than 30 breeding pairs.

The estimated territory size of Secretarybirds in good habitat in Gauteng is 3150ha and thus 189 000ha would be required to accommodate 60 breeding pairs.

9.2.1.10. White-bellied Korhaan (*Eupodotis senegalensis*)

Rationale for inclusion

IUCN = LC (Ekstrom & Butchart 2004 - BirdLife International Red List Authority); RSA = VU A1c + A2c + C1 (Barnes 2000e). Local race endemic to southern Africa. Main threats include habitat loss.

Raw distribution data sources

GDARD field data, general public, specialist consultants, Coordinated Avifaunal Roadcount (CAR) database.

Distribution mapping/modeling general

The White-bellied Korhaan occurs in grassland and open woodland (Tarboton *et al.* 1987), habitat types which occur widely within the province, yet confirmed records are few and patchy. This may simply reflect poor sampling or as yet undetermined habitat limitations. Until this issue is further resolved, modeled habitat was restricted to those areas of natural habitat with clusters of confirmed White-bellied Korhaan records. Areas with few isolated records were excluded pending further surveys.

Distribution mapping/modeling technical

Simply buffering confirmed points with 120-400ha (based on density estimates discussed below) of suitable habitat provided an unsatisfactory model of this species distribution as large areas of otherwise suitable and conterminous habitat were needlessly fragmented and large portions excluded for want of a direct observation of a species that is difficult to detect in its preferred long grass habitat. For this reason, the full extent of patches of conterminous habitat around confirmed points falling outside the urban edge were mapped. Artificial barriers such as roads were used to demarcate patch boundaries and all unsuitable habitat including agricultural holdings, actively cultivated fields (i.e. land cover codes 24, 25, 26, 27, 551 & 9999 – see Table 1), fragments of suitable habitat <100ha (minimum viable management unit) and "slivers" of natural habitat (e.g. road verges) were excluded.

Targets

120 breeding pairs @ 120ha per pair = 14 400ha.

Target motivation

For Vulnerable species listed under the IUCN Red List Criteria of B, C or D Pfab *et al.* (2010) recommend that all populations must conserved *in situ*. However, conservation of this species within the urban edge is not considered feasible due to poor habitat connectivity and fire-based habitat management requirements.

The size of the Gauteng White-bellied Korhaan population is unknown, but the province's proportional share (based on relative extent of national range falling within Gauteng outside of the 2007 urban edge i.e. approximately 4.7%) of the estimated <5000 White-bellied Korhaan remaining regionally (Barnes 2000) is approximately 120 breeding pairs.

Data on the foraging range requirements of this species is not available, but Blue Korhaans are known to occur at a density of 1 bird/50 ha in optimum habitat (Tarboton *et al.* 1987) and outnumber White-bellied Korhaan 4:1 where they occur in the same area. While this suggests that the White-bellied Korhaan may have larger spatial requirements (approximately 400ha per pair), they tend to prefer longer thicker grass than the Blue Korhaan (Tarboton *et al.* 1987) and due to detection difficulties they may occur at higher densities. Indeed, Tarboton reportedly estimated a density of 2.5 birds/100ha for fragmented habitat patches in the Wakkerstroom area (Barnes 2000e). At such densities, and given that this species is usually found in pairs or accompanied by an immature (Tarboton *et al.* 1987), a breeding pair and a single offspring might require approximately 120ha.

9.2.1.11. White-backed Night-Heron (*Gorsachius leuconotus*)

Rationale for inclusion

IUCN = LC (Ekstrom & Butchart 2004 - BirdLife International Red List Authority); RSA = VU A1a + A2bc + C1 (Parker & Barnes 2000). Main threats include habitat loss.

Raw distribution data sources

General public, Tarboton *et al.* 1987.

Distribution mapping/modeling general

The White-backed Night-Heron occurs patchily within the province and is found along both large rivers and small streams where suitable cover in the form of wooded margins or over-hanging vegetation exists (Tarboton *et al.* 1987; Parker & Barnes 2000). Rivers for which the species has been confirmed (either in recent surveys or historically according to Tarboton *et al.* (1987)) were mapped.

Distribution mapping/modeling technical

The maximum extent of rivers along which this species has been confirmed (i.e. Hennops and Pienaar's) or was known to occur historically (i.e. Skeerpoort, Crocodile and Vaal) was selected. For the Vaal River, remaining suitable stretches of habitat were identified by van der Westhuizen Coetzer *et al.* (2005). A buffer including the riparian zone and 100m (outside the urban edge) OR the riparian zone and 32m (inside the urban edge) as per the Aquatic Unit's requirement for safe-guarding water quality was adopted.

The Blesbokspruit which is probably marginal, the Pienaa's upstream (south) of Roodeplaat and the Sesmyspruit (a tributary of the Hennops River) upstream (east) of Rietvlei Nature Reserve were excluded as these stretches were considered unsuitable.

Targets

20 breeding pairs: 100% of modeled suitable habitat

Target motivation

For Vulnerable species listed under the IUCN Red List Criteria of B, C or D Pfab *et al.* (2010) recommend that all populations must be conserved *in situ*.

The White-backed Night-Heron is secretive and nocturnal (Tarboton *et al.* 1987) and the size of the local population is unknown, but Gauteng's proportional share (based on relative extent of national range falling within the province i.e. approximately 3.7%) of the estimated 500-1000 individuals remaining regionally (Parker & Barnes 2000) is approximately 10-20 breeding pairs.

Data on the foraging range requirements of this species is not available. However, due to the linear connectivity of their habitat, impacts such as destruction of overhanging trees and increased water turbidity resulting from erosion (Martin 1997) have consequences not only at the point of impact, but downstream too. Consequently, the full extent of suitable modeled habitat along each identified river (except the Vaal) needs to be conserved if the integrity of this species habitat is to be maintained. The Vaal River is highly impacted and thus only remnant patches of suitable habitat identified by van der Westhuizen Coetzer *et al.* (2005) were included in the target.

9.2.2. Species excluded from C-Plan 3

Species below were included in either C-Plan version 1 or 2, but were excluded from C-Plan 3. Additional threatened bird species have been recorded for the province, but those categorized as vagrants, erratic visitors or erratic migrants to the province (Tarboton 1997) have been intentionally excluded from the conservation plan as their unpredictable occurrence in both space and time renders them all but impossible to effectively conserve in a small province with high development pressure. While these species could benefit indirectly from other conservation action in Gauteng, the main responsibility for their protection must fall on those conservation agencies within their core distribution areas.

- a. Martial Eagle (*Polemaetus bellicosus*) [Vulnerable]. Few records for province and no recent records of breeding. Impractical to attempt target for foraging habitat alone.
- b. Lesser Kestrel, (*Falco naumanni*) [Vulnerable]. Decline due primarily to threats in palearctic breeding grounds, not a Gauteng-based problem.
- c. Black Stork (*Ciconia nigra*) [Near-Threatened]. Few records for province and no recent records of breeding. Impractical to attempt target for foraging habitat alone.

- d. Lanner Falcon (*Falco biarmicus*) [Near-Threatened]. Status in province uncertain. Forages widely and apparently occurs in passage, but no confirmed breeding sites known. Impractical to attempt target for foraging habitat alone.
- e. Greater Flamingo (*Phoenicopterus ruber*) [Near-Threatened]. Mainly threatened by activities in breeding areas i.e. outside Gauteng. Standard wetland buffer adequate for this species.
- f. Lesser Flamingo (*Phoenicopterus minor*) [Near-Threatened]. Mainly threatened by activities in breeding areas i.e. outside Gauteng. Standard wetland buffer adequate for this species.
- g. Yellow-billed Stork (*Mycteria ibis*) [Near-Threatened]. Reviewers considered this species to be marginal in Gauteng. Only regularly recorded at one wetland and elsewhere erratically and infrequently, therefore not a considered conservation priority.
- h. Red-billed Oxpecker (*Buphagus erythrorhyncha*) [Near-Threatened]. Species is expanding its range in bushveld areas. Red list concern related to use of pesticides and therefore solution lies in appropriate management of chemicals and not in spatial planning.

9.3. Invertebrates (Ian Engelbrecht)

9.3.1. Butterflies

9.3.1.1. Highveld blue butterfly (*Lepidochrysops praeterita*)

Rationale for inclusion

Proposed for the Red List Category Endangered (EN A2c, B1ab(iv) + 2ab(iv); Henning et al. 2009) based on limited distribution and extent of mining and agricultural activities within its range. Largely endemic to Gauteng, extending into Potchefstroom area in north west. (Specify the distribution and threat parameters if provided)

Raw distribution data sources

SABCA atlas (Provided by B. Coetzer); field visits by Ian Engelbrecht (GDARD) and Jeremy Dobson (LepSoc); one record from C-Plan V2.1

Distribution mapping/modeling general

This species appears to be limited to the ridge system extending from Meyerton in the east, through to Potchefstroom in the west, largely following the direction of the N12 highway. This ridge system is composed primarily of Pretoria group arenite and shale. The strata are inclined northwards for most of the extent of the ridge, with the inclination shifting to eastwards in the Meyerton area. Site visits confirmed that this species is largely confined to the long, gentle, south facing (and west facing in the Meyerton area) slopes on this ridge system. The species is not uniformly distributed on these slopes due to subtle changes in geology/soils and vegetation, but these were not considered in mapping as the necessary fine scale spatial data are not available.

Distribution mapping/modeling technical

All mapping was done for the extent of the abovementioned ridge system.

Slope and aspect layers were created from the 90m SRTM DEM.

Appropriate ranges and values for slope and aspect were determined by intersecting points representing known locality records with slope and aspect layers. The upper and lower values for each were selected to represent the range of possible values for the species.

All cells falling within these ranges were selected from the slope and aspect layers and

Visual inspection of results indicated that footslopes on north and east facing slopes of the ridge system were selected using this method. It appears that the species does not occupy these areas though and that this selection is effectively an artifact of the mapping method used. Thus these were removed manually to produce the final distribution map.

Targets

100% of known localities.
100% of modeled distribution.

Target motivation

100% of known populations is the standard target for species listed under criterion B. The motivation is that for threatened species any further declines should be avoided, and thus all known populations should be protected.

70% of suitable habitat is set as the target for metapopulation persistence of the species. It is generally indicated that estimates of metapopulation extinction risk are higher when location specific population dynamics are included in metapopulation models (Baguette and Schtickzelle 2003, Lopez and Pfister 2001). There are also several cases where it is indicated that a large number of habitat patches are required for metapopulation persistence, and that currently available habitat is below the required threshold, thus implying an 'extinction debt' for the species (Schtickzelle et al 2005, Bulmann et al 2007, Kuussaari et al 2009). While it would be ideal to provide an empirical estimate of the number of patches required for persistence of this species, the data required are not available. Thus, this target is based on a conservative gut feel of what will be required.

The target of 30% of 'unsuitable habitat' is included to maximize the likelihood of some level of connectivity between patches of suitable habitat. The metapopulation ecology literature indicates that the quality of the matrix between suitable patches is an important factor in metapopulation persistence. 30% is a generally accepted threshold below which connectivity within a landscape substantially decreases (Fischer and Lindenmayer 2007). It is acknowledged that simple, 'rule of thumb' values such as this are not ideal as they may inadequately represent the requirements of the species, but in this case the absence of information on population sizes, dispersal rates and extinction/colonization dynamics does not allow a more rigorous analysis.

Confirmed Buffers:

Point 5, Lenasia 9kmSW, not included in this analysis.
Each point buffered by 500m.

Motivation is species is large and a strong flier, seen to occur widely at these points in the field.
Intersect of this buffer with habitat model to produce final buffered points for inclusion in C-Plan3.
file: lep_praet_buff_final

Note: These areas should be interpreted as the area where the species carries out its lifecycle.
Edge effect buffers should still be added as per standard procedure for threatened species

Habitat model:

Extent set to include chosen ridges, Potchefstroom and Vredefort dome
Cell size as for SRTM dataset (90m)
z factor used: 0.00000956

Slope and aspect generated in Spatial Analyst using SRTM 90mDEM
Points intersected with aspect and slope

Point 5 (Lenasia, 9km SW) ignored as it is atypical habitat and specimens seen were probably dispersing
Aspect range taken from remaining points (97.56 - 292.16, ie E to W)
Slope included full range of values where species recorded (3.5 - 8.99 degrees)

Suitable slopes intersected with suitable aspect and reclassified to binary surface

GRID converted to polygon layer
Triangles resulted from generalised boundaries
Calculated area for polygons (using Albers Equal Area projection with no modifications to parameters) in km²
Deleted all polygons smaller than 0.13km_sq (smallest patch where species recorded, ie Potchefstroom)
Deleted polygons outside of potential distribution range (eg Klipriviersberg, other small ones in the middle of nowhere, etc)
Deleted polygons representing probable unsuitable habitat, eg footslopes
Deleted polygons on the edges of mine dumps and slimes dams

This produced layer of potential habitat for further surveys - lep_praet_hab

Deleted polygons on Vredefort Dome and other small ridge systems to produce layer for inclusion in C-Plan 3 [lep_praet_hab2].

9.3.1.2. Heidelberg Copper Butterfly (*Chrysoritis aureus*)

Rationale for inclusion

Proposed for inclusion in IUCN Red list (VU B1ab(ii, iv) + 2 ab(ii, iv), D2; Henning et al. 2009). This is a monophagous, myrmecophilous butterfly species, known from a handful of localities on the Heidelberg-Balfour-Greylingstad ridge system.

Raw distribution data sources

SABCA atlas (Provided by B. Coetzer); field visits by Ian Engelbrecht (GDARD) and Graham Henning (LepSoc); some records from C-Plan V2.1

Distribution mapping/modeling general

Mapping has not yet taken place for this species. It is not immediately apparent what the habitat of this species is, ie what factors determine suitable habitat. The known records represent colonies of this butterfly which occur around rock faces inhabited by the host ant species and where the host plant also occurs. Colonies are made up several tens of individuals which are active over an area of about 100m² in the vicinity of the ant colonies. The butterflies do not occur in areas where the host plant grows larger than about 1m in height. It has been speculated that the species only occurs at the highest altitudes on the ridge system, but there are some colonies found lower than the proposed suitable altitudinal range. It has also been speculated that it only occurs in 'rain shadow' areas on the ridge, usually on SE facing slopes, where the resultant water stress inhibits the production of allelochemicals in the host plant, but this has not been tested. Fire has been demonstrated to be important for the species in that it keeps the vegetation structure open (Terblanche et al 2003).

My suspicion is that the species is more widely distributed on this ridge system than is currently known, and that the limited number of records is as a result of difficulties in surveying the rugged terrain extensively, and in the low likelihood of encountering colonies due their small spatial extent. It is also possible that the small relative size of the host plants can be attributed to shallow soils on the rocky outcrops where the colonies are found, and that fire dynamics result in changes in habitat suitability over time.

I (Ian Engelbrecht) would like to map the habitat of this species as all open, grassland habitats on the ridge system above the lowest elevation recorded for the species. Targets will be set to conserve known populations, and to ensure connectivity of natural habitat on the ridge system thus allowing for persistence of colonization/extinction dynamics in the species. Most of the ridge is currently untransformed, and is likely to remain as such for the foreseeable future.

Distribution mapping/modeling technical

TBC

Targets

100% of known localities.

100% of modeled distribution. NB, if we decide later to reduce habitat targets I will need to change the modeled habitat on Suikerbosrand. My model has indicated all of the high lying ridges on the reserve as potential habitat, which I don't believe is correct but I've left it in anyway as it won't affect anything if we use a 100% target. If we reduce the target these areas could meet the target alone (being in the nature reserve) to the detriment of populations outside the reserve.

Target motivation

100% of known populations is the standard target for species listed under criterion B. The motivation is that for threatened species any further declines should be avoided, and thus all known populations should be protected.

70% of suitable habitat is set as the target for metapopulation persistence of the species. It is generally indicated that estimates of metapopulation extinction risk are higher when location specific population dynamics are included in metapopulation models (Baguette and Schtickzelle 2003, Lopez and Pfister 2001). There are also several cases where it is indicated that a large number of habitat patches are required for metapopulation persistence, and that currently available habitat is below the required threshold, thus implying an 'extinction debt' for the species (Schtickzelle et al 2005, Bulmann et al 2007, Kuussaari et al 2009). While it would be ideal to provide an empirical estimate of the number of patches required for persistence of this species, the data required are not available. Thus, this target is based on a conservative gut feel of what will be required.

The target of 30% of 'unsuitable habitat' is included to maximize the likelihood of some level of connectivity between patches of suitable habitat. The metapopulation ecology literature indicates that the quality of the matrix between suitable patches is an important factor in metapopulation persistence. 30% is a generally accepted threshold below which connectivity within a landscape substantially decreases (Fischer and Lindenmayer 2007). It is acknowledged that simple, 'rule of thumb' values such as this are not ideal as they may inadequately represent the requirements of the species, but in this case the absence of information on population sizes, dispersal rates and extinction/colonization dynamics does not allow a more rigorous analysis.

9.3.1.3. Roodepoort Copper Butterfly (*Aloeides dentatis dentatis*)

Rationale for inclusion

Proposed for inclusion in IUCN Red list (BU B2ab(ii, iv); Henning et al 2009). This is a monophagous, myrmecophilous butterfly species, known from three localities in Gauteng province. Importantly, all localities fall within protected areas (i.e. Ruimsig Entomological Reserve, Klipriviersberg Nature Reserve, Suikerbosrand Nature Reserve).

Raw distribution data sources

SABCA atlas (Provided by B. Coetzer); field visits by Ian Engelbrecht (GDARD) and Jeremy Dobson (LepSoc); records from C-Plan V2.1

Distribution mapping/modeling general

It is not clear what the habitat of this species is. All populations are in open grassy areas. In Ruimsig the species is on a footslope, while at Klipriviersberg and Suikerbosrand it is on hill slopes and crests. Specimens have been recorded along wetlands at Suikerbosrand, but it is not certain as to whether these belong to the subspecies *dentatis maseroena*, or *dentatis dentatis*. There is also some uncertainty about whether these subspecies are valid.

Given this uncertainty, I have taken the decision to only include known populations of this species in the conservation plan, and to map their extent as the extent of the area where butterflies have been observed.

Distribution mapping/modeling technical

Polygons were created in ArcGIS using Quickbird satellite images as a backdrop. Suitable habitat in the vicinity of observations of these butterflies was mapped as habitat.

Targets

100% of suitable areas at known (confirmed) localities for the species.

Target motivation

100% of known populations is the standard target for species listed under criterion B. The motivation is that for threatened species any further declines should be avoided, and thus all known populations should be protected.

9.3.2. Beetles

9.3.2.1. Stobbia's fruit chafer beetle (*Ichneustoma stobbiai*)

Rationale for inclusion

This species qualifies for the Vulnerable category of the IUCN Red List (VU B1ab(ii, iii, iv); assessment conducted by myself in conjunction with researchers from University of Pretoria and Transvaal Museum and private beetle collectors). It occurs in the northern parts of Gauteng province, with an estimated Extent of Occurrence of just less than 6000km², of which 25% has been transformed to date. The distribution falls within the area of Gauteng where the rate of transformation is substantial due to rapid urban development.

Raw distribution data sources

Distribution records were obtained from Transvaal Museum, University of Pretoria, private beetle collectors and C-Plan V2.1.

Distribution mapping/modeling general

The habitat requirements of this species are not clearly apparent. It appears to exhibit a highly patchy distribution across its range, but it is not apparent what habitat factors influence the occurrence of populations. In some areas the species occurs on dolomite geology, on gentle hillslopes, while at others it occurs on the tops of quartzite ridges. Other populations are on other rock types and some populations occur in grassland while others are in savanna.

An expert driven mapping approach was used for the species to map the area likely to be occupied by the beetle at known localities. All suitable, untransformed habitat in the vicinity of known records were mapped as suitable, occupied habitat for the species. No attempt was made to predict the occurrence of additional populations in other areas.

Distribution mapping/modeling technical

Polygons were created around point records in ArcGIS, using Quickbird imagery as a backdrop and to determine the extent of suitable habitat.

Targets

100% of known localities.

100% of 'modeled' distribution. By modeled distribution I mean the areas of habitat around the known localities that we mapped together using Quickbird with Christian and Ute from UP.

Target motivation

The reasoning for the 100% targets for the modeled habitat is the area of occupancy of the models in all cases falls below the thresholds for inclusion in the Endangered category of the IUCN list under Criterion B.

9.3.3. Invertebrates excluded from C-Plan 3

Some invertebrate species included in C-Plan 1 and 2 were not included in C-Plan 3 (see the table below). Many of the changes resulted from research done after C-Plan 1 & 2.

Table 5: Invertebrate species not included in C-Plan 3

| Species | Common Name | Motivation for inclusion in C-Plan 2 | Motivation for exclusion from C-Plan 3 |
|------------------------------|---------------------------|--|---|
| <i>Orachrysops mijburghi</i> | Mijburgh's Blue Butterfly | Known only from one population in Gauteng | Only marginal in Gauteng, and Gauteng population protected in Suikerbosrand NR |
| <i>Metisella meninx</i> | Marsh Sylph Butterfly | Limited distribution and association with wetlands | Found to be widespread. SABCA conservation assessment shows the species to be Least Concern |
| <i>Trichocephala brincki</i> | Brinck's Chafer Beetle | Rarity and limited distribution | Although very rare, distribution range found to be large and rarity |

| Species | Common Name | Motivation for inclusion in C-Plan 2 | Motivation for exclusion from C-Plan 3 |
|------------------------------------|----------------------------|---|---|
| | | | is probably an artifact of cryptic habits |
| <i>Hadogenes gunning</i> | Rock scorpion | Limited distribution and occurrence on ridges | Found to be widespread and common |
| <i>Opisthophthalmus pugnax</i> | Burrowing scorpion | Limited distribution | Found to be widespread and common |
| <i>Harpactira hamiltoni</i> | Common Baboon Spider | Rarity and limited distribution | Found to be widespread and common |
| <i>Brachionopus pretoriae</i> | Lesser Baboon Spider | Limited distribution | Taxonomic problems and uncertainty about distribution |
| <i>Calommata simoni</i> | Purse Web Spider | Rarity and limited distribution | Taxonomic problems and uncertainty about distribution |
| <i>Ancylotrypa rufescens</i> | Wafer lid trapdoor spider | Limited distribution | Taxonomic problems and uncertainty about distribution |
| <i>Stasimopus suffusus</i> | Cork lid trapdoor spider | Limited distribution | Taxonomic problems and uncertainty about distribution |
| <i>Galeosoma pilosum</i> | Armoured trapdoor spider | Limited distribution | Taxonomic problems and uncertainty about distribution |
| <i>Galeosoma pallidum</i> | Armoured trapdoor spider | Limited distribution | Taxonomic problems and uncertainty about distribution |
| <i>Galeosoma robertsi</i> | Armoured trapdoor spider | Limited distribution | Taxonomic problems and uncertainty about distribution |
| <i>Galeosoma scutatum</i> | Armoured trapdoor spider | Limited distribution | Taxonomic problems and uncertainty about distribution |
| <i>Galeosoma hirsutum</i> | Armoured trapdoor spider | Limited distribution | Taxonomic problems and uncertainty about distribution |
| <i>Gorgyrella schreineri minor</i> | Front eyed trapdoor spider | Limited distribution | Taxonomic problems and uncertainty about distribution |
| <i>Segregara monticola</i> | Front eyed trapdoor spider | Limited distribution | Taxonomic problems and uncertainty about distribution |
| <i>Idiops pretoriae</i> | Front eyed trapdoor spider | Limited distribution | Taxonomic problems and uncertainty about distribution |

9.4. Mammals (Lihle Dimalisile)

9.4.1. Species included in C-Plan 3

9.4.1.1. Juliana's golden mole (Bronberg sub-population) (*Neamblysomus julianae*)

Rationale for inclusion

The species is endemic to South Africa and is listed as Vulnerable [B2 ab (ii,iii)] with the Bronberg sub-population listed as Critically Endangered [B1 ab (iii,iv) + 2ab (iii,iv)] by the IUCN (Bronner, 2008). The species is known from three geographically isolated sub-populations (Bronberg ridge, Nylsvley Nature Reserve & Kruger National Park – Jackson, *et.al.*, 2008). Habitat loss due to urbanization and sand mining are major threats for this species. DNA and dental analyses suggest that the Kruger National park population could be a different species; which would bring the known populations of this species to only two.

The following e-mail is also relevant:

Date: 30 October 2010

From: Galen B. Rathbun, Chair, IUCN Afrotheria Specialist Group

Subj: Juliana's Golden Mole

*"In recent years, several members of our IUCN (International Union for Conservation of Nature) Afrotheria Specialist Group have expressed serious concern about the conservation status of the Vulnerable Juliana's Golden Mole, *Neamblysomus julianae*. We continue to be concerned.*

The population of Juliana's Golden Mole that occupies the slopes of the eastern Bronberg Ridge, and particularly the deeper sands of the Shere and Zwavelpoort areas on the north-facing corridor between the length of the Bronberg ridge and a provincial road, is Critically Endangered. This corridor, and the greater Bronberg/Shere/Zwavelpoort area, have been radically transformed during the past two decades, largely due to uncoordinated and rapid urbanisation. This area is not only critical for the golden mole, but also supports other Threatened species, and is an important part of the local ecosystem because it recharges watersheds, groundwater, and wetlands. It also provides wildlife habitat, including dispersal corridors and essential areas for pollinators.

We understand that the South African Department of Environmental Affairs and the South African National Biodiversity Institute have added the greater Bronberg area to an official 2009 list of 'threatened ecosystems', which will soon be promulgated into legislation. We are grateful for this interest and action, and fully support it.

However, to ensure the long-term protection of the unique area, including the golden mole, and to reduce cumulative adverse impacts to the ecosystem, we urge the relevant authorities and interest groups to draft a strategic biodiversity conservation plan.

If our Specialist Group (www.afrotheria.net) can be of any assistance in developing effective protection for the golden mole and its habitat, please feel free to contact me. In the meantime, thank you for your consideration."

Raw distribution data sources

Presence absence data collected by Craig Jackson *et. al.* 2008 as part of the study on habitat utilization of the species.

Distribution mapping/modeling

A new habitat model was created by Pieta Compaan in the Bronberg area based on known locations and environmental parameters of available spatial data as follows:

GIS method:

Extent: the extent of the previous habitat model used in C-Plan 2, plus the outer boundary of the Bronberg Ridge created by GDARD, plus the extent of the habitat model created by Robertson & Jackson (2010) in the Bronberg area (with values more than 0.004) were all merged to create an extent of occurrence. This extent was used in ModelBuilder as a mask for the new habitat model.

Intersected all confirmed points with existing environmental parameters using Hawth's Tools.

Environmental parameters included:

Altitude: 1200-1700m

Geology: Andesite, quartzite, shale

Landtypes (broad soil types): Ab, Ba, Ib

Clay content: $\geq 15\%$ - 35%

Soil depth: < 750mm

Natural land cover classes in land cover 2009 were also included in the model. Areas digitised as "excluded" for C-Plan 3 were also used as a limiting factor to avoid built-up areas and mines.

Slope and aspect were found not to be a limiting factor and were not considered in the model. Used single map algebra in ModelBuilder as follows:

```
con([cp3_avail] == 1111,1) & con([alt09_100] == 4 | [alt09_100] == 5 | [alt09_100] == 6 | [alt09_100] == 7  
| [alt09_100] == 8,1) & con([geol09_agis] == 1 | [geol09_agis] == 17 | [geol09_agis] == 20,1) &  
con([ltbrdsoil09] == 1 | [ltbrdsoil09] == 3 | [ltbrdsoil09] == 13,1) & con([soilclay09] == 2,1) &  
con([soildpth09] < 3,1) & con([lc09_rcls] < 8,1)
```

The habitat model around confirmed points recorded by GDARD (Dr Dean Peinke, Helen Nonyane – both of them not with GDARD any longer, Lihle Dumalisile, as well as confirmed GPS records received from De Wet Botha in January 2011 (Prism Environmental Management Services) were refined and edited based on QuickBird imagery. The rest of the habitat model was also refined but not in as much detail as around confirmed points. Gaps were filled using EditTools.

Targets

100% of suitable habitat, including

Target motivation

100% of known populations is the standard target for species listed under criterion B. The Bronberg population faces a high risk of extinction; therefore all remaining suitable habitat must be conserved *in situ*.

9.4.1.2. Southern African hedgehog (*Atelerix frontalis*)

Rationale for inclusion

Listed as Near Threatened by the South African Red Data Book for mammals, the southern African hedgehog occurs in such a wide variety of habitats, such that it is a challenge to assess their habitat requirements. In Gauteng, they are confined in the grassland biome. The species is listed as a Protected Species in the TOPS regulations. Hedgehogs are under threat due to habitat destruction, road kills and direct persecution by humans or/and domestic animals.

Raw distribution data sources

Historical data from the Transvaal museum and data collected by GDARD staff

Distribution mapping/modeling general

Within the grassland biome, areas with an annual rainfall range of 300-800mm, excluding area in close proximity to wet areas and urban areas were selected, concentrating more in areas in which the species has been recorded before.

Distribution mapping/modeling technical

Circle with area of 3000 ha

1 ha = 10 000 m²

∴ 3000 ha = 30 000 000 m²

22/7 r² = 30 000 000 m²

r² = (30 000 000 m² * 7) / 22

r² = 9 545 454.54 (need to get square root of this number)

∴ r = 3 090 m

Radius of 3000 ha circle is 3090 m around each confirmed point.

Targets

Using the National species target guidelines: 11 locations to be conserved *in situ* to avoid a Vulnerable listing under the B criterion in the event that the species is subject to a decline or extreme fluctuations and at least 10 000 mature individuals to be conserved *in situ* to avoid a VU listing under C criterion in the event that the species is subject to extreme fluctuations.

GP target: 3000 hectares of grassland with dry cover

9.4.1.3. Spotted-necked otter (*Lutra maculicollis*)

Rationale for inclusion

Listed as Near Threatened by the South African Red Data Book, the Spotted-necked otter is an aquatic species and spends very little time in dry land compared to its counterpart the African clawless otter. It is listed as a Protected Species in the TOPS regulations. Because they use sight to hunt their diet of fish, crabs and other aquatic invertebrates, they cannot survive in polluted water. Like all other aquatic and

semi-aquatic species, the Spotted-necked otter's habitat is under threat from wetland drainages and extraction of water from rivers for agriculture. They are also killed by humans for food and medicinal purposes

Raw distribution data sources

Data collected during the GAP analysis and incidental sightings by GDARD staff

Distribution mapping/modeling general

The otter is distributed throughout most of South Africa, where there is aquatic habitat available (virtually in all the provinces), but not all available aquatic habitats are suitable - has been recorded in Limpopo (except for the dry northern parts and excluding the Limpopo river), North West Province (occurring in the south-east and not in the dry western parts), Northern Cape (known only from the Vaal river), Mpumalanga, Eastern cape, Western cape (along the south coast), KwaZulu-Natal (confined in the western half of the province), Free State (although there are no material records, just scattered sight records) and Gauteng.

Perennial rivers and wetlands intersecting the urban edge were buffered by 100m outside the urban edge and 32m within the urban edge. Waterbodies like Rietvlei Dam, Roodeplaat, Bon Accord, etc (not buffered) that intersected these perennial drainage lines were also included.

Targets

Using the National species targets guidelines: 11 locations to be conserved *in situ* to avoid a Vulnerable listing under the B criterion in the event that the species is subject to a decline or extreme fluctuations and at least 10 000 mature individuals to be conserved in situ to avoid a VU listing under C criterion in the event that the species is subject to extreme fluctuations.

Perennial rivers for SA from the 1:500 000 data set were extracted for the known distribution of the otter as illustrated in the image below:

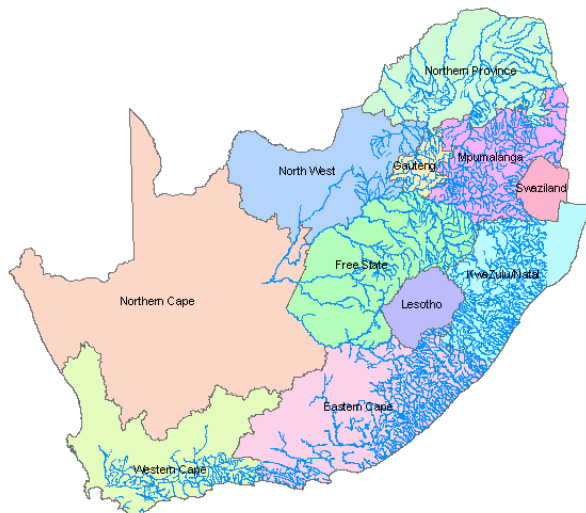


Figure 7: Known distribution of spotted-necked otter in perennial rivers for SA on 1:500 000 scale

The rivers in the illustration above were buffered by 100m outside the urban edge and 32m within the urban edge. The total area was 1 353 810ha. The new target for otter, after revision, is 1.5% for Gauteng: 20 300 ha (rounded off).

Target motivation

The target for otter, after revision, is 1.5% for Gauteng. This means we require about 150 individuals to meet the national target. I (Lihle Dimalisile) have come to a conclusion to use an estimated density of 1 otter for every 5km of river (minimum space needed by 1 individual when in open water); which results in a spatial target of 750km of water. This should be concentrated in areas of permanent water (perennial

rivers, large dams, wetlands and other permanent water bodies) – considering the areas where otter has been recorded before first. The target was calculated to be 20 300 ha.

9.4.1.4. White tailed mouse (*Mystromys albicaudatus*)

Rationale for inclusion

The white-tailed mouse is endemic to South Africa and is currently listed as Endangered (A3c). Predominantly a grassland species, but not confined to this biome, the white-tailed mouse is a low density species and is under threat from habitat fragmentation. The population is recorded as declining as a result of grazing and agricultural pressures.

Raw distribution data sources

Historical data from the Transvaal museum and data collected by GDARD staff

Distribution mapping/modeling general

Within the savanna grassland, areas with moderately dense grass cover and a sandy substrate were selected; also rocky areas with a good grass cover, concentrating in areas in which the species has been recorded before.

Distribution mapping/modeling technical

Existing confirmed points (buffered)

Circle with area of 4000 ha

Radius of 4000 ha circle is 3568 m around each confirmed point.

Result: 7152 ha in total grassland within 3568m around each historical point after patches < 100ha have been deleted.

Targets

National target: 11 locations to be conserved *in situ* to avoid a Vulnerable listing under the B criterion in the event that the species is subject to a decline or extreme fluctuations and at least 10 000 mature individuals to be conserved *in situ* to avoid a VU listing under C criterion in the event that the species is subject to extreme fluctuations.

GP target: 2000 hectares of untransformed grassland.

Target motivation

Only a small proportion of the species' natural distribution range falls within Gauteng (approximately 10%) and one viable population of 1000 individuals is therefore considered adequate to meet the national target for the species. This is a low density species and at an estimated ratio of 1 individual per 2 hectares, 2000 hectares of untransformed grassland is considered adequate.

9.4.1.5. Rusty pipistrelle/bat (*Pipistrellus rusticus*)

Rationale for inclusion (spp not included in the end – reason unknown)

The Rusty pipistrelle is known from only two discrete populations – the northern population in parts of West Africa and the southern population in Zambia and the northern parts of the southern African subregion. A savanna woodland species, it has been recorded in parts of Gauteng, Limpopo and Mpumalanga provinces. There is very little known of this species' habitat preferences and densities but they have been found in crevices of trees, under the bark of dead Acacia trees, and once in an old building, caves and other substantial shelter such as mine adits.

Raw distribution data sources

Point location data collected by GDARD staff.

Distribution mapping/modeling general

All known cave populations, with a 500m buffer.

Distribution mapping/modeling technical

All known cave populations, with a 500m buffer.

Targets

Using the National species targets guidelines: 11 locations to be conserved *in situ* to avoid a Vulnerable listing under the B criterion in the event that the species is subject to a decline or extreme fluctuations and at least 10 000 mature individuals to be conserved *in situ* to avoid a VU listing under C criterion in the event that the species is subject to extreme fluctuations.

GP target: All known roosting sites for these species to be conserved *in situ*.

Target motivation

Because the species utilizes caves for roosting, it is important to protect all known populations of the species as that also provides protection to the overall unique cave ecosystem. The species was unfortunately not included in analysis of C-Plan 3 due to an unknown reason. It is therefore of utmost importance that caves where this species occurs, be protected.

9.4.1.6. Blasius's/Peak-saddle horseshoe bat (*Rhinolophus blasii*)

9.4.1.7. Darling's horseshoe bat (*Rhinolophus darlingi*)

9.4.1.8. Geffroy's horseshoe bat (*Rhinolophus clivosus*)

9.4.1.9. Hildebrandt's horseshoe bat (*Rhinolophus hildebrandtii*)

Rationale for inclusion for all four species

With the exception of *R. blasii* which is listed as Vulnerable, these horseshoe bats are listed as Near Threatened by the South African Red Data Book for mammals (in Skinner & Chimimba, 2005). They are savanna woodland species and exclusively roost in caves. Roost sites are extremely important and sensitive as they are focal areas of activity. In addition to daily roosting they are used for hibernating, mating and rearing of young. Even minor disturbances to these roost sites can have dramatic effects on the overall bat population. *Rhinolophus* species are very specific in the environment of the caves they occupy and slight changes in temperature and humidity could deem the cave inhabitable. Climate change and human disturbance to roosting site (caves) are the biggest threats to the populations.

Raw distribution data sources

Point locality data collected by GDARD staff.

Distribution mapping/modeling general

All known cave roosting sites, including a 500m buffer.

Distribution mapping/modeling technical

All known cave roosting sites, including a 500m buffer.

Targets

National target for *R. blasii*: 100% of available habitat; GP target: 100% of available habitat. Using the National species targets guidelines: 11 locations to be conserved *in situ* to avoid a Vulnerable listing under the B criterion in the event that the species is subject to a decline or extreme fluctuations and at least 10 000 mature individuals to be conserved *in situ* to avoid a VU listing under C criterion in the event that the species is subject to extreme fluctuations.

GP target: 100% of known roosting sites.

9.4.1.10. Scheiber's long-fingered bat (*Miniopterus schreibersii*)

Rationale for inclusion

The Schreiber's long-fingered bat is listed as Near Threatened in the South African Red Data Book for Mammals (in Skinner & Chimimba, 2005). The species is a cave dweller and the availability of caves or other substantial shelter such as mine adits is an essential habitat requirement. The species occurs in immense colonies with numbers reaching up to 300 000. Roost sites are extremely important and

sensitive as they are focal areas of activity. In addition to daily roosting they are used for hibernating, mating and rearing of young. Even minor disturbances to these roost sites can have dramatic effects on the overall bat population. The species' roosting sites can be negatively affected by the climate change, which may result in some of the caves being inhabitable. Cave destruction by human activities is also a huge threat to their survival.

Raw distribution data sources

Data collected by GDARD staff.

Distribution mapping/modeling general

Habitat: All caves with a 500m buffer.

Confirmed: All known populations with a 500m buffer around caves.

Distribution mapping/modeling technical

All known populations with a 500m buffer around caves.

Targets

Using the National species targets guidelines: 11 locations to be conserved *in situ* to avoid a Vulnerable listing under the B criterion in the event that the species is subject to a decline or extreme fluctuations at least 10 000 mature individuals to be conserved *in situ* to avoid a VU listing under C criterion in the event that the species is subject to extreme fluctuations.

GP target: All known roosting sites for this species to be conserved *in situ*.

Target motivation

The species occurs in large numbers and they are cave dwellers, it is important to protect all known populations of the species as one single event could affect the entire population; also all cave dwelling bat species are ambassadors for the conservation of cave ecosystems and must be provided adequate protection.

9.4.1.11. Temminck's hairy bat (*Myotis tricolor*)

9.4.1.12. Welwitsch's hairy bat (*Myotis welwitschii*)

Rationale for inclusion for both species

Listed as Near Threatened by the South African red Data Book for mammals, the Temminck's hairy bat's distribution is not well documented as very few and scattered recordings of the species are available. The Welwitsch's is also listed as Near Threatened. Both species are savanna woodland species and roost in caves. Roost sites are extremely important and sensitive as they are focal areas of activity. In addition to daily roosting they are used for hibernating, mating and rearing of young. Even minor disturbances to these roost sites can have dramatic effects on the overall bat population. Roosting sites are threatened by climate change and human disturbance. Refer to Skinner & Chimimba, 2005.

Raw distribution data sources

Data collected by GDARD staff.

Distribution mapping/modeling

All known populations with a 500m buffer around caves.

Targets

Using the National species targets guidelines: 11 locations to be conserved *in situ* to avoid a Vulnerable listing under the B criterion in the event that the species is subject to a decline or extreme fluctuations and at least 10 000 mature individuals to be conserved *in situ* to avoid a VU listing under C criterion in the event that the species is subject to extreme fluctuations.

GP target: All known roosting sites for these species to be conserved *in situ*.

Target motivation

Because the two species use caves for roosting, it is important to protect all known populations as this also provides protection to the overall unique cave ecosystem.

9.4.2. Species excluded from C-Plan 3

African marsh rat (*Dasymys incomtus*)

The African marsh rat is listed as Near Threatened by the South African Red Data Book (in Skinner & Chimimba, 2005) and is confined to marshland. It is associated with reedbeds and semi-aquatic grasses throughout its known distribution, is dependent on open water and occurs in very low densities. The biggest threat to the survival of the African marsh rat is the destruction of the aquatic habitats through extraction of water for agricultural purposes.

Reason for exclusion from C-Plan 3

Due to lack of information on the distribution of this species, the raw occurrence data for *Otomys* sp. collected during Gap surveys by GDARD was initially considered to be used for a habitat model for African marsh rat as the two species share the same habitat requirements. After some more consideration, discussion and more searching on the Water (African marsh) rat, I (L Dumasile June 28, 2010 – pers. comm.) have decided to exclude it for C-plan 3. This because there is very little information available regarding this species and we don't have any confirmed points for it in the province. A reliable target could not be set because of the lack of information and point locality data. The species is semi-aquatic (occurs next to wetlands, rivers and other aquatic bodies) and these are being afforded protection by C-plan; so the species is afforded protection although not flagged.

9.5. Fish – Maloney's Eye sub-catchment (Siyabonga Buthelezi)

Side stream around Maloney's Eye contain three unique fish species naturally intolerant to changes in flow; has high invertebrate species diversity; contains unique habitats. These fish species are:

- Lowveld Largescale yellowfish *Labeobarbus marequensis*;
- Bushveld Smallscale Yellowfish *Labeobarbus polylepis*; and
- Mountain catfish *Amphilius uranoscopus*.

Maloney's Eye has unique habitat and taxa, and therefore, low impact catchment management around the eye is required. This includes the assessment and management of groundwater linkages. (This info is from the SoR Report that Piet Muller and others produced.)

Threats include water abstraction (both ground and surface), overharvesting, presence of alien fish invaders and habitat modification. However, there are plans to address these, and habitat modification, which is mostly smothering of spawning habitats for the Yellows, will be addressed by GDARD and SANBI: WfWet. Reserve determination will need to be done urgently, and compliance monitoring (by DWA) strengthened. Although fish barriers, such as weirs are generally not recommended, in this case they may be left as they seem to prevent migratory movement of alien fish invaders; and each reach has suitable spawning habitat for these species, especially the Yellows.

Target

Maloney's Eye sub-catchment was digitized on-screen including three streams where indigenous fish species occur. The target was set to 100%.

9.6. Herpetofauna (Gavin Masterson)

9.6.1. Species included in C-Plan 3

Striped Harlequin Snake (*Homoroselaps dorsalis*)

The Striped Harlequin Snake (*Homoroselaps dorsalis*) is distributed from Limpopo through Mpumalanga, Gauteng, the Free State, KwaZulu-Natal and even occurs in Swaziland. Records of *H. dorsalis* are very infrequent giving the species' distribution a patchy and disjointed appearance. The species was listed as Rare in Branch (1988) and will probably be listed as Near Threatened in the revision of the red list (Burger, in press).

Gauteng represents approximately 10 % of the total extent of occurrence for the species, meaning 10 % of 11 populations need to be protected in Gauteng in order to prevent *H. dorsalis* from becoming listed as Vulnerable, which is effectively 1 population. *Homoroselaps dorsalis* occurs in close proximity to the Egoli Granite Grassland (EGG) Nature Reserve, and if it is found there during surveys or by chance encounters, the local population should also be protected but the recommended minimum target is the protection and conservation of the Suikerbosrand Nature Reserve population.

The model of suitable habitat for *H. dorsalis* within Suikerbosrand Nature Reserve is based on the observations of *H. dorsalis* and the Spotted Harlequin Snake (*H. lacteus*) within the reserve during the past five years. Four Harlequin Snakes (2 *H. dorsalis* and 2 *H. lacteus*) have been recorded in Suikerbosrand since 2006. All of the records have occurred on land type Ib43 (Land Type Survey Staff, 2006) and all records were associated with ridges or ridge slopes with a soil-rock mix and low clay content (< 35 %). In the literature, Broadley (1983), Branch (1998) and Marais (2004) all indicate that the current knowledge of *H. dorsalis* habits and habitat is based on the assumption that it is similar to the more widely distributed and better known Spotted Harlequin Snake (*H. lacteus*). Branch (1998) indicates that *Homoroselaps* spp. are typically found under rocks and burrowing in loose soil.

The total area of the land type is 12 000 ha, meaning that if we assume a patchy occupancy that results in a density of 1 *H. dorsalis* individual per 10 ha (i.e. very low densities) we would be conserving a population of 1 200 individuals, thereby exceeding the requirement for the protection of at least 1000 individuals in this one locality. The protection of *H. dorsalis* in Suikerbosrand Nature Reserve, Sedibeng District Municipality will meet the conservation targets for the species in Gauteng.

Target

The target for the species is 100 % of suitable habitat.

9.6.2. Species excluded from C-Plan 3

Rationale for removal of herpetofaunal species from C-Plan 3

Giant Bullfrog (*Pyxicephalus adspersus*)

The Giant Bullfrog (*Pyxicephalus adspersus*) was listed as Near Threatened in South Africa, Lesotho and Swaziland by du Preez and Cook (2004) and included in C-Plan v. 2. The rationale for the listing of *P. adspersus* was based on evidence that the species was declining in parts of its range, particularly in Gauteng, due to extensive crop agriculture and industrial and urban development (du Preez and Cook, 2004; du Preez and Carruthers, 2009). In certain parts of Gauteng, it is estimated that there have been declines of up to 80 % in *P. adspersus* numbers (du Preez and Cook, 2004) but data on declines are restricted to a few localities that have undergone severe habitat transformation. Globally, *P. adspersus* is Least Concern (du Preez and Cook, 2004) and does not therefore merit inclusion in C-Plan 3 as a species layer.

C-Plan 3 targets for *P. adspersus* are the same as they are for any Least Concern species i.e., protection that is sufficient to prevent an increase in the threat status of the species. The targets for *P. adspersus* will be met using provincial protected areas and the protection of important habitat i.e., pans and wetlands. Records of *P. adspersus* are known for five of the six provincial protected areas, but the best habitat for *P. adspersus* is found in Abe Bailey Nature Reserve, Merafong City Municipality and Leeuwfontein Collaborative Nature Reserve, Nokeng tsa Taamane Local Municipality.

For pans, the addition of a pan layer in C-Plan 3 means that the catchments of pans that are not severely transformed will be prioritised for protection from habitat transformation, particularly urban and industrial development. Priority catchments also play an important role in *P. adspersus* and indeed all amphibian conservation in Gauteng, as they are given a greater degree of protection in C-Plan 3. Wetlands are still a priority for protection in C-Plan 3 and their protection plays an important role in the reproduction and movement of the in areas such as Diepsloot, City of Johannesburg Municipality. In summary, targets for *P. adspersus* in C-Plan 3 are the same as for all globally Least Concern species, and will be met using the protected area network, the protection of wetlands, pans and the priority catchments.

Southern African Python (*Python natalensis*)

The Southern African Python (*Python natalensis*) was listed as Vulnerable by Branch (1988) and included in C-Plan v. 2. The recent revision of the red list status of *P. natalensis* during the Southern African Reptile Conservation Assessment (SARCA) will lead to a listing of Least Concern (Alexander, in press). As with the Giant Bullfrog (*Pyxicpehalus adspersus*), the species no longer warrants specific consideration of its conservation in C-Plan 3, but must be protected by habitat protection. The difference is that *P. natalensis* does not occur throughout Gauteng Province, as it reaches a range edge that appears to be related to high altitude (Alexander, 2007). Suitable habitat for *P. natalensis* in Gauteng is found in the Metsweding District Municipality in north-eastern Gauteng. The species occurs in two of the provincial protected areas in Metsweding i.e., Leeuwfontein Collaborative Nature Reserve, Nokeng tsa Taemane Local Municipality (Whittington-Jones et al., 2008) and Roodeplaat Dam Nature Reserve, Kungwini Local Municipality (Masterson et al., in press). The species is also known to occur in Tswaing Nature Reserve, City of Tshwane District Municipality and in the West Rand District Municipality in and around the Magaliesberg Mountains.

Habitat protection in the provincial protected area network and the prevention of urban sprawl are two of the key mechanisms for protecting the populations of *P. natalensis* still extant in Gauteng. The recent breeding of *P. natalensis* in Roodeplaat Dam Nature Reserve (Masterson et al., submitted) is a positive sign for the future of the species in Gauteng but the species does need to be considered a candidate for protection via stewardship agreements and incentives. These fall beyond the scope of C-Plan 3 however and the species has thus been removed as a specific layer.

9.7. Pan clusters

9.7.1. Pans within near-pristine quaternary catchments

Pans occurring within near-pristine quaternary catchments that remained after “ground truthing” with Quickbird and land cover buffered with 1km.

Target

Pan clusters within PQ4s were included into C-plan 3 as a feature with a 100% target.

9.7.2. Good quality Pans

The benchmark for transformation is 40% urban development (see paragraph on “Establishing rate of transformation for pans” below) within the pan catchment (pans buffered by 1 km). Good quality pans that were prioritized by the bird specialist were included in C-Plan 3 with a buffer of 1 km (20 pans selected).

Target

The target for good quality pan clusters is 100%. The remaining pans were included in the ESAs (see paragraph on this later in this document).

Establishing rate of transformation for pans

- Buffer pans with 1 km into pan clusters.
- Clip to Gauteng boundary.
- Reclassify land classes from land cover 2009 developed by GTI extracted by using the pan cluster file as a mask into class 1 (natural), class 551 (cultivated), class 561 (old land) and class 9999 (transformed) as illustrated in the table below:

Table 6: Reclassifying land cover 2009 to establish rate of transformation of pans

| Gridcode | Name | Group |
|--|---|-------------|
| 1 | Dense Trees / Bush | Natural |
| 2 | Woodland / Open Bush | Natural |
| 3 | Wooded Grassland | Natural |
| 4 | Grassland | Natural |
| 5 | Degraded | Natural |
| 6 | Non-Vegetated / Bare | Natural |
| 7 | Natural Bare Rock | Natural |
| 8 | Rocky Grass Matrix | Natural |
| 11 | Urban Woodland | Natural |
| 12 | Urban Grass | Natural |
| 13 | Natural Water | Natural |
| 15 | Wetland (non pan) | Natural |
| 16 | Wetland Pans | Natural |
| 24 | Smallholdings: Dense Trees / Bush | Natural |
| 25 | Smallholdings: Woodland / Open Bush | Natural |
| 26 | Smallholdings: Wooded Grassland | Natural |
| 27 | Smallholdings: Grassland | Natural |
| 550 551 was: 17-19,29 561 was: 30-41 | Cultivated Land Old Lands (including degraded & Non-Vegetated / Bare) | Natural |
| 9999 was: 9,10,14, 20-23,28 | Plantation & Woodlot, Urban Trees, Man-made Water, Intensive Cattle Camps, Urban, Mines, Sports & Recreation Grassland, Smallholdings: Degraded | Transformed |

- Convert the result to a shapefile (not generalized).
- Capture a unique ID for each cluster (pans buffered by 1 km) and calculate the area. (58 and 70 became one cluster after verification. Used 58. 70 not to be used again.)
- Union the shapefile containing reclassified land cover with pan clusters.
- Remove areas that do not coincide (slivers are produced by circled buffering of pans and square cells of land cover raster data [GRIDCODE = 0; "FID_pan_gd" = -1 – delete both).
- Union the result with excluded areas digitized for C-Plan 3 (the latter will not be considered by C-Plan analyses, so there is no use keeping them in the final pan cluster file). Add a new field for gridcodes that will be reclassified (the original gridcode is kept for information).
- If an area was excluded or had the gridcode 9999 (transformed) a new gridcode 8888 was allocated. Cultivated land and old lands were given code 500.
- Dissolve the shapefile using cluster_id, cluster_ha and group (new gridcode field).
- Add field for Group category and populate with "Natural", "Cultivated/Old land" and "Transformed".
- Calculate areas.
- Open the shapefile's dbf and save it to an Excel spreadsheet

- n. Make a back-up worksheet for safety
- o. Do a pivot table (row field = Cluster_ID, column field = gridcode, data item = ha per gridcode. For Q4 use (row field = Q4, column field = gridcode, data item = ha per gridcode (land cover per Q4)
- p. Insert a new worksheet and copy results. Save the file as dbf.
- q. In ArcMap, in the original pan cluster (buffered by 1 km) put in a fields for "Natural", "Cultivated/Old land" and "Transformed.
- r. Link original pan cluster to dbf file with statistics and capture information above.
- s. Calculate percentage of transformation.

Reasoning on transformation

Gauteng does not have many truly undisturbed pans and the ones surrounded by agriculture are often in the best condition relative to others. While cultivation does impact on the biodiversity of a pan as it affects hydrology, nutrient availability, foraging habitat for semi-aquatic species and connectivity between pans amongst other things, there are pans in areas that are actively cultivated that still support a diversity of amphibians and an abundance and diversity of birds and thus do merit conservation attention. Therefore while agriculture is considered to be a disturbance, it is a comparatively low disturbance with a potential for restoration of secondary grassland. In conclusion it was recommended that pans not be excluded from consideration unless the pan surface itself has been ploughed (Dr Craig Wittington-Jones: *pers. comm.*). Agriculture was therefore not included as part of urban development to establish "good quality" pans.

9.8. Near-pristine Quaternary Catchment

Near-pristine Quaternary Catchments (PQ4s) were part of the ecological processes (ESAs in C-Plan 3) layer in C-Plan 2. In C-Plan 3 it is included as part of biodiversity features used in analysis to establish CBAs. PQ4s include: Wilge-, Skeerpoort-, Upper Suikerbosrant- and Elands River Quaternary Catchments.

Target

Based on analyses to determine transformation of the above PQ4s targets were set as follows:

- a. For maintaining rivers in a **B state definition??** (Ecological Category): at least 59% of the quaternary catchment must remain untransformed (i.e. 59% of catchments making up the Skeerpoort, Elands and Wilge). B state rivers are defined as follows by Kleynhans & Louw (2008): "Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged".
- b. For maintaining rivers in a **C state** (Ecological Category): at least 46% of the quaternary catchment must remain untransformed (i.e. 46% of catchments making up the Upper Suikerbos). C state rivers are defined as follows by Kleynhans & Louw (2008): "Moderately modified. Loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged"

9.9. Bioclimatic zones

A layer was prepared based on environmental parameters such as altitude, slope, aspect, geology to identify areas that contain unique bioclimatic classes. The result was analysed by Dr Stephen Holness at NMU using MARXAN to establish unique bioclimatic zones as input for C-Plan 3. The method followed is discussed in the following paragraphs.

9.9.1. Preparation of input for MARXAN analyses

- a. Created a DEM from SRTM90 using a 200 m cell size for Gauteng.
- b. Created raster layers for the following environmental parameters:

- i. altitude (200m interval, 5 classes below)

| Code | Altitude |
|------|-------------|
| 1 | 930 - 1100 |
| 2 | 1100 – 1300 |
| 3 | 1300 – 1500 |
| 4 | 1500 – 1700 |
| 5 | 1700 – 1909 |

- ii. slope (4 classes below)

| Code | Description | Degrees |
|------|-------------|---------|
| 1 | Flat | 0 – 2 |
| 2 | Gentle | 2 – 5 |
| 3 | Moderate | 5 – 7 |
| 4 | Steep | >7 |

- iii. aspect (5 classes below)

| Code | Aspect Value | Description |
|------|------------------|-------------|
| 1 | 315 – 359.851959 | North |
| 1 | -0.01 - 45 | North |
| 2 | 45 - 135 | East |
| 3 | 135 -225 | South |
| 4 | 225 - 315 | West |
| 9 | -1 - -0.01 | Flat |

- iv. Geology (AGIS data, 21 classes below). Although unions will be done using shapefiles, the geology was rasterized first to enable coinciding boundaries with other rasters converted to shapefiles to reduce number of unique classes in the result.

| Code | Description |
|------|--|
| 1 | Andesite |
| 2 | Arenite |
| 4 | Clinopyroxenite |
| 5 | No data in the field – may be dam or wetland |
| 6 | Dolerite |
| 7 | Dolomite |
| 8 | Dunite |
| 9 | Gabbro |
| 10 | Gneiss |
| 11 | Granite |
| 12 | Harzburgite |
| 13 | Lutaceous Arenite |
| 14 | Migmatite |
| 15 | Mudstone |
| 16 | Norite |
| 17 | Quartzite |
| 18 | Rhyolite |
| 19 | Sedimentary |
| 20 | Shale |
| 21 | Syenite |
| 22 | Tillite |

- c. Converted altitude, slope, aspect and geology to shapefiles.
d. Did a union between altitude and aspect
e. Did a union between the result and geology
f. Did a union between the result and slope
g. Modified field names and populated with gridcodes derived from raster grids.
h. The result was finally prepared for MARXAN analyses done by Dr Stephen Holness (MARXAN Prioritization of Bioclimatic data layers) as follows:

- i. Clipped the bioclimate & ridges layers back to the GP boundary (planning domain)
- ii. Dissolved bioclimate layer on combination of unique fields (altitude, aspect, geology, slope and id)
- iii. Buffered ridges by 200m, 500m and 1km
- iv. Clip the buffered ridges back to GP again
- v. Dissolved each of the 4 ridge files
- vi. Intersected the bioclimate layer with each of the results in v.
- vii. Dissolved each of the results in vi. on the bioclimatic combination of unique fields

Results:

- Number of unique bioclimate classes in planning domain: 992. Area: 1 817 831 ha.
- Number of unique bioclimate classes contained within ridges: 873. Area: 235 358 ha.
- Number of unique bioclimate classes contained within ridges buffered with a 200m buffer zone: 896. Area: 352 763 ha.
- Number of unique bioclimate classes contained within ridges buffered with a 500m buffer zone: 910. Area: 499 607 ha.
- Number of unique bioclimate classes contained within ridges buffered with a 1km buffer zone: 925. Area: 693 711 ha.

Discussion:

Michele Pfab:

"These results are very interesting. Of the unique bioclimatic classes in Gauteng, 88% of them are represented on the ridges and koppies/hills of the province. When the adjacent flat areas are included in the calculation by way of buffering the ridges with 200m, 500m and 1km, 90%, 92% and 93% respectively of the unique bioclimatic classes in the province are represented. This makes complete sense. One of the motivations for conserving ridges/hills is that they are characterized by a diversity of microclimatic conditions due to the diversity of slopes, aspects, altitudes etc. As such, they can be regarded as a hotspot for evolutionary processes – "biodiversity factories". This was all contained in the ridges policy I drafted for Gauteng. The calculations Pieta Compaan has performed above demonstrate that the ridges are also very important for adaptation to climate change.

So, I think the best way to include the bioclimatic layer into the conservation plan is to buffer all the ridges/hills with 500m and include this as a cost surface into the site selection process, i.e. preferentially select sites from ridges and within 500m thereof. Just another way we would be planning for climate change."

Dr Stephen Holness:

"I really like your bioclimatic layer. What I have managed to do is produce a more efficient solution than including the buffered ridges (similar number of variables represented in far smaller area). I think it makes better use of the bioclimatic layer."

Decision

Based on expert opinion of Dr Holness, it was decided to include bioclimatic zones as a biodiversity feature for analysis to establish CBAs for C-Plan 3. Dr Holness used the input layer created above and ran different MARXAN analysis on it to create the final layer. Below are metadata received from him:

9.9.2. MARXAN analyses (Dr S Holness - sholness@nmmu.ac.za)

9.9.2.1. Shapefiles:

MARXAN Bioclimate all options.shp
 MARXAN optimal efficient basket.shp
 MARXAN optimal big basket.shp
 MARXAN single solutionb.shp
 MARXAN Optimal Efficient Outside Urban.shp

9.9.2.2. Original data:

The layers were developed based on the following underlying data layers created by Michelle Pfab and Pieta Compaan of GDARD:

- bioclimatic_gp_diss_200_1006_al24.shp - a stratification of Gauteng into areas of probable different bioclimatic attributes based on altitude, aspect, geology and slope. 992 classes are identified.
- CP3_Excluded_Areas_100423_al24.shp – transformed areas of Gauteng which are not available to the conservation plan.
- Ridge_v61_gp_diss_100601_al24.shp – identified ridges in Gauteng.
- Urban_Edge_2007_v5_al24.shp - areas within the urban edge. These areas were excluded from a final additional run.

Refer to the descriptions and metadata of these layers for additional information.

9.9.2.3. Analysis method:

The analysis was aimed at identifying priority areas for representing the range of bioclimatic variables found in the province was undertaken in a MARXAN conservation planning environment.

Targets:

Targets were set 10% of the original extent of each of the 992 bioclimatic variables. In addition a 30% target was set for ridge areas based on their original extent.

Areas available for selection:

The bioclimatic variable layer and the ridges layer were clipped to exclude transformed areas. Only remaining intact areas were made available for selection. 978 of the bioclimatic variables remain after the exclusion of transformed areas. In an additional final run, areas within the urban edge were excluded.

Planning units:

100 ha hexagon were used as the planning units.

Boundary lengths:

The boundary lengths between planning units were calculated in meters.

Cost surface:

The base cost used was 1 unit per hectare for intact areas. Transformed areas were given a cost of 100 units. The overall cost for a hexagon planning unit was calculated as an area weighted mean of these base costs multiplied by the number of hectares. This allowed transformed areas to be strongly avoided unless they were absolutely required to meet targets. These values were derived from a series of trial runs.

MARXAN technical specifications:

The final MARXAN run was undertaken with the following specifications:

Boundary length modifier:

BLM 2 – to encourage a moderate level of clumping of selected planning union rather than a shotgun effect of selected sites. This value was determined by repeating MARXAN runs with increasing BLM values until the efficiency of the solutions were compromised – i.e. significant additional areas were required beyond those needed to meet representivity targets.

SPF value:

1 000 000 – a high SPF value was used to force selection of areas to meet targets for all features.

Runs:

500 runs of 1 000 000 iterations were used

Exclusions:

Areas within the urban edge were excluded from a final run.

Final steps:

The outputs of the final MARXAN run were clipped to the remaining natural areas. Various shapefiles (explained later) were created of the various potential solutions. These solutions are evaluated below.

9.9.2.4. Evaluation:

Benchmark:

The following two benchmarks were used for comparison:

- The ridge layer buffered by 500m which includes areas with representivity of 92% of the Bioclimatic Variables. The total area is 499 370ha.
- The ridge layer only with representivity of 88% of the Bioclimatic Variables in 235 246ha.

Analysis of Marxan Outputs:

The MARXAN analysis identified a more efficient set of spatial priorities for representing the range of bioclimatic variables present in the province (Table 7 and Figure 8). In addition a separate run which excludes urban areas was produced.

Table 7: Efficiency of MARXAN outputs

| Run name | scr50 | scr100 | scr150 | singlebest | scr200 | scr250 | scr300 | scr350 | scr400 | scr450 | scr500 | Urban excluded |
|---|--------|--------|--------|------------|--------|--------|--------|--------|--------|--------|--------|----------------|
| Area required (ha) | 830697 | 581932 | 340979 | 278082 | 176278 | 93134 | 51447 | 33874 | 21711 | 13590 | 7582 | 78829 |
| Representivity (# Bioclimatic variables) | 977 | 977 | 977 | 977 | 977 | 965 | 928 | 863 | 810 | 728 | 638 | 905 |
| Percent of possible representivity achieved | 99.9 | 99.9 | 99.9 | 99.9 | 99.9 | 98.7 | 94.9 | 88.2 | 82.8 | 74.4 | 65.2 | 92.5 |
| Percent of total representivity achieved | 98.5 | 98.5 | 98.5 | 98.5 | 98.5 | 97.3 | 93.5 | 87.0 | 81.7 | 73.4 | 64.3 | 91.2 |

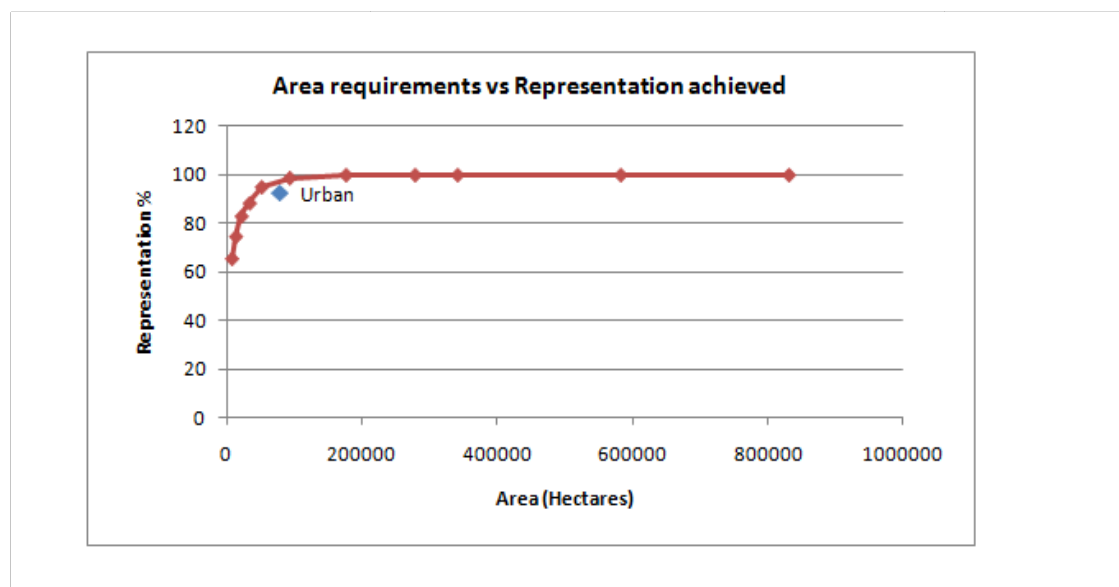


Figure 8: Efficiency of MARXAN outputs.

The MARXAN modeling process could achieve spatial efficiencies significantly better than using either the ridges or the ridges buffered by 500m as a unit to represent bioclimatic variability. For example, selection of areas with a MARXAN selection frequency of over 350 times out of 500 gives an area with representivity of 88% of the maximum possible or 863 bioclimatic variables (i.e. similar to the ridges

benchmark) but in an area of 33874 ha or around 15% of the area required by the “ridge proxy”. The selection of areas with a MARXAN selection frequency of over 400 times out of 500 gives an area with representivity of 83% of the maximum possible or 810 bioclimatic variables (i.e. similar to the ridges plus 500m buffer benchmark) but in an area of 21 711 ha or around 4.5% of the area required by the “ridge plus buffer proxy”. The identified areas are also selected to favour connected adjacent areas where possible, and hence the sites are both efficient and located in a configuration which is ecologically reasonable (Note: The ridges proxy is also ecologically reasonable, just not as spatially efficient).

Examination of the MARXAN outputs suggest that the selection of additional planning units with lower MARXAN scores (a selection frequency of 200 or less per 500 runs), results in no increase in representivity (although the full 10% target of the different bioclimatic variables is fully met for more variables) while the area required increases from 176 278ha to 830 697ha.

Four potential “good solutions” are highlighted and presented as separate shapefiles.

- The MARXAN Optimal Efficient Basket.shp is a set of areas that have a selection frequency of 300 or more out of 500 runs. This solution covers 51 447ha and includes representivity of 928 Bioclimatic Variables or 94.9% of the possible.
- The MARXAN Optimal Bigger Basket.shp is a set of areas that have a selection frequency of 250 or more out of 500 runs. This solution covers 93 134ha and includes representivity of 965 Bioclimatic Variables or 98.7% of the possible.
- The MARXAN Single Solutionb.shp is the best single solution out of the 500 runs. This solution covers 278 082ha and includes representivity of 977 Bioclimatic Variables or 99.9% of the possible. This solution is however spatially not very efficient if the objective is to meet represent the range of Bioclimatic Variables in a small area. It nevertheless represents a well linked set of area to meet the full targets for variables in a ecologically sensible manner.
- The MARXAN Optimal Efficient Outside Urban.shp is a set of areas that have a selection frequency of 300 or more out of 500 runs. This solution covers 78 829ha and includes representivity of 905 Bioclimatic Variables or 92.5% of the possible. This version completely avoids urban areas.

9.9.2.5. Recommendation for inclusion in CPLAN 3:

Quote from Dr S Holness: *“I would suggest that one of the following is used: the MARXAN Optimal Efficient Basket.shp areas are used as a feature in the conservation plan with a high target; or that MARXAN Optimal Bigger Basket.shp are used as features with a lower target; or that MARXAN Optimal Efficient Outside Urban.shp with a high target. The choice between the layers will depend entirely on what in fits in best with other biodiversity features and what is feasible from an implementation perspective. The MARXAN Optimal Efficient Outside Urban run is significantly less spatially efficient than the other two favored options, but this is probably fully offset by the selection of areas with lower prospect for conflict. This is preferable to incorporating the layers into a cost surface. These areas represent highly important areas for climate change adaptation and are fairly small parts of the province. I don’t really like the MARXAN Single Solution.shp as it is not particularly efficient, but nevertheless it may be appropriate for inclusion either as a feature or as part of a cost surface.”*

9.9.2.6. Layers and fields:

MARXAN Bioclimate all options.shp

This layer provides a summary of the selection of planning units for the runs summarized above. In all cases, a “1” indicates that that planning unit is selected during that run, while a “0” indicates that that planning unit is not selected.

Fields:

- scr50 – Selected in 50 or more runs per 500.
- scr100 – Selected in 100 or more runs per 500.
- scr150 – Selected in 150 or more runs per 500.
- scr200 – Selected in 200 or more runs per 500.

scr250 – Selected in 250 or more runs per 500.
 scr300 – Selected in 300 or more runs per 500.
 scr350 – Selected in 350 or more runs per 500.
 scr400 – Selected in 400 or more runs per 500.
 scr450 – Selected in 450 or more runs per 500.
 scr500 – Selected in 500 or more runs per 500.
 Singlebest – Selected in the single best run.

MARXAN optimal efficient basket.shp

This layer provides a summary of the selection of planning units in the “optimal efficient” solution. A “1” indicates that that planning unit is selected during that run, while a “0” indicates that that planning unit is not selected.

Fields:

scr300 – Selected in 300 or more runs per 500.

MARXAN optimal big basket.shp

This layer provides a summary of the selection of planning units in the “optimal bigger basket” solution. A “1” indicates that that planning unit is selected during that run, while a “0” indicates that that planning unit is not selected.

Fields:

scr300 – Selected in 250 or more runs per 500.

MARXAN single solutionb.shp

This layer provides a summary of the selection of planning units in the “best single solution” MARXAN run. A “1” indicates that that planning unit is selected during that run, while a “0” indicates that that planning unit is not selected.

Fields:

Singlebest – Selected in the single best run.

MARXAN Optimal Efficient Outside Urban.shp

This layer provides a summary of the selected planning units in the MARXAN run that excludes areas within the urban edge. It is otherwise identical in cutoffs and input parameters to the Optimal efficient Run. A “1” indicates that that planning unit is selected during that run.

Fields:

Extra – Selected in the single best run.

9.9.3. Final decision on bioclimate zone layer

It was decided to include the result for “Optimal efficient basket outside urban edge” as a biodiversity feature in C-plan 3 with a high target after Dr Holness redid the Marxan analysis by excluding areas within the urban edge.

Target

As there were a fair overlap between the areas identified in the Marxan exercise executed by Dr S Holness and either the biodiversity features and/or the ridges and also because the feature covered a relatively small area (4.3% of the province) it was regarded as a safe measure to go with a target of 90%.

9.10. Carbon sequestration: Woodland (Mesic / Scarp)

Carbon sequestration refers to the removal and storage of carbon from the atmosphere in carbon sinks (such as oceans, forests or soils) through physical or biological processes, such as photosynthesis (<http://www.greenfacts.org/glossary/abc/carbon-sequestration.htm>). In Gauteng there are no real forests,

so it was decided to use wooded areas occurring on steep slopes and in steep ravines for and input layer for C-Plan 3. These areas are not only a carbon store but an extremely rare vegetation type in Gauteng with unique biodiversity attributes (with potentially rare species or at least species that are rare in Gauteng, maybe even species that are at the limits of their distribution and therefore unique genetically – advantageous for adaptation to climate change (Pfab, 2010, *pers. comm.*)). The layer was created as follows:

Created a model that identified areas with all of the following features:

- 1) Ridge areas in the Magaliesberg, Suikerbosrand and in the Dinokeng area.
- 2) Very steep slopes (i.e. the steepest slopes in each of these areas; forests are usually located in steep ravines)
- 3) South facing slopes (forests usually on the south facing slopes)

Overlaid the results of this model with the Quickbird imagery to locate woodland patches. These patches (treed areas with a closed canopy (i.e. no gaps between the trees) were digitized and evaluated by David Hoare and amended where necessary.

Target

The following woodland areas were included with a 100% target after excluded areas digitized for C-Plan 3 were removed:

- Suikerbosrand Mesic Woodland
- Dinokeng Scarp Woodland
- Magaliesberg Scarp Woodland
- Wilge Scarp Woodland

9.11. Primary Vegetation

A new vegetation map using many years of releve data collected by GDARD in the province was developed for Gauteng by David Hoare, Michele Pfab, Lorraine Mills and Pieta Compaan (who aided with GIS work) in 2010. The map is quite similar to the existing SA vegmap, the major difference being the absence of Egoli Granite Grassland and Tsakane Clay Grassland (both soon to be published Threatened Ecosystems). The map still in beta format and is expected to be published in a local scientific journal by the end of 2011. More information on the vegetation map may be obtained from David Hoare at dbhoare@iburst.co.za and Michele Pfab at Pfab@sanbi.org.

The final vegetation map was intersected with a primary (untransformed) vegetation layer that was derived from untransformed grassland, woodland and wetlands extracted for GTI land cover 2009 (as well as GDARD and metro wetlands from Dr Stephen Hollness).

The vegetation layer and final input for C-Plan 3 were created as follows:

9.11.1. Vegetation modelling

1. Environmental envelope models were constructed by P Compaan in ArcGIS 9.3.1 for each of the 11 vegetation communities created by Hoare, Pfab and Mills (unpublished) to identify all areas of the province where environmental conditions are similar to the environmental conditions at the location of relevés representing each vegetation community. Environmental attributes included in models were as follows:

- *Average topsoil clay content
- *Average soil depth
- *Terrain unit
- *Long term mean annual rainfall
- *Long term mean maximum annual temperature
- *Long term mean minimum annual temperature
- *Land type
- Geology (from AGIS)

Slope (derived from the 90m SRTM DEM)

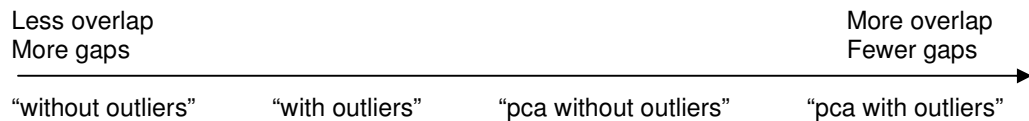
Altitude (derived from the 90m SRTM DEM)

** All climate and soil related data were obtained from ISCW.*

Four sets of the above environmental models were constructed:

- i. Using approximate* absolute minimum and maximum values for continuous environmental data (long term mean annual rainfall, long term mean maximum annual temperature, long term mean minimum temperature, slope and altitude) and all categories associated with relevés for categorical data. (designated: "with outliers")
- ii. Using minimum and maximum values calculated as the average \pm standard deviation for continuous environmental data (long term mean annual rainfall, long term mean maximum annual temperature, long term mean minimum temperature, slope and altitude), while for categorical data, categories were excluded from the model if they were represented by only one relevé and the relevé was located near the edge of an area assigned to that particular category. (designated: "without outliers")
- iii. Same as models in (a) but including principal components only – rainfall, minimum temperature, altitude. (designated: "pca with outliers")
- iv. Same as models in (b) but including principal components only – rainfall, minimum temperature, altitude. (designated: "pca without outliers")

**Average difference between values for relevés calculated and added or subtracted from absolute maximum or minimum to get approximate maximum and minimum values.*



2. Resulting models for vegetation communities 1 to 11 unioned into one layer for each model set (a), (b), (c) and (d).
3. Map built for each unioned model set (a), (b), (c) and (d), as follows:
 - i. All areas where there were no overlaps selected, i.e. all areas modeled as only one of the 11 vegetation communities.
 - ii. Remaining areas sorted from largest to smallest. All large areas (>800ha) examined and where there was an overlap of only two modeled vegetation communities, the most likely vegetation community chosen based on (1) the classification of the associated relevés if present or (2) the neighbouring vegetation community designated in step (i) above.
 - iii. All relevés located within areas where three or more modeled vegetation communities overlap examined and most likely vegetation community chosen based on the dominant classification of the associated relevés.
4. Final maps for model set (a), (b), (c) and (d) unioned into one layer.
5. Final map built as follows:
 - i. All areas where all model sets agreed selected and relevant vegetation community assigned.
 - ii. Remaining areas sorted from largest to smallest. All large areas (>800ha) examined and where there was an overlap of only two modeled vegetation communities, the most likely vegetation community chosen based on (1) the classification of the associated relevés if present and/or (2) the neighbouring vegetation community designated in step (i) above and/or (3) the best fit model set overall and the best fit model set for that

- particular vegetation community (Overall, the best fit model set was “with outliers”, followed in order by “pca without outliers”, “pca with outliers” and “without outliers”).
- iii. All relevés located within areas where three or more modeled vegetation communities overlap examined and most likely vegetation community chosen based on the dominant classification of the associated relevés.
 - iv. Remaining areas sorted from largest to smallest. All large areas (>800ha) examined and where there was an overlap of three or more modeled vegetation communities, the most likely vegetation community chosen based on (1) the neighbouring vegetation community designated in steps (i) to (iii) above and (2) the best fit model set overall and the best fit model set for each vegetation community (Overall, the best fit model was “with outliers”, followed in order by “pca without outliers”, “pca with outliers” and “without outliers”).)
 - v. Final gaps filled by selecting groups of remaining areas and choosing the most likely vegetation community based on the neighbouring vegetation community designated in steps (i) to (iv) above.

9.11.2. Finalizing Primary Vegetation layer

Michele Pfab created a vegetation map from the numerous models Pieta Compaan created and it was sent to David Hoare for expert verification and finalization. The result delivered to Pieta Compaan was filled in at the edges of the Gauteng boundary where she found gaps and checked one last time with David Hoare.

A primary vegetation map was created that incorporated all wetlands, pans, rivers, grass- and woodland data (for C-Plan 2 only wood/grassland were included) excluding all transformed areas from the GTI 2009 land cover (i.e. built, mines, sports and recreation, cultivated and old lands etc as well as digitized areas for excluded areas to be ignored by C-Plan 3). The result was used as a mask to clip each vegetation type to the “primary vegetation” layer, creating a primary vegetation layer as input for C-Plan 3.

Target:

The target was calculated as follows (more information on this may be obtained from Michele Pfab at Pfab@sanbi.org):

Table 8: Establishing targets for primary vegetation for C-Plan 3

| Vegetation | Hectares | y2 | y1 | x2 | x1 | z | S | A | Target (ha) |
|--|--------------|--------|--------|--------|----|--------|-----|---------|-------------|
| Central Sandy Bushveld | 193 187.11 | 2.6675 | 1.4914 | 5.2860 | -2 | 0.1614 | 0.8 | 0.2510 | 48 486 |
| Clay Grassland | 30 603.46 | 1.9085 | 1.3424 | 4.4858 | -2 | 0.0873 | 0.8 | 0.0776 | 2 374 |
| Gauteng Grassland | 1 046 364.46 | 2.6884 | 1.5441 | 6.0197 | -2 | 0.1427 | 0.8 | 0.2093 | 219 044 |
| Loskop Mountain Bushveld | 39 986.69 | | | 4.6019 | -2 | | 0.8 | *0.2287 | 9 145 |
| Magaliesberg Mountain Bushveld | 23 822.37 | 2.5587 | 1.6021 | 4.3770 | -2 | 0.1500 | 0.8 | 0.2259 | 5 383 |
| Marikana Thornveld | 89 778.08 | 2.5092 | 1.5185 | 4.9532 | -2 | 0.1425 | 0.8 | 0.2089 | 18 750 |
| Moot Plains Bushveld | 48 749.97 | 2.4742 | 1.4771 | 4.6880 | -2 | 0.1491 | 0.8 | 0.2239 | 10 913 |
| Mountain Bushveld | 180 224.93 | 2.6928 | 1.5441 | 5.2558 | -2 | 0.1583 | 0.8 | 0.2443 | 44 027 |
| Norite Koppies Bushveld | 3 020.92 | 2.3766 | 1.4472 | 3.4801 | -2 | 0.1696 | 0.8 | 0.2683 | 810 |
| Rand Highveld Grassland | 143 674.09 | 2.6314 | 1.6721 | 5.1574 | -2 | 0.1340 | 0.8 | 0.1892 | 27 187 |
| Springbokvlakte Thornveld | 18 068.49 | 2.3424 | 1.5315 | 4.2569 | -2 | 0.1296 | 0.8 | 0.1788 | 3 230 |
| Waterberg-Magaliesberg Summit Sourveld | 349.99 | | | 2.5441 | -2 | | 0.8 | #0.2259 | 79 |

y2: log(total number of species in a land class)

y1: log(average number of species per survey sample)

x2: log(total area of land class)

x1: log(average area of samples)

S: proportion of species

A: proportion of area

Target: Hectares x A

*No data - take average of all savanna/bushveld vegetation types

#No data - use Magaliesberg target

10. Creating input files for C-Plan 3

C-Plan GIS software requires three files that are used as input to build a C-Plan database on which analysis is executed in ArcView 3.x. These three files are the Planning Units (in C-Plan 2 referred to as the site database), the biodiversity feature file (referred to as the target table in CLUZ), and the site-by-feature file (referred to as the abundance table in CLUZ). The files required, were created as follows:

10.1. Planning Unit File

The planning unit file contains available-, excluded- and protected areas. The areas needed for the file, was created as follows:

10.1.1. Excluded Areas

- a. The areas were based on GTI land cover 2009 for Gauteng, GTI land cover 2006 for North West (Merafong area), Quickbird Images 2004/05 (digitized on-screen) and some polygons were extracted from Quickbird land cover 2004/05:

- Built-up Area
 - Mine
 - Large areas of exotic plantations
 - Dense or areas > 0.2 ha for small holdings and farmsteads
- b. Select and dissolve areas to be classified as excluded areas (the latter are ignored by C-Plan during analyses).
 - c. Do a Multipart on the file.
 - d. See paragraph on “Create fields for Initial PU” for fields needed.
 - e. Add text field for STATUS and populate it with the term “Excluded”. **Tip:** only change the field name to TENURE in the final file. This is easier when CLUZ is used to help build files for C-Plan (CLUZ requires the field to be called STATUS).
 - f. Add numeric field for AREA (no decimals) and calculate areas in sq meters. **Tip:** only convert the field (and name) to HECTARES in the final file. This is easier when CLUZ is used to help build files for C-Plan (CLUZ requires the field to be called AREA).
 - g. Areas < 0.2 ha were deleted.

10.1.2. Protected Areas

Data Source: Protected areas (PAs) were digitized on-screen by Nature Conservation using 1: 50 000 farm boundaries. Where available, areas were updated against declaration documentation received from DEA in 2010.

Nature Conservation’s ecologists, Patrick Duigan and Quintin Joshua, revised the PAs’ classifications extensively based on ecological intactness, management plans to biodiversity and legal declaration. Only level 1 and level 2 protected areas are included into the planning units. Reserves for C-Plan 3 are classified as follows:

- a. **Level 1 protected areas:** Proclaimed i.t.o. relevant legislation specifically for the protection of biodiversity (or for the purposes of nature conservation); management plan in place with conservation of biodiversity as the priority management objective; ecologically intact.
- b. **Level 2 protected areas:** Proclaimed i.t.o. relevant legislation specifically for the protection of biodiversity (or for the purposes of nature conservation); **OR** management plan in place with conservation of biodiversity as the priority management objective; ecologically intact.
- c. **Level 3 protected areas:** Not proclaimed; no management plan; ecologically intact.
- d. **Level 4 protected areas:** Disturbed/degraded – a review committee to decide on whether the area should be discarded/de-proclaimed or whether it is worthy of intervention for eventual “upgrading” to level 3 or above.

The table below illustrates level 1 and level 2 protected areas included in the Planning Unit file.

Table 9: Protected Areas included in C-Plan 3

| Protected Area | Type | Declaration | Level | Hectares |
|-----------------------------|---------------------------|-------------|-------|----------|
| Abe Bailey | Provincial Nature Reserve | | 2 | 5090.43 |
| Alice Glöckner | Provincial Nature Reserve | | 2 | 155.19 |
| De Onderstepoort | Private Nature Reserve | 204/55 | 2 | 2948.39 |
| Ezemvelo (Gauteng part) | Private Nature Reserve | | 2 | 2733.53 |
| Faerie Glen | Municipal Nature Reserve | | 2 | 126.59 |
| Glen Austin | Bird Sanctuary | 92/94 | 2 | 20.19 |
| Klipriviersberg | Municipal Nature Reserve | 1827/84 | 2 | 696.12 |
| Korsman | Bird Sanctuary | 223/54 | 2 | 45.33 |
| Krugersdorp | Municipal Nature Reserve | | 2 | 1351.42 |
| Leeuwfontein | Provincial Nature Reserve | | 2 | 2224.97 |
| Marievale Bird Sanctuary | Provincial Nature Reserve | 597/78 | 2 | 1011.93 |
| Melville Koppies | Municipal Nature Reserve | 62/67 | 2 | 48.08 |
| Plovers Lake Nature Reserve | Natural Heritage Site | | 2 | 261.93 |

| Protected Area | Type | Declaration | Level | Hectares |
|-------------------------|---------------------------|-------------|-------|----------|
| Rhenosterpoort | Private Nature Reserve | 613/73 | 2 | 905.53 |
| Rietvlei Dam | Municipal Nature Reserve | 296/54 | 1 | 4479.71 |
| Rondebult | Bird Sanctuary | 1440/77 | 2 | 99.63 |
| Roodeplaat Dam | Provincial Nature Reserve | | 2 | 774.93 |
| Ruimsig | Municipal Nature Reserve | | 2 | 13.23 |
| Suikerbosrand | Provincial Nature Reserve | 514/74 | 1 | 11657.60 |
| Suikerbosrand extension | Provincial Nature Reserve | | 2 | 6322.15 |
| Tswaing | Meteorite Crater Reserve | | 2 | 1980.93 |
| Voortrekker Monument | Private Nature Reserve | 270/92 | 2 | 259.04 |
| Walter Sisulu | Botanical Garden | | 2 | 286.24 |
| Wonderboom | Municipal Nature Reserve | 223/54 | 1 | 120.13 |

SANDF properties (Ditholo, Heidelberg Military Base, Wallmansthal and Zwartkop) were excluded from C-Plan 3 (previously included in C-Plan 2) as they were reclassified to level 3 in June 2010 (ecologically intact, no management plan). Litsitsirupa and Papillon were reclassified as level 3 for the same reason. Pumula, although a declared reserve, was classified as level 4 because P Duigan (GDARD) found that the site is badly degraded and transformed and has extensive development threats in the surrounding areas.

Suikerbosrand Provincial Nature Reserve

Only the part of the extension of Suikerbosrand that GDARD has officially acquired (as in June 2010) was included. Daniel Koen (officer from Suikerbosrand) has indicated that the rest of the areas will not be resolved before completion of C-Plan 3. Below is an illustration of the area included in C-Plan 3 (blue indicating the extended area obtained in 2008-2009).

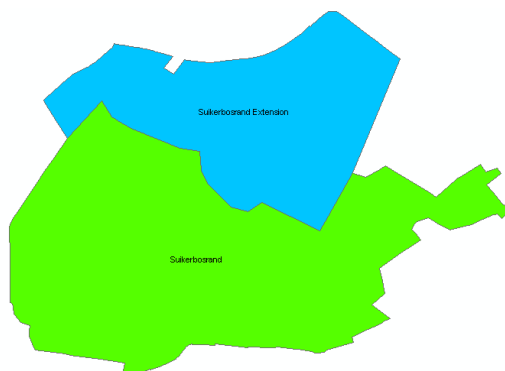


Figure 9: Suikerbosrand Nature Reserve (green) and newly acquired land (blue)

PAs were included as a whole for C-Plan 3 purposes i.e. Suikerbosrand and its extension is one complete unit and not separated into two parts based on their level classification. Furthermore, PAs were not intersected with the 100 ha hexagonal units used for the PU file, but included into the planning units as whole units (i.e. their full extent not divided into 100ha units).

10.1.3. Available Areas

Available areas are those that are untransformed according to available data at the time of creating them. Below are the steps that were followed in building available areas included in the PU file:

10.1.3.1. Build an Initial Planning Unit (PU) File

- In ArcView load the extension for Repeating Shapes.
- Change Mapping and Distance Units in the menu option for View Properties both to metres.
- Add the Gauteng boundary (projected to Albers).
- Click on the tool for “generating repeated shapes”.
- Choose “Within the Extent of a particular Theme” in the pop-up menu.
- Select Gauteng boundary.
- Select “Hexagons”
- In the “Hexagon Properties” window, fill in the Area in sq meters (i.e. 10000 for 1 ha) and accept 0.00 for the Degrees Offset. 1 000 000 (100ha) were used for Gauteng.
- Define the projection in ArcCatalog to Albers.
- Clip the file in ArcMap with the Gauteng boundary and call the file PU_init_al24.

10.1.3.2. Erase Excluded Areas from the Initial PU

- Do a union between the initial PU and Excluded Areas.
- Start an edit session in ArcMap.
- Select all areas containing “Excluded” in the STATUS field and delete records from the file (one could have used an “Erase” function if it was available for this step instead of doing a Union first).

10.1.3.3. Create fields for the Initial PU

The fields in the table below were included in the initial PU file, but (the final file included excluded areas and PAs too). **Tip:** it is suggested to use field names needed for CLUZ/MARXAN when initially building the PU file and then use this file to create the target (BDF) and abundance (SBF) files in CLUZ. When done with all, the file names can be changed to C-Plan field names just before C-Plan tables are built.

- Add fields and names as displayed in the first column in the table below.

Table 10: Initial Planning Unit table

| Initial Field Name CLUZ/MARXAN | Final Field Name C-Plan | Type | Length | Deci- mals | Note |
|-----------------------------------|----------------------------|---------------|--------|---------------|---|
| Unit_ID | Unit_ID | Short integer | 10 | 0 | Unique PU/site key |
| | Unit_Name | Text | 45 | | To include reserve names. <i>Not needed in MARXAN.</i> |
| Area | Hectares | Short integer | 12 | 0 | Extent of each PU. Do not use any decimals in numbers as it is much easier on analyses. |
| Cost | | Short integer | 12 | 0 | Cost of including the unit in any conservation portfolio. <i>Not needed in C-Plan.</i> |
| Status | Tenure | Text | 20 | | Available, excluded, reserved (and Earmarked) |

- Add the word “Available” in the STATUS field.
- Do a Multipart, as some parts on opposite sides where excluded areas were removed may be part of the same polygon.
- Append the original Excluded Areas file that already indicates which areas are excluded (in the STATUS field).
- Add a unique ID (FID+1) in the UNIT_ID field.
- Delete unnecessary fields.

10.1.3.4. Erase Protected Areas from the Initial PU

- Do a union between the initial PU and Protected Areas.
- Start an edit session in ArcMap.

- c. Select all areas containing "Reserved" in the STATUS field and delete records from the file (one could have used an "Erase" function if it was available for this step instead of doing a Union first).
- d. Do multipart to separate areas on opposite sides of reserves that were split.
- e. Append Protected Areas as complete areas.

10.1.4. Final Planning Unit File

10.1.4.1. Combine Excluded Areas, Protected Areas and the Initial PU

- a. Do a union between Protected Areas and Excluded Areas.
- b. Do a multipart on the result to get single polygons.
- c. Identify all **overlapping areas** and include them in the appropriate area.
- d. Append Excluded Areas and Protected Areas with the initial PU.
- e. Finalize attribute fields.
- f. Calculate areas.

10.1.4.2. Remove smaller than the minimum size polygons and slivers

Transformed areas to be avoided by C-Plan analysis were used as complete shapes causing adjacent hexagon boundaries to change and not necessarily 100 ha any longer. Areas smaller than one third of the original hexagon were merged with adjacent areas with the same attribute causing the shape to be irregular and of different sizes, but no bigger than 130ha. Areas unsuitable for biodiversity conservation (transformed i.e. built/mines) were classified as excluded and ignored by C-Plan analyses. The following steps were followed:

- a. Use ArcView and set View Properties: Map Units to meters, Distance Units to Kilometers
- b. Load Dissolve Adjacent Polygons extension and click on the icon
- c. Polygon theme = planning units; and ID field = unit ID
- d. Decide the minimum size and type the number in at a: dissolve all polygons smaller than....(i.e. 10000 sq. map units for 1 ha). For C-Plan 3 areas < than one third (333 333 m²) of initial PU areas were dissolved with the smallest adjacent polygon.
- e. Check mark the following boxes:
 - Dissolve only polygons within size range
 - Polygon with the smallest adjacent polygon.
 - Share common line or border

A test was done to decide between dissolving with the smallest adjacent polygon and with the polygon sharing the longest boundary. The result of the latter produce 673 polygons > 100 ha (total area 77 241ha), the biggest polygon was 184 ha and 47 polygons were > 135ha. The result of dissolving with the smallest adjacent polygon produced 250 polygons > 100ha (total area 26 925ha) and the biggest polygon was 135ha. It was decided to use dissolving with the smallest adjacent polygon to keep PU sizes as near as possible to 100ha.

- f. There were still be a number of polygons with smaller than the limit size of 100ha but no adjacent polygons to dissolve with sharing the same attribute (because they were islands). Areas around all protected areas were first investigated and slivers were removed. Areas were recalculated and those islands < 10m were deleted. This size was decided on to prevent deleting areas containing small pans.
- g. Define projection as Albers in ArcCatalog.
- h. Ensure that:
 - the terms "Available", "Excluded" and "Reserved" are in the STATUS field
 - areas are recalculated
 - unique IDs in all planning units
 This is the final PU file.

10.2. Biodiversity Feature File (BDF):

It was found to be much quicker and less labor intensive to build this file using the CLUZ extension in ArcView 3.x. The file name "Target" for the BDF was used as automatically created in CLUZ. The following steps were followed to build the biodiversity feature file:

10.2.1. Fields needed for BDF

The attributes needed for the BDF file are illustrated in the table below:

Table 11: Biodiversity Feature File

| Field Name | Type | Length | Note |
|--|---------------|--------|---|
| CLUZ required fields (automatically created when target table is created in CLUZ, just add the fields highlighted in grey manually) | | | |
| Link target table to biodiversity shapefile table with C-Plan fields below and add data for all fields except SPF, Conserved and Total. Do not use the same field names in the two table parts as ArcView will not add the data. | | | |
| ID | Short integer | 12 | Unique number for each conservation feature. Must be integer for CLUZ. See numbering system in next paragraph. |
| Name | Text | 65 | Full name of the feature. CLUZ truncates this field to 30 characters when it creates the target table. Lengthen the field in Excel (make a backup copy first) before linking to C-Plan field table to add full name from Feature field below. Place apostrophe before the number in the 1st row to avoid changing it to a number field when saving to dbf. Do not include any numbers in this field as it may be problematic to CLUZ/MARXAN. |
| Type | Short integer | 12 | See numbering system for type numbers |
| Target | Short integer | 12 | No decimals – easier. Required amount of each feature that should be represented in the final portfolio. |
| SPF | Short integer | 12 | No decimals – easier. Lists the species penalty factor. Not needed for C-Plan. |
| Conserved | Short integer | 12 | Amount of each feature that is found in units that have Conserved or Earmarked status |
| Total | Short integer | 12 | Total amount of each feature in all of the units |
| Pc_target | Short integer | 12 | Bdfs remaining under-represented in the portfolio. |
| Featype | Text | 35 | Create this field after target table has been created. |
| Stat | Text | 10 | Create this field after target table has been created. |
| Vuln | Short integer | 10 | Create this field after target table has been created. |
| C-Plan fields in biodiversity feature shapefiles – these were used in the initial files created for all biodiversity created in ArcMap and then linked on ID field to target table in CLUZ to add attributes | | | |
| FKEY | Text | 12 | ID field needed for C-Plan must be text. Take care that the number is exactly the same as the ID field for CLUZ, except that it is preceded by F (for GDARD purposes). See numbering system in next paragraph. |
| Taxonname | Text | 65 | Name |
| Feature | Text | 65 | Use this field to link to table above in CLUZ to add full name. As taxonname may occur more than once (i.e. for confirmed records as well as habitat) the taxonname is used together with "conf" or "hab", etc. |
| BDF_Type | Text | 35 | Do not use the word "Type" as it is needed for CLUZ. |
| STATCODE | Text | 10 | See paragraph on Vulnerability for status codes. |
| VULNCODE | Short integer | 10 | Value 1-5, with 1 the highest |
| PC_TARG | Short integer | 10 | Required % to be calculated for target, i.e. 20% of sensitive vegetation to conserve |
| HECTARES | Double | 12,3 | 3 Decimals for sensitivity project, no decimals for CPlan. |
| HA_TARG | Short integer | 12 | Hectares required for target, no decimals. |
| BDF_ID | Short integer | 12 | Same as FKEY, except that it is a number without the preceding "F" – used to link back to ID field above in CLUZ. Without this field named exactly like this, CLUZ cannot add data. |
| FEATKEY | Short integer | 12 | Features have to be numbered chronologically from 1,2,3....etc if vulnerability values are going to be used in C-Plan analysis. VULN values are imported into C-Plan database after the database has been built – C-Plan does not import them automatically. |

10.2.2. Numbering system for BDFs

An internal numbering system was developed to keep unique numbers for each biodiversity feature as systematic as possible. CLUZ requires the unique ID to be an integer, whereas C-Plan requires it to be text. So the number was duplicated for the purpose of the two software packages but preceded by the letter F for C-Plan purposes.

Table 12: Systematic numbering system used for biodiversity features

| Biodiversity feature | Abr | Type | FKEY |
|--|-------|----------|-------------------|
| Vegetation | | 1 | |
| Vegetation (Primary) | | 111 | F111001-F111... |
| Woodland (Mesic / Scarp) | | 112 | F112001-F112... |
| Plant (habitat includes metapop models) | | 2 | |
| Plant Red List Confirmed Buffered | RLC | 211 | F211001-F211... |
| Plant Red List Confirmed Centroid | RLCC | 212 | F212001-F212... |
| Plant Red List Habitat Polygon | RLH | 213 | F213001-F213... |
| Plant Red List Habitat Centroid | RLHC | 214 | F214001-F214... |
| Plant Orange List Confirmed Buffered | OLC | 221 | F221001-F221... |
| Plant Orange List Confirmed Centroid | OLCC | 222 | F222001-F222... |
| Plant Orange List Habitat Polygon | OLH | 223 | F223001-F223... |
| Plant Orange List Habitat Centroid | OLHC | 224 | F224001-F224... |
| Mammal | | 3 | |
| Mammal Red List Confirmed | MRLC | 311 | F311001-F311.... |
| Mammal Red List Historical & Habitat | MRLH | 312 | F312001-F312..... |
| Bird | | 4 | |
| Bird RL Confirmed Habitat | BRLCH | 411 | F411001-F411.... |
| Amphibian | | 5 | |
| Frog RL Confirmed | | 511 | F511001-F511... |
| Frog RL Habitat | | 512 | F512001-F512... |
| Reptile | | 6 | |
| Reptile RL Confirmed | RRLC | 611 | F611001-F611... |
| Reptile RL Habitat | RRLH | 612 | F612001-F612... |
| Invertebrate | | 7 | |
| Invert RL Confirmed | | 711 | F711001-F711... |
| Invert RL Core Population Confirmed | | 712 | F712001-F712... |
| Invert RL Habitat | | 713 | F713001-F713... |
| Unallocated | | 8 | |
| | | | |
| Other BDFs | | 9 | F900001- |
| Pan | | 911 | F911001-F911... |
| Near-pristine Quaternary Catchment | | 921 | F921001-F921... |
| Bioclimatic zone | | 931 | F931001-F931... |
| *Cave | | 941 | F941001-F941... |

* Not included in C-Plan 3

10.2.3. Vulnerability (sensitivity) values

The conservation status of species are indicated by their vulnerability scores as indicated in the table below. Vulnerability scores was however, not used in C-Plan 3 analyses.

Table 13: Vulnerability scores based on species conservation status

| Vulnerability | STATCODE (Status) | Value |
|---|-------------------|-------|
| Critically Endangered / Extinct | CE / X | 1 |
| Endangered | E | 2 |
| Vulnerable | V | 3 |
| Rare / Near Threatened / Rare-Spares / Data Deficient | R/NT/RS/ DD | 4 |
| Least Concern / Declining | LC / D | 5 |

10.2.4. Creating the BDF table

- Each biodiversity feature must have a unique number. Confirmed buffered species, metapopulation layer, a habitat layer, or a point location layer for the same spp must each have a unique number (see numbering system for BDFs).
- NB! Tip: Make ID field an integer so that the BDF together with the PU can be used in CLUZ to build the initial SBF/abundance table. The target table created in CLUZ was imported into C-Plan 3 as the BDF. See how later in this document in the paragraph on CLUZ. Also, do not use the word "name" for the biodiversity feature, this word is reserved for CLUZ target.dbf.

10.3. Site-by-Feature File (SBF) / PU versus BDF File

It is easier to use the Abundance table built in CLUZ (see paragraph 7.4 on CLUZ) for the SBF matrix required by the C-Plan database. However, take care that the ID of the BDF (or target) table starts with the same ID in the same format (for example starting with F). The SBF file can alternatively be created with the Tabulate areas tool in ArcView or in ArcMap. This is explained shortly as CLUZ was used to build the SBF file in ArcView 3.x for C-Plan 3.

10.3.1. ArcView: Tabulate areas



- Click on the menu Analysis and Tabulate Areas. Use PU as the Row Theme, Unit_ID as the Row Field, SPP as the Column Theme, and FKEY as the Column Field.
- In the Temporary Grid Specification widow, use "Same as PU" as the Output Grid Extent, and make the Output Grid Cell Size between 10m-100m (the smaller the grid, the longer the processing time, but it may be more accurate then). Number of Rows and Columns will update automatically. Click OK and wait...

10.3.2. ArcMap: Tabulate areas


- Use Spatial Analyst Tools, Zonal, Tabulate Area to create a pivot table for the Site-by-Feature (SBF) table. PU is the 1st input and BDF the 2nd. Export table to dbf.
- Tabulate Areas does not include all PUs, only the area intersected between PU and BDF.
- The result of Tabulate Areas is in m². To create a SBF table with all Unit_IDs and all BDF's occurrence in them in hectares, follow steps in CLUZ mentioned above.

10.4. Building DBF and SBF in CLUZ

Microsoft Office 2003 software including Excel (using the PivotTable function amongst others) and Access were used to build the SBF for C-Plan 2. This was very labor intensive as Excel has a limitation for the number of records it could handle and exporting a file from Access larger than a certain size proved to be tricky too. Since then the CLUZ software was learned which saved a tremendous amount of time and very simple ways compared to MS Office software to build both the DBF and SBF with. The following steps were followed for C-Plan 3:

- 1.1. Create folders for C-Plan files, Input and Output (the latter 2 will be used by CLUZ/MARXAN) under main working folder.
- 1.2. Copy a folder contain MARXAN software files under the main working folder (tip received on workshop).
- 1.3. Open ArcView and open a new View
- 1.4. Set the working directory to the main working folder.
- 1.5. Switch on the extensions for CLUZ and Spatial Analyst.
- 1.6. Change view properties: map units to meters; distance units to kilometres.
- 1.7. Save the project.
- 1.8. Add PU to new theme (fields: UNIT_ID, AREA, COST, STATUS). Tip: CLUZ needs the word **"Conserved"** for reserved/protected areas.
- 1.9. Create new CLUZ setup file but do not specify the abundance and target table yet, save (overwrite existing settings) and close.
- 1.10. Create a **blank** target table (this will become the BDF for C-Plan) -- specify the decimal places as zero. The table will have one row which has to be deleted later.
- 1.11. Create a **blank** abundance table (this will become the SBF for C-Plan). The table will have only field containing the Unit_ID.
- 1.12. Update the setup file with the location of these two tables and save.
- 1.13. Save your project.
- 1.14. Clip species/biodiversity features shape files to the extent of the study area (i.e. Gauteng boundary).
- 1.15. Add species/biodiversity features shape files to ArcView (tip: different biodiversity features may be kept separate and added separately as needed in the same way as the next 3 steps). Fields: ID (short integer), NAME, TARGET (short integer), SPF (short integer). **NB: CLUZ uses only 30 characters for the NAME field. When you later link biodiversity files with the target file to add names, this is important to know as longer biodiversity names will be truncated. Do not include any numbers in the NAME field as MARXAN cannot use numbers in this field!** (tip: different fields with longer names can be used to import data into C-Plan). Possible tip: use Edit Tools in ArcMap to extend Name field before importing into C-Plan?
- 1.16. Click on CLUZ and **convert** themes to abundance data – accept F (only F) to identify features, **divide by 10,000 to get hectares**, specify 0 decimal numbers as it is easier on analysis.
- 1.17. When done, check that the data have been imported correctly by clicking on the **Open Abundance Table** button .
- 1.18. Close the abundance table, open the target table  and notice that new rows have been added to the table and the numerical identifier of the added features has been added to the **Id** field.
- 1.19. **Delete the first row of the TARGET table** (which should have an Id value of -999). Fields will initially have the following values:

| | |
|------------|---|
| Name: | ID number (NB: See next point and remember field length is only 30) |
| Type: | 0 |
| Target: | 0 |
| Spf: | 0 |
| Conserved: | area conserved |
| Total: | total area |
| Pc_target" | -1.00 |
- 1.20. Open the target file in Excel (make a backup first for in case you need it) and extend the NAME field long enough so that the bdf names fit in. Tip: put an apostrophe in before the first feature number i.e. '1502 in the NAME field – else the field format will change to number instead of text.

- 1.21. Link the target table and the biodiversity table on the ID field (the ID field in the biodiversity table has to be an integer). Note: long names may be truncated -- try and use shorter names for BDFs. **Do not include any numbers in the NAME field as MARXAN cannot use numbers in this field**
- 1.22. Update target table as follows:
 - Add the species name in the name field (note that long names will be truncated if longer than 30 characters -- short names are advised).
 - Complete the type field (see paragraph on numbering system – the table can be saved and linked to the target table to add values in the type field):
 - If 100% of distribution is required as target, then put the total in the target field. If you later import more BDF files **Recalculate target table data**. Open the target table  - CLUZ has updated the values in the **Total** field with the total amount of the corresponding feature found in all of the planning units as well as the amount found in the **Conserved** field. In the case of a certain % target required i.e. Vegetation, calculate the needed % of the total and place into the TARGET field.
 - The SPF may be the same as the target. CLUZ tutorial suggested SPF of 100,000 for a start for all spp. This was however, not needed for C-Plan 3 as analysis was done in C-Plan.
 - Remove all links.
- 1.23. Click on CLUZ and troubleshoot files to check that all is okay.
- 1.24. The files above can be used for **C-Plan** with some easy modifications. Even easier: add all fields needed by C-Plan (see paragraph 7.2.1 on Fields needed for BDF) in the target table while in CLUZ, link BDF tables and add attributes to the target table. Both the abundance and target table can be used as is for the BDF file in building C-Plan.

If centroids are used as input for i.e. confirmed plants and each centroid represents one population, but each population represents a different number of individuals (for example: 14 populations of plant X, centroid 1 has 200 individuals, centroid 2 has 700 individuals, etc so one might end up with 2000 individuals but only 14 centroids). CLUZ will add the number of centroids (14) and if your target is 800 individuals the target and abundance table have to be edited manually.

Solution from Dr Stephen Holness:

"This is an ongoing CLUZ coding problem. If you have lots of points, then I would suggest that you bring the population data in via a table. The table would need to have the planning unit #, the species id and the number of individuals. Just be careful that if you have more than one point in a planning unit, that you summarize and only have one row with all the populations in that planning unit. I have tended to take my points with the populations in a field, and code them with the planning unit number via a transfer attributes function. I would then join the points shapefile with the site by features matrix on the basis of the planning unit id, and then copy the populations from the points to the appropriate column in the site by features matrix. However, if you only have a few points, then I tend to just manually edit the site by features matrix and replace the current present/absence value with the population number.

If you want to target both a minimum population size and a minimum number of sites, the way I do this is that I would effectively create a shadow feature, and set 2 separate targets for the features. One target would be for plant numbers one for centroids. It does mean that you effectively have two different overlapping features for that type (and this does have consequences for summed irreplaceability) at the same locations. This method means that the sites with lots of that species will be favoured when one is prioritizing the top x number of centroids. Not an elegant solution, but it works, and is effort efficient!"

The issue was resolved as follows:

- a. Do a spatial join in ArcMap between centroids and planning units to import the Unit_ID of planning units.
- b. Link the abundance table in ArcView with the file above on the Unit_ID.
- c. Edit the abundance table and put the number of individuals in the planning unit – see the figure below for an example on a *Lithops* species. Be careful where more than one centroid in one planning unit i.e. those highlighted in yellow in the figure below. There will be only one row in the abundance table. The total number of individuals are 65 in the abundance table.

- d. Edit the target table and place the total number of individuals in the total field (1629).
- e. Change the target with the number needed.
- f. Finally recalculate the target table.

| ID | TAXONNAME | POP_NO | No_mat_ind | UNIT_ID |
|--------|--------------------------------|--------|------------|---------|
| 222017 | Lithops lesliei subsp. lesliei | LITL13 | 10 | 100012 |
| 222017 | Lithops lesliei subsp. lesliei | LITL14 | 5 | 100012 |
| 222017 | Lithops lesliei subsp. lesliei | LITL11 | 50 | 100012 |
| 222017 | Lithops lesliei subsp. lesliei | LITL09 | 50 | 200536 |
| 222017 | Lithops lesliei subsp. lesliei | LITL12 | 3 | 200536 |
| 222017 | Lithops lesliei subsp. lesliei | LITL01 | 11 | 202376 |
| 222017 | Lithops lesliei subsp. lesliei | LITL08 | 300 | 202574 |
| 222017 | Lithops lesliei subsp. lesliei | LITL04 | 300 | 203659 |
| 222017 | Lithops lesliei subsp. lesliei | LITL02 | 200 | 204112 |
| 222017 | Lithops lesliei subsp. lesliei | LITL03 | 300 | 204271 |
| 222017 | Lithops lesliei subsp. lesliei | LITL07 | 150 | 205374 |
| 222017 | Lithops lesliei subsp. lesliei | LITL05 | 100 | 208547 |
| 222017 | Lithops lesliei subsp. lesliei | LITL06 | 50 | 210286 |
| 222017 | Lithops lesliei subsp. lesliei | LITL10 | 100 | 212977 |

Figure 10: Lithops example for the 1st solution (14 populations/centroids, total number of individuals = 1629)

10.5. Cost / Threat Layer

A cost/threat layer was created to be used in C-Plan 3 analysis. The purpose of this layer is to steer away from areas with a high cost/threat in favor of those especially with values 1-3 in the table below. The features tabulated below were included in the threat layer:

Table 14: Cost / Threat values and features used

| COST VALUE | FEATURES |
|------------|---|
| 1 | Level 3 protected areas (level 1 and 2 reserves were included in planning units for C-Plan 3, but value 1 was assigned to avoid having areas with value = 0) Conservancies Low cost areas for metros (from Dr Stephen Holness) |
| 2 | Corridors |
| 3 | Ecological processes – includes following features all merged together <ul style="list-style-type: none"> • Dolomite • Ridges • Perennial rivers plus buffers (urban = 32m; rural = 100m) • Wetlands plus buffers (urban = 30m; rural = 50m) • Poor condition / transformed pans (more than 40% <u>urban</u> landcover within the 1km pan catchment) plus buffers (urban = 30m; rural = 50m) • Good condition pans (less than 40% <u>urban</u> landcover within the 1km pan catchment) plus buffers (1km) |
| 4 | Low threat (agriculture from composite threat map) |
| 5 | Moderate threat (mineral hotspots from composite threat map) |
| 6 | High threat (urban from composite threat map) |

- a. Create the composite threat map first using the highest values (urban, agriculture, mineral hotspots).
- b. Union the composite map with the other cost layers (value 1-3) and use lowest values where different cost layers overlap.

- c. Assign a cost value to each available area in the planning unit file. Where there are two or more cost values on one site, use the lowest value. (Excluded areas in C-Plan 3 received value 6 else they would have value 0).

10.6. C-Plan Database

The Abundance table built in CLUZ was saved as the SBF matrix, and the target table built in CLUZ was saved as the BDF file required by the C-Plan software. The following steps were then followed to build the C-Plan database with C-Plan Table Editor.

10.6.1. Build C-Plan database

- a. Add the PU, BDF and SBF files in the C-Plan Table Editor software.
- b. Click on Wizards and select Build C-Plan databases.
- c. Click on Key Field next to abundance/sbf table and then on Add Table. Click Next.
- d. Click on Key Field next to PU file and check that correct **Key** field and **Unit Name** are selected. If you use a Name field in the PU file, remember to capture a name in this field i.e. "Unit" & [PU_ID] else the name field will be empty. Click Next.
- e. Click Next on the next window (leave 0 subset).
- f. Click in the Key field for PU table and check that correct **Key** field and **Area** field are selected. Click Next.
- g. Click in the Key field for PU table and check that correct **Key** field and **Tenure** (status) field are selected. Click Next.
- h. Assign Tenure Classes. Click Next.
- i. Click in the Key field for BDF table (Target table for CLUZ) and check that correct **Key** field (the one in **Text format, i.e. FEAT_ID – be careful not to select ID (integer field) that was used for CLUZ**) and **Name** field are selected. Click Next.
- j. Click in the Key field for BDF table and check that correct **Key** field (the one in **Text format – see previous point**) and **Target** fields are selected. Click Next.
- k. Name the C-Plan database.
- l. Click OK and wait until the last window disappears. It may take a long while – just wait (go and have coffee....).

10.6.2. Import the Vulnerability Score

The vulnerability score was not used in C-Plan 3 analysis. This paragraph is only included for information if it is to be used in future.

The VULN field (user-defined ranking from 1 to 5 with 1 the highest value – most vulnerable) relating to the 'need for conservation' for each feature used in the calculation of the summed irreplaceability vulnerability weighting) is not included in the C-Plan database automatically. **It has to be imported, but there is another trick. C-Plan changes the values of the ID field to 1,2,3.....!** These values have to be added to the DBF file to be able to import the vulnerability field.

- a. Add an integer field called **FEAT_NR** in your BDF file and capture values using ArcMap in this field ([FID]+1) or ([OID]+1).
- b. Make a backup of your C-Plan feature file before importing data as the Table Editor directly overwrites or replaces data in this file.
- c. Open the C-Plan feature file that was just created with C-Plan Table Editor as well as the original BDF file.
- d. From the menu select **Wizards | Import into Table**, this will launch the wizard.
- e. Click on the table that you want to import data into (target table or C-Plan feature table) from the list.

- f. Select the correct key field for this table from the drop down list box. Ensure that the key field in the C-Plan feature table (**FEATKEY**) is the same as the key field in the bdf/target table (**FEAT_NR – the integer numbers 1,2,3.....**). They do not have to have the same field name but they must have the same list of key values!
- g. In the next window in the table editor change the Key in the top half if necessary (FEAT_NR in this case).
- h. In the bottom half of the window in the "Import Field" select the field to import (VULN in this case). Leave the "New Name" the same.
- i. Click on the button called "add field to list".
- j. Click on the button "next" to finish.
- k. Check that the field was imported correctly and exit.

11. Critical Biodiversity Areas (CBAs)

The C-Plan database built in the previous step was used in analysis to create the first part of C-Plan 3, that is the CBAs (which include irreplaceable, important and protected areas). The following steps were followed in executing C-Plan 3 analysis in ArcView 3.2:

11.1. Set up C-Plan Database in ArcView

- a. Open ArcView and set extension for C-Plan before adding PU file.
- b. Set working directory and save project.
- c. Add PU. To enable the link between C-Plan and ArcView include the planning unit layer (shapefile) in the same folder as the C-Plan database (all three files - features, matrix, sites) as well as the file for cplan.ini. C-Plan requires all files that will be used in the ArcView project to be in the same folder.
Tip: do not organize files neatly under different folders, as C-Plan will probably later not open.
- d. Click on View and change Map Units to meters, and Distance Units to Kilometers.
- e. Save project.
- f. Click on C-Plan icon.
- g. Select the planning unit file if requested.
- h. Select the key field.
- i. You may get a window "display warnings". You may choose to ignore it.
- j. Check the bottom of the C-Plan window and wait until it has finished updating the tenure for C-Plan.
- k. Click on "user-defined" targets and click on "Select a target instead" and select the ITARGET option. C-Plan will calculate irreplaceability.
- l. Continue with analysis below.

11.2. Method for analysis

- a. Select all irreplaceable sites into conservation plan (([Display] = "Ir1")). These areas were classified as irreplaceable and part of CBAs in C-Plan 3.
- b. As many targets have not been met by the step above, the steps below were repeated iteratively:
 - i. Select top 5% summed irreplaceability sites (value = 001 and 002 in the display field in the planning unit file).
 - ii. Select from this set all sites with cost values of 1 (see paragraph 7.4 for explanation on cost values) and post them into the "Negotiated" box of the C-Plan software.
 - iii. Recalculate summed irreplaceability values.

- iv. Repeat step i to iii. If no sites with cost value 1 were found, select all sites with cost values of 2 into conservation plan (into the “Negotiated” box of the C-Plan software).
- v. Recalculate summed irreplaceability values.
- vi. Repeat step i to step v continuing with value 3 and 4 if no sites with cost value 1 or 2 were selected (going back to value 1 after each recalculation). Value 4 was only used in a few instances.
- vii. On the 42nd round no sites with cost value 1-3 were selected, so an efficient CBA design (minset function in C-Plan software) was employed selecting the highest irreplaceable value, if a tie was found, the biggest area was selected.
- viii. Steps were repeated from the top to check that all targets were achieved.
- ix. At stage 67 in the process the CBA design of step vii was employed until all targets were achieved.

11.3. Discussion

All targets were met with the iterative summed irreplaceability approach. This approach worked well in producing a set of areas that could be presented as an efficient set of "Critical Biodiversity Areas" (containing irreplaceable and important areas). Selecting the top 5% each time gave a less fragmented picture and also resulted in a far quicker result with a lot less processing and fewer iterations than it would be if the top 1% was selected in each iteration.

A first round of analysis found that CBAs constituted 41.0% of Gauteng – see table on the left below. This was regarded as too “land hungry”. A second round of analysis was executed, first selecting all irreplaceable areas and then employing a simple minset in C-Plan excluding the cost/threat layer so that no lower cost areas were favoured above those with a higher cost, selecting areas until all targets have been reached. The result in the table on the right proved not to be more efficient (40.9%).

Table 15: Statistics for 1st analysis including cost and 2nd analysis excluding cost for C-Plan 3

| Cost and Minset - 1st Analyses | | |
|---------------------------------------|------------------|--------------|
| Area | Ha | % |
| Excluded | 378 363 | 20.8 |
| Available | 694 531 | 38.2 |
| Important areas | 493 037 | 27.1 |
| Irreplaceable areas | 208 394 | 11.5 |
| Reserved | 43 513 | 2.4 |
| Grand Total | 1 817 838 | 100.0 |
| Total CBAs in C-Plan 3 | 744 944 | 41.0 |

| Simple Minset (no cost) - 2nd Analyses | | |
|---|------------------|--------------|
| Area | Ha | % |
| Excluded | 378 363 | 20.8 |
| Available | 696 315 | 38.3 |
| Important areas | 491 253 | 27.0 |
| Irreplaceable areas | 208 394 | 11.5 |
| Reserved | 43 513 | 2.4 |
| Grand Total | 1 817 838 | 100.0 |
| Total CBAs in C-Plan 3 | 743 160 | 40.9 |

Highlighted areas = C-Plan 3 areas

A less fragmented picture was also achieved by implementing the cost surface in the iterative selection process in the first analysis (image the left below – the image to the right shows the result excluding the cost layer.). This method gave a reasonably strong alignment with "low cost areas" that are to a greater or lesser extent already in municipalities' EMFs and SDF etc under some level of development restriction, or this is anticipated for these areas.

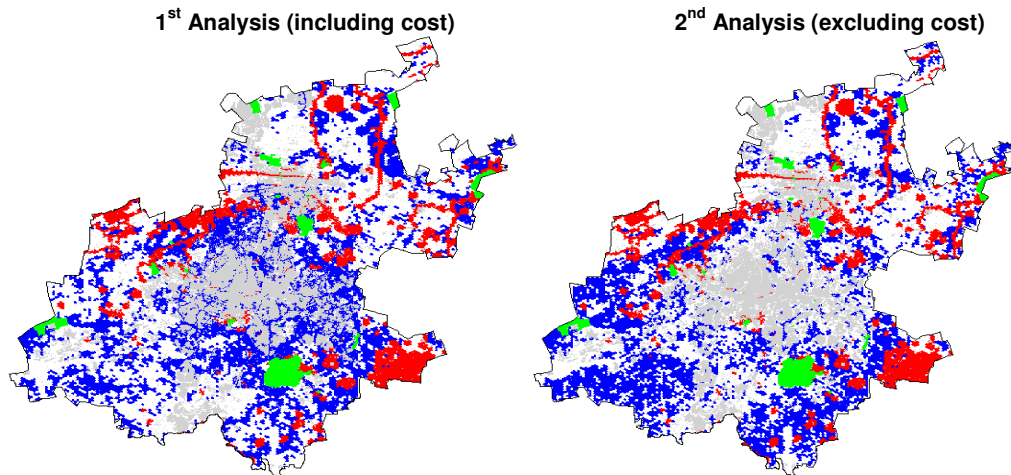


Figure 11: 1st Analysis (including cost) and 2nd Analysis (excluding cost)

Green = protected area, red = irreplaceable area, blue = important area.

To find a solution to the problem, it was decided to remove areas within Planning Units identified as irreplaceable/important that did not contain any biodiversity feature from the input files. To explain, the green coloured hexagons in the image below on the left shows the result of the 1st analysis that selected complete planning units of 100 ha each even if all biodiversity units combined only covered a part of each PU. The image on the right hand side shows the result after areas not containing any biodiversity features were removed.

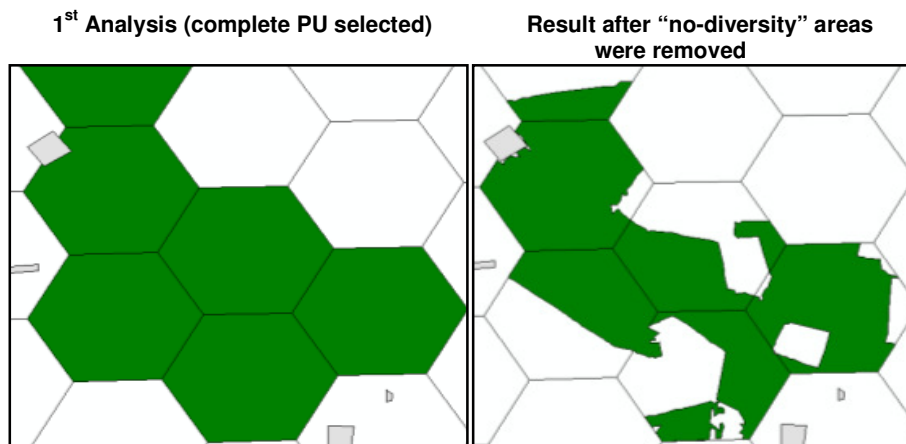


Figure 12: 1st Analysis (complete PU selected) and result after clipping to biodiversity features

Green areas constitute CBAs.

The result after the previous step proved to be much more efficient in selecting areas to be included into CBAs. All areas < 5 ha were consequently removed. C-Plan 3 therefore identified 31.8% of Gauteng (see

table on the right below) as Critical Biodiversity Areas of which only 2.4% of Gauteng is currently under some form of formal protection (level 1 and 2 PAs).

Table 16: Statistics for sub-final and final result for C-Plan 3 areas

| SUB-FINAL RESULT - C-Plan 3 | | | FINAL RESULT - C-Plan 3 | | |
|---|------------------|-------------|---|------------------|-------------|
| 1st Analyses clipped to features | | | 1st Analyses clipped to features and areas <5ha deleted | | |
| Area | Ha | % | Area | Ha | % |
| Important Areas | 356 270 | 19.6 | Important Areas | 351 217 | 19.3 |
| Irreplaceable Areas | 183 846 | 10.1 | Irreplaceable Areas | 182 896 | 10.1 |
| Protected Areas | 43 513 | 2.4 | Protected Areas | 43 513 | 2.4 |
| Rest of Gauteng | 1 234 208 | 67.9 | Rest of Gauteng | 1 240 212 | 68.2 |
| Grand Total | 1 817 838 | 100 | Grand Total | 1 817 838 | 100 |
| Total CBAs in C-Plan 3 | 583 630 | 32.1 | Total CBAs C-Plan 3.2 | 577 626 | 31.8 |

Totals for CBAs in C-Plan 3 areas highlighted in yellow.

12. C-Plan Version 3.3

12.1. Background

Since C-Plan 3 was released in December 2010, discussions took place between the C-Plan 3 Team, Dr Stephen Holness and Michele Pfab. Some municipalities were apparently concerned about agricultural areas found in some CBAs.

Agricultural areas were not included in habitat models, but agricultural areas and old lands are classified as "available" when C-Plan analyses are done. This means that they may be selected as CBAs especially by the following biodiversity features in C-Plan 3: bio-climatic regions, near-pristine quaternary catchments, fish catchment, primary vegetation (although an attempt was made to keep it "clean" using available data), wetlands and pan clusters. These areas however, are not only very sensitive for the sustainability of the biodiversity features mentioned, but also for surrounding bird habitat and it is ill advised to remove them from C-Plan.

After careful consideration it was decided to reclassify agricultural areas and old lands found in CBAs (irreplaceable, important and reserved areas) to ESAs (ecological support areas). This will align C-Plan 3 better with the National Bioregional Plan for RSA soon to be published.

C-Plan 3.1 released at the end of July 2011, contained the first round of changes made. It was realized that it needed further editing, so visual, manual checks/digitizing were done during September 2011 to produce C-Plan 3.2. All agricultural areas and old lands found by Dr Holness and by visually checking C-Plan previously classified as CBAs were classified as ESAs. Further edits were executed to remove hard transformed areas (built-up, mines, etc) that were picked up during this cleanup.

It was soon discovered that the edits caused some of the biodiversity features not to be completely reflective of the attributes in the CBAs as some of the units became separated. In other words, if parts of a CBA were reclassified to ESAs, that unit became smaller or even divided into more than one part. The smaller parts do not necessarily contain all the biodiversity features any longer that the original bigger unit contained. That may seem like errors in C-Plan 3, so it became crucial to re-intersect biodiversity features with the edited C-Plan 3.2 CBAs.

All CBAs that were left after agricultural areas and old lands were reclassified to ESAs were re-intersected one by one with each biodiversity feature (bdf) and the attributes were integrated with CBAs after each intersection for that bdf. After this process more than 4000 parts of CBAs that contained no biodiversity feature were found. It was decided to also move these parts to ESAs as they were part of original planning units selected for C-Plan 3 in the initial analysis in December 2010.

After the process above, separated parts from CBAs had to be integrated with existing ESAs. The shapefile was very complicated and large, so the software (ArcEditor) kept on bailing when an attempt was made to dissolve or explode areas due to computer memory and storage capacity problems. The Adjacent Tool in ArcView to integrate neighboring polygons sharing boundaries with each other was then tried to complete the process. After it ran for hours, and checking the result, it was discovered that many large polygons have disappeared. Examining the >4000 polygons to be integrated, it was realized that they were dissolved in cases where they came from previous CBAs (i.e. many parts with one ID dissolved into one polygon). They were exploded and they suddenly became more than 66000 polygons! The Adjacent Tool was tried again, but after an hour it was realized that the software hung up.

To solve the problem, the ESA file was divided into 7 separate smaller shapefiles and dissolved and exploded (multipart) each one in turn. The resulting files were then appended together and in the end the result contained 8670 ESAs. Because of the process that was followed, ESAs had to be renumbered, so they have completely new IDs now.

The updated CBA file and the ESA file were merged and all areas recalculated. The result for C-Plan 3.3 should now be better aligned with the planned bioregional plans.

12.2. Statistics for C-Plan 3.3

Statistics for C-Plan 3.3 were recalculated in Table 17 below. On the left the results of C-Plan 3 released in December 2010 are displayed so one can easily compare the statistics for version C-Plan 3.3 released in October 2011 on the right hand side of the table.

Currently a total of 26% of Gauteng is considered to be Critical Biodiversity Areas. Of great concern is that only 2.4% (included in this figure) is under some kind of formal protection (see Table 9 under paragraph 7.1.2 for the list of Protected Areas). It is therefore of utmost importance that CBAs containing irreplaceable and important areas be very carefully considered in areas involved in development applications.

Of the 43 956 ha under protection, only 27 761 ha (1.5% of the province) are part of provincial nature reserves. Part of Marievale and part of Suikerbosrand are classified as level 1 reserves which totals only 11 840 ha (0.7% of the province). Level 2 provincial reserves add up to 15 921 ha (0.9% of the province). The slight increase in the size of protected areas in C-Plan 3.2 came about because part of the farm Daggafontein 125-IR donated to GDARD was added to Marievale's extent.

The size of ESAs in C-Plan 3.3 increased due to reclassification of agricultural areas in CBAs to ESAs and a missing river buffer, a few large dams (to connect rivers) and some wetlands were added. The increase in the rest of Gauteng not containing any CBAs or ESAs was the result of the removal of completely transformed areas removed from C-Plan 3.3.

Transformed areas can unfortunately not all be addressed in real time, especially since Gauteng is such a fast developing province. Base data are already "old" when analyses for C-Plan starts. Hence it is very important to do ground-truthing for any projects that may involve C-Plan 3. Total accuracy cannot be guaranteed due to the nature of the data, but C-Plan Version 3.2 certainly is an improved product.

Table 17: C-Plan 3 and the final C-Plan 3.3 results

| C-Plan 3 released December 2010 | | | C-Plan 3.3 released October 2011 | | |
|---------------------------------|------------------|-------------|----------------------------------|------------------|-------------|
| Area | Ha | % | Area | Ha | % |
| Important areas | 351 217 | 19.3 | Important areas | 298 915 | 16.4 |
| Irreplaceable areas | 182 896 | 10.1 | Irreplaceable areas | 129 081 | 7.1 |
| Protected areas | 43 513 | 2.4 | *Protected areas | 43 956 | 2.4 |
| Ecological Support Areas | 251 473 | 13.8 | #Ecological Support Areas | 333 124 | 18.3 |
| Rest of Gauteng | 988 739 | 54.4 | Rest of Gauteng | 1 012 763 | 55.7 |
| Grand Total | 1 817 838 | 100 | Grand Total | 1 817 838 | 100 |
| Total CBAs in C-Plan 3 | 577 626 | 31.8 | Total CBAs C-Plan 3.2 | 471 951 | 26.0 |

*Marievale now includes Daggafontein

#Missing river buffer, wetlands and agricultural areas and old lands previously CBAs now included in ESAs.

Totals for CBAs in C-Plan 3 areas highlighted in yellow.

| Area | Hectares |
|-----------------|-------------------|
| Protected | 42 956 (2.4%) |
| CBAs | 427 996 (23.5%) |
| ESAs | 333 124 (18.3%) |
| Rest of Gauteng | 1 012 763 (55.7%) |

13. Ecological Support Areas (ESAs)

Ecological Support Areas are an imperative part of C-Plan 3 to ensure sustainability in the long term (persistence principle, Margules and Pressey, 2000b, Cowling, et al., 2003e). According to these authors a conservation plan that does not include ESAs would not be sustainable as it would assume a static (as opposed to a dynamic) environment. ESAs are part of the entire hierarchy of biodiversity, but it is not possible to include all biodiversity features. Landscape features associated with ESAs (termed spatial surrogates for ESAs) that are essential for the maintenance and generation of biodiversity in sensitive areas and that require sensitive management were incorporated into C-Plan 3 (in C-Plan 2 it was a separate file). Spatial surrogates included dolomite, rivers, wetlands, pans, corridors for climate change and species migration, ridges and low cost areas for Johannesburg and Tshwane received from Dr S Holness).

13.1. Method to create ESAs

13.1.1. Dolomite

- Dissolve C-Plan 3 result = cp3_diss.
- Intersect dolomite from AGIS_Geology with cp3_diss.
- Remove gaps from the result.
- Add field called type, capture "Dolomite" in it and dissolve on type. This is the final dolomite file for ecological processes.

13.1.2. Rivers

The 1:50 000 river data from Department of Water Affairs were mainly used. Data that were wrongly classified were reclassified. Some river lines were edited where it was completely built-up in the Johannesburg area, but some may still exist. Polygon data for rivers in the Ekurhuleni metropolitan area (good quality data!) received from Dr S Holness, were used instead of 1:50 000 DWAF drainage lines. Polygon data for the Vaal-, Suikerbosrant-, Blesbok- and parts of the Klip River digitised on-screen from Quickbird Imagery 04/05 were also used instead of 1:50 000 DWAF drainage lines.

Method:

- a. Dissolve result from C-Plan 3.
- b. Buffer non-perennial rivers with 20m.
- c. Buffer perennial rivers **within**-urban edge with 32m.
- d. Buffer perennial rivers **outside**-urban edge with 100m.
- e. Merge the three river files.
- f. Use "Select by Location" and select all rivers that intersect the C-Plan 3 result.
- g. Farm dams that broke the river lines were included for rivers intersecting C-Plan 3.

13.1.3. Wetlands

13.1.3.1. Pans

a. Good quality pans

Pans remaining after prioritisation with less than 40% urban landcover within the 1km pan catchment (that were not included in C-Plan 3 as a feature) were buffered with 1km.

b. Transformed pans:

Buffer transformed pans with more than 40% urban landcover within the 1km pan catchment by 30m / 50m depending on whether they are in/outside the urban edge.

13.1.3.2. Other Wetlands

Wetlands were updated extensively since C-Plan 2 using Quickbird Imagery 04/05 up to the end of November 2010. Riparian areas digitized for birds during 2009-2010 by GDARD were integrated into GDARD wetlands. Wetlands for Ekurhuleni metropolitan area received from Dr S Holness (very good quality!) were integrated into GDARD's wetland layer. Some wetlands received from Dr S Holness for the Johannesburg metro were not updated by GDARD due to lack of time. These were kept in a separate layer (the quality was good in places, but not so good in others).

- a. Buffer GDARD & Ekurhuleni wetlands with nominal buffers from the edge of the temporary zone of 30m and 50m within and outside the urban edge respectively.
- b. Used land cover 2009 from GTI and assessed rate of transformation for wetlands in priority quaternary catchments.
- c. Buffer good quality wetlands (< 40% urban transformed) inside priority quaternary catchments by 340m. This buffer was used on advise of Dr C Whittington-Jones who provided the following information as motivation: "*Semlitsch & Bodie (2003) recommend several zones (aquatic buffer, core terrestrial habitat and terrestrial buffer) of protection around wetlands and streams to conserve water quality and to provide sufficient terrestrial habitat to meet the requirements of associated semi-aquatic reptile and amphibian diversity. The maximum combined extent of these zones is 340m around the wetland*".
- d. Merged all buffered wetlands above and appended unbuffered Johannesburg metro wetlands (those not updated). The latter was not buffered as they were not deemed to be of the same quality as those of Ekurhuleni, but they were still useful.

13.1.4. Corridors

In order to facilitate wildlife dispersal between priority biodiversity areas and particularly in response to climate change, a corridor network was created to be included in the ESAs for C-Plan 3.

Corridor analyses done in 2006 were repeated from scratch because:

- i. Updated land cover for 2009 done by GeoTerra Image (GTI) became available.
- ii. Gauteng land use changes quite rapidly and many areas were transformed since C-Plan 2 of 2005.
- iii. The Gauteng boundary changed in certain areas and now it also now includes the Merafong municipal area.

Using GTI land cover 2009 data, two frictional surfaces were created, one favouring ridges and hills and a second favouring rivers and wetlands as suitable movement corridors. Low frictional values were assigned to natural land cover, while high frictional values were assigned to transformed areas of the landscape. Least cost pathways between priority biodiversity areas and along expected gradients of climatic change, specifically relating to temperature and rainfall, were determined using cost and distance surfaces derived from the frictional surfaces. A standard width of 600m was applied to all identified corridors. A separate document detailing the method, is available. Below is a summary.

Method:

Corridors for Gauteng were developed in five stages:

- i. Two frictional surfaces (riparian and ridges) were created based on GTI 2009 land cover created from SPOT 5 satellite imagery.
- ii. Several cost- and distance surfaces were created based on:
 - Points for species migration and climate change; and
 - The frictional surfaces created in stage i.
- iii. Shortest routes / paths between points were created using cost and distance surfaces created in stage ii.
- iv. All shortest pathways were next buffered by a standard width of 300m (600m wide corridors).
- v. In the last stage, shortest routes were merged into 1 layer depicting a corridor for species migration and a corridor for climate change.

ESRI's ArcGIS 9.3.1 GIS software was used in the analysis including Spatial Analyst, ModelBuilder and Spatial Analyst Tools such as Cost Distance and Shortest Path.

The following values were used for each frictional surface classified to a common scale ranging between 1-1000:

Table 18: Ridges frictional surface features and values

| Value | Land use |
|-------|--|
| 1 | Ridges coinciding with C-plan 2.1 irreplaceable, important & reserved sites |
| 3 | Remaining untransformed ridges not coinciding with C-plan areas |
| 10 | Remaining C-plan areas (irreplaceable, important & reserved areas not included in first feature). |
| 30 | All untransformed land (natural vegetation) that does not coincide with any of the above. The following from GTI 2009 land cover were used: Dense Trees / Bush, Grassland, Natural Bare Rock, Natural Water, Rocky Grass Matrix, Urban Grass, Urban Woodland , Wetland (non pan), Wetland Pans, Wooded Grassland, Woodland / Open Bush |
| 60 | All land within 300m of transformed land (urban, mines & intensive cattle camps but not smallholdings). |
| 100 | All agricultural (including secondary vegetation / "old lands") & degraded land. The following from GTI 2009 land cover were used: All Old Lands, all cultivated areas, Degraded land, Man-made Water, Non-Vegetated / Bare land, Plantation & Woodlot, Smallholdings: Cultivated, Urban Trees |
| 500 | Sports & Recreation Grassland and the following land cover on all Smallholdings: Degraded, Dense Trees / Bush, Grassland, Wooded Grassland, Woodland / Open Bush. |

| | |
|--------|--|
| 800 | Minor roads (one lane in each direction) |
| 1000 | Major roads (two or more lanes in each direction) |
| NoData | All transformed land (urban, mines and intensive cattle camps) |

Assign highest frictional value to cell/grid (where two values apply to same grid) - No Data is "higher" than 1000.

Table 19: Riparian frictional surface features and values

| | |
|--------|---|
| 1 | Wetlands & rivers (perennial & non-perennial) coinciding with C-plan 2.1 irreplaceable, important & reserved areas. |
| 3 | Wetlands & rivers (perennial & non-perennial) not included in the above. |
| 10 | Remaining C-plan areas (irreplaceable, important & reserved areas not included in first feature). |
| 30 | All untransformed land (natural vegetation) that does not coincide with any of the above. The following from GTI 2009 land cover were used: Dense Trees / Bush, Grassland, Natural Bare Rock, Natural Water, Rocky Grass Matrix, Urban Grass, Urban Woodland , Wetland (non pan), Wetland Pans, Wooded Grassland, Woodland / Open Bush. |
| 60 | All land within 300m of transformed land (urban, mines & intensive cattle camps but not smallholdings). |
| 100 | All agricultural (including secondary vegetation / "old lands") & degraded land. The following from GTI 2009 land cover were used: All Old Lands, all cultivated areas, Degraded land, Man-made Water, Non-Vegetated / Bare land, Plantation & Woodlot, Smallholdings: Cultivated, Urban Trees. |
| 500 | Sports & Recreation Grassland and the following land cover on all Smallholdings: Degraded, Dense Trees / Bush, Grassland, Wooded Grassland, Woodland / Open Bush. |
| 800 | Minor roads (one lane in each direction) |
| 1000 | Major roads (two or more lanes in each direction) |
| NoData | All transformed land (urban, mines and intensive cattle camps) |

Assign highest frictional value to cell/grid (where two values apply to same grid) - No Data is "higher" than 1000.

13.1.5. Ridges

Ridges version 7 includes:

- Ridges version 6 for Gauteng (excluding Merafong) that present the distribution of ridges / koppies / mountains (slopes that are equal to, or greater than, 5° (i.e. => 8.8%, => 1 in 11 gradient steepness).
- Ridges received from Tshwane municipality were used as a basis to update some ridges. Due to lack of time, not all of them could be done. Their data could not be used as is, as it included many steep areas next to highways, sport stadiums, or even high rise buildings.
- Ridges and koppies received from North West Province in 2009 for Merafong.

Ridges were re-analysed for rate of transformation to establish and classified as follows (not needed for C-Plan 3):

Class 1: >= 95% natural

Class 2: >= 65% and < 95% natural

Class 3: >= 35% and < 65% natural

Class 4: < 35% natural.

Method:

- Buffer cp3_diss with 1500m = cp3_diss_buf1500m.
- Use "Select by location" to select all ridges that intersect cp3_diss_buf1500m.
- Export selected ridges.
- Remove excluded areas (built-up areas & mines) digitized for C-Plan 3 from ridges.

13.1.6. Metropolitan low cost areas

Dr S Holness provided a layer for low cost/threat for the Johannesburg & Tshwane metros to be incorporated into ecological support areas. Metadata received from Dr Holness follow:

13.1.6.1. Original data

The layers were developed based largely on the following documents and their associated data layers:

- Ekurhuleni Metropolitan Open Space System
- Tshwane Open Space Framework
- City of Johannesburg Open Space Framework

Refer to these documents for descriptions and additional information where available.

13.1.6.2. Data compilation method

Spatial data underlying the Open Space Frameworks and Open Space Systems for the various Metropolitan Areas of Gauteng were examined in order to identify areas that are either part of the current open space systems of these metros, are reflected as such in the applicable zoning system or equivalent land use planning mechanism such as an Environmental Management Framework, or alternatively have been identified as being high value areas for inclusion into the open space system.

Summary of the data compilation method:

- Ekurhuleni Metropolitan Open Space System and EMF:
 - The underlying data used for the analysis of the EMOSS system, were examined. Two key categories of data were extracted:
 - Sites within the identified open space system that either enjoy current protection or alternatively are identified to become part of this system.
 - Additional high value sites identified in the EMOSS analysis that are not part of final system, but nevertheless are identified by the EMOSS or EMF as being of high value (usually intact primary grasslands or wetlands) but that are not necessarily included in the major nodes, minor nodes or corridors of the EMOSS.
- City of Johannesburg Open Space Framework:
 - The outcomes of the Open Space Framework planning process were examined. The key data that were extracted were:
 - Identified portions of the “Green Network” (Nodes, corridors etc) which are effectively sites with presumed high ecological value.
 - Areas that are currently form part of or are zoned as Public Open Space.
- Tshwane Open Space Framework:
 - The outcomes of the Open Space Framework planning process were examined. The key data that were extracted were:
 - Green Nodes – current and future sites of high value
 - Green Ways – broader important linkages (especially ridges and corridors)
 - Blue Ways – as above but for wetland features.

These layers were combined and significantly refined. Numerous topological errors were eliminated. Sites of under 2ha were removed as being inappropriate for the provincial level plan.

13.1.6.3. Recommendation for inclusion in CPLAN 3:

The purpose is to identify areas which could be included into CPlan3 with little or no conflict with underlying spatial planning instruments for the metros. These areas would be:

- Already part of an open space system

- Identified as priority areas for the expansion of the open space system
- Zoned or reflected in a way that restricts development options at a site
- Known high ecological value sites that are reflected in metro planning processes.

Importantly, this does not necessarily mean that there are high value features at the specific site or that these should necessarily all be included in a CPlan3 output. Nevertheless where the identified sites formed part of the CPlan3 outcome, they would be likely to enjoy far quicker mainstreaming into planning processes and the features found on these sites would be likely to enjoy stronger protection than similar features on sites outside of this network. Inclusion of natural portions of these areas into Cplan3 could be undertaken at significantly lower "cost" than areas that are outside these footprints. It is recommended that where any of these areas which contribute to any targets (even if they are not the most efficient sites) that they should be included in the identified set of Critical Biodiversity Areas.

The recommendation from Dr Holness was accepted and this layer was incorporated into ESAs.

13.2. Final Ecological Support Areas

Combine separate layers created above into the ESAs file as follows:

- Added all layers, two at a time and dissolved files [the software bailed when attempting to dissolve all layers simultaneously probably due to lack of RAM and hard disk too full] and then did a multipart. Even this made the software bail at times and some were done using XTools in ArcView 3.2 which seems to be less memory intensive.
- The process was repeated until all were dissolved into one layer.
- Did a union between C-Plan 3 result and the Gauteng province.
- Extracted part of Gauteng that does not coincide with any C-Plan 3 areas.
- Did a multipart on the result.
- Intersect the combined ESAs with the previous result to remove any area that overlaps C-Plan 3 areas.

14. Conclusion

C-Plan 3 released in December 2010 was edited in July 2011 (C-Plan 3.1) September 2011 (C-Plan 3.2), and lastly in October 2011 producing C-Plan 3.3. C-Plan 3.3 includes the following that will be used as input into the National Bioregional Plan for the country:

- Critical Biodiversity Areas containing Irreplaceable, Important and Protected Areas all merged together into one layer. The attribute table will still contain a field displaying the old symbology of Irreplaceable, Important and Protected Areas. A field is also included indicating what type of biodiversity is contained in planning units.
- Ecological Support Areas containing all layers as compiled in paragraph 13. Due to the size of the file, attributes were not included in the file.

Overall C-Plan 3.3, especially after the updates during 2011, is regarded as a huge improvement on C-Plan 2. Transformed areas can unfortunately not all be addressed in real time, especially since Gauteng is such a fast developing province. Base data are already "old" when analyses for C-Plan starts. Hence it is very important to do ground-truthing for any projects that may involve C-Plan 3.3. Total accuracy cannot be guaranteed due to the nature of the data, but C-Plan Version 3.3 certainly is an improved product.

A 1:50 000 scale would probably be applicable for implementation. Many input layers were of a much finer scale, but layers such as geology, land types, etc have a much rougher scale.

15. Acknowledgements

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17. List of Spatial Data used

| Data set | Data Source / Custodian |
|--|---|
| Bioclimatic zones (for Climate change layer) | GDARD (assisted by Dr Stephen Holness NMMU) |
| Birds (Red Listed Priority birds habitat models based on confirmed occurrence) | GDARD |
| Carbon sequestration layer included unique woodland areas digitized using QuickBird Imagery, Google Earth and field visits. | GDARD (assisted by David Hoare) |
| Catchments (Near-pristine Quaternary) | DWA |
| Climate Information System. © ARC-Institute for Soil, Climate and Water, Pretoria. | ARC-Institute for Soil, Climate and Water, Pretoria. Agrometeorology Staff. (2001). |
| Cost / Threat layer derived from various data layers, i.e.: Protected areas, Conservancies, low cost areas for metros received from Dr S Holness, Corridors and Ecological processes (dolomite, ridges, perennial rivers, wetlands and apans). Composite threat map created by GDARD for C-Plan 2 (2004) including agriculture, and urban areas: | GDARD |
| Conservancies | GDARD |
| Cultivated Areas | GDARD |
| Cultivated areas. Used to augment data created by GDARD. | National Department of Agriculture. (2007) |
| Fish (Maloney's Eye sub Catchment containing unique fish species) | GDARD (assisted by Piet Muller) |
| Geology | AGIS (Agricultural Geo-Referenced Information System) |
| Invertebrates (Red Listed confirmed buffered records and habitat models) | GDARD |
| Land Types for Gauteng | AGIS (Agricultural Geo-Referenced Information System) |
| Land Types of South Africa: Digital map (1:250 000 scale) ©. ARC-Institute for Soil, Climate and Water, Pretoria. | ARC-Institute for Soil, Climate and Water, Pretoria. Land Type Survey Staff. (1972 – 2006). |
| Land-Cover Raster Dataset for Gauteng based on single date SPOT5 10m resolution satellite imagery, acquired during both 2009 and 2008, and 50cm resolution aerial photography acquired in 2009 | GeoTerralimage (GTI) Pty Ltd. Pretoria, South Africa. (2009). |
| Mammals (Red Listed confirmed buffered records and habitat models) | GDARD Data were received by the following persons too: <ul style="list-style-type: none"> - Botha D (PRISM Environmental Management Services): <i>Neamblysomus julianae</i> and <i>Chrysospalax villosus</i> data. - Jackson CR: <i>Neamblysomus julianae</i> - Maree S. & Botha D. (2008-2012). Biodiversity site surveys for Juliana's golden mole (<i>Neamblysomus julianae</i>). |

| Data set | Data Source / Custodian |
|---|--|
| | <ul style="list-style-type: none"> - Strijbis, L. 2007. <i>Myotis welwitshii</i> encountered near Bronkhortspruit, Gauteng, South Africa. African Bat Conservation News Volume 17. (This is for the record near Bronkhortspruit). - Gauteng and Northern Regions Bat Interest Group (Personal Communications). (This is for the Springs <i>Myotis welwitshii</i> record; Julio Balona from GNORBIG agrees that it should be Pers. Comm.) |
| Plants (Red and Orange Listed confirmed buffered records and habitat models) | GDARD (assisted by M Pfab of SANBI) |
| Protected Areas | GDARD |
| QuickBird Land cover. (2006). Based on Quickbird satellite imagery 2004/05. Data modified by GDARD from "Zonation of High Potential Agricultural land in Gauteng Province" project. | EnviroGIS (Pty) Ltd |
| QuickBird satellite imagery 2004/05 (0.61m pixel resolution degree of detail). Used extensively as a backdrop and updating of land cover / use data. | Department of Housing in 2006 (Obtained data from them) |
| Ridges | GDARD |
| Rivers (1:50 000 scale). Augmented in areas by GDARD (digitized based on QuickBird Imagery 2004/05) | DWA |
| Reptiles (Red Listed habitat model based on confirmed occurrence) | GDARD |
| Soil inventory database (1:250 000 scale). ©. ARC-Institute for Soil, Climate and Water, Pretoria. | ARC-Institute for Soil, Climate and Water, Pretoria. Land Type Survey Staff. (1972 – 2006). |
| DEM: SRTM 90m Digital Elevation Model version 4. Mosaiced by DWA. (2008 received 2009). Other data layers GDARD derived from the DEM included altitude, aspect and slope used in habitat modeling. | Consortium for Spatial Information (CGIAR-CSI) (http://srtm.csi.cgiar.org/) |
| Vegetation | Hoare D, Pfab M & GDARD (2010) |
| Wetlands & Pans | GDARD |
| Wetlands for Ekurhuleni & Johannesburg Metros | Holness S Nelson Mandela Metropolitan University (Received data from him) |

Appendix 1: Red and Orange Listed plant species (amended January 2009) and their targets used in C-Plan 3

| Species | Priority Grouping | Conservation Status (¹ global status; ² national status) | Area confirmed (ha) Target 100% | Total nr of habitat & meta-populations | Target nr habitat & meta-populations |
|---|--------------------------|--|--|---|---|
| <i>Adromischus umbraticola</i> subsp. <i>umbraticola</i> | A2 | Near Threatened ¹ | 408 | 31 | 9 |
| <i>Alepidea attenuata</i> | B | Near Threatened ² | | 18 | 1 |
| <i>Aloe peglerae</i> | A2 | Endangered ¹ | 2 918 | | |
| <i>Argyrobium campicola</i> | A3 | Near Threatened ¹ | | 7 | 2 |
| <i>Argyrobium megarrhizum</i> | A3 | Near Threatened ¹ | | 15 | 3 |
| <i>Blepharis uniflora</i> | A2 | Rare ¹ | | 11 | 1 |
| <i>Bowiea volubilis</i> subsp. <i>volubilis</i> | B | Vulnerable ² | 4 180 | | |
| <i>Brachycorythis conica</i> subsp. <i>transvaalensis</i> | A3 | Vulnerable ¹ | 187 | 57 | 15 |
| <i>Brachystelma discoideum</i> | B | Endangered ² | | 13 | 3 |
| <i>Ceropegia decidua</i> subsp. <i>pretoriensis</i> | A1 | Vulnerable ¹ | 868 | 75 | 36 |
| <i>Ceropegia turricula</i> | A3 | Near Threatened ¹ | | 25 | 5 |
| <i>Cheilanthes deltoidea</i> subsp. nov. Gauteng form | A2 | Vulnerable ¹ | 287 | 116 | 17 |
| <i>Cineraria austrotransvaalensis</i> | A3 | Near Threatened ¹ | 24 | 95 | 29 |
| <i>Cineraria longipes</i> | A1 | Vulnerable ¹ | 2 446 | 117 | 39 |
| <i>Cleome conrathii</i> | A3 | Near Threatened ¹ | 296 | | |
| <i>Cucumis humifructus</i> | B | Vulnerable ² | | 13 | 3 |
| <i>Delosperma gautengense</i> | A1 | Vulnerable ¹ | 153 | | |
| <i>Delosperma leendertziae</i> | A2 | Near Threatened ¹ | 1 453 | 4 | 1 |
| <i>Delosperma macellum</i> | A2 | Endangered ¹ | 92 | | |
| <i>Delosperma purpureum</i> | A1 | Endangered ¹ | 70 | | |
| <i>Dioscorea sylvatica</i> | B | Vulnerable ² | | 63 | 1 |
| <i>Encephalartos lanatus</i> | A2 | Vulnerable ¹ | 412 | 13 | 3 |
| <i>Encephalartos middelburgensis</i> | A2 | Critically Endangered ¹ | 1 960 | | |

| Species | Priority Grouping | Conservation Status (¹ global status; ² national status) | Area confirmed (ha) Target 100% | Total nr of habitat & meta- populations | Target nr habitat & meta- populations |
|---|-------------------|---|---------------------------------------|--|--|
| <i>Eulophia coddii</i> | A2 | Vulnerable ¹ | | 72 | 24 |
| <i>Frithia humilis</i> | A2 | Vulnerable ¹ | 573 | 8 | 3 |
| <i>Frithia pulchra</i> | A2 | Rare ¹ | 97 | | |
| <i>Gladiolus pole-evansii</i> | A2 | Rare-sparse ¹ | | 17 | 1 |
| <i>Gladiolus robertsoniae</i> | A3 | Near Threatened ¹ | 63 | 12 | 3 |
| <i>Gnaphalium nelsonii</i> | A2 | Rare-sparse ¹ | | 33 | 8 |
| <i>Habenaria barbertoni</i> | A2 | Near Threatened ¹ | 83 | 55 | 15 |
| <i>Habenaria bicolor</i> | B | Near Threatened ² | | 100 | 27 |
| <i>Habenaria kraenzliniana</i> | A3 | Near Threatened ¹ | 78 | 161 | 44 |
| <i>Habenaria mossii</i> | A1 | Endangered ¹ | 553 | 57 | 17 |
| <i>Holothrix micrantha</i> | A1 | Endangered ¹ | | 24 | 11 |
| <i>Holothrix randii</i> | B | Near Threatened ² | 474 | 126 | 35 |
| <i>Khadia beswickii</i> | A1 | Vulnerable ¹ | 1 759 | 8 | 2 |
| <i>Kniphofia typhoides</i> | A3 | Near Threatened ¹ | 779 | 39 | 1 |
| <i>Lithops lesliei</i> subsp. <i>lesliei</i> | B | Near Threatened ² | 1 629 | | |
| <i>Lithops lesliei</i> subsp. <i>lesliei</i> var. <i>rubrobrunnea</i> | A1 | Endangered ¹ | 258 | 1 | 1 |
| <i>Melolobium subspicatum</i> | A1 | Vulnerable ¹ | 1 748 | 5 | 2 |
| <i>Nerine gracilis</i> | A3 | Near Threatened ¹ | 277 | | |
| <i>Prunus africana</i> | B | Vulnerable ² | | 11 | 3 |
| <i>Searsia gracillima</i> var. <i>gracillima</i> | A1 | Near Threatened ¹ | 126 | 22 | 8 |
| <i>Stenostelma umbelluliferum</i> | A3 | Near Threatened ¹ | 169 | 89 | 19 |
| <i>Trachyandra erythrorrhiza</i> | A3 | Near Threatened ¹ | 1 056 | 134 | 35 |

Appendix 2: Vegetation (Hoare, et. al., 2010) and their targets included in C-Plan 3

| Vegetation | Total Vegetation (ha) | Total Untransformed / Primary Vegetation (ha) | Target (ha) | Target % of Total Vegetation | Target % of Primary Vegetation |
|--|-----------------------|---|-------------|------------------------------|--------------------------------|
| Central Sandy Bushveld | 193 187 | 111 298 | 48 486 | 25 | 44 |
| Clay Grassland | 30 604 | 12 961 | 2 374 | 8 | 18 |
| Gauteng Grassland | 1 046 365 | 296 153 | 219 044 | 21 | 74 |
| Loskop Mountain Bushveld | 39 987 | 37 030 | 9 145 | 23 | 25 |
| Magaliesberg Mountain Bushveld | 23 822 | 19 888 | 5 383 | 23 | 27 |
| Marikana Thornveld | 89 778 | 32 359 | 18 750 | 21 | 58 |
| Moot Plains Bushveld | 48 750 | 21 589 | 10 913 | 22 | 51 |
| Mountain Bushveld | 180 225 | 140 178 | 44 027 | 24 | 31 |
| Norite Koppies Bushveld | 3 021 | 2 328 | 810 | 27 | 35 |
| Rand Highveld Grassland | 143 674 | 49 995 | 27 187 | 19 | 54 |
| Springbokvlakte Thornveld | 18 069 | 7 985 | 3 230 | 18 | 40 |
| Waterberg-Magaliesberg Summit Sourveld | 350 | 346 | 79 | 23 | 23 |

Appendix 3: Near-pristine Quaternary Catchments and their targets included in C-Plan 3

| Quaternary Catchment | *State of rivers | Total Area (ha) | Target (ha) | Target (%) |
|--|-------------------------|------------------------|--------------------|-------------------|
| Elands Quaternary Catchment | B | 68 766 | 40 572 | 59 |
| Skeerpoort Quaternary Catchment | B | 11 055 | 6 522 | 59 |
| Upper Suikerbosrant Quaternary Catchment | C | 74 910 | 34 459 | 46 |
| Wilge Quaternary Catchment | B | 77 267 | 45 588 | 59 |

*State of River Health Report

Appendix 4: Priority Red Listed birds and their targets included in C-Plan 3

| Bird | Status | Total Habitat Area (ha) | Target (ha) | Target (%) |
|--|-----------------|--------------------------------|--------------------|-------------------|
| <i>Alcedo semitorquata</i> | Near Threatened | 11 863 | 11 863 | 100 |
| <i>Anthropoides paradiseus</i> breeding area | Vulnerable | 6 160 | 3 420 | 56 |
| <i>Anthropoides paradiseus</i> overwinter area | Vulnerable | 9 624 | 9 624 | 100 |
| <i>Circus ranivorus</i> | Vulnerable | 23 357 | 10 000 | 43 |
| <i>Eupodotis caerulea</i> | Near Threatened | 14 937 | 10 000 | 67 |
| <i>Eupodotis senegalensis</i> | Vulnerable | 21 337 | 14 400 | 67 |
| <i>Gorsachius leuconotus</i> | Vulnerable | 5 112 | 5 112 | 100 |
| <i>Gyps coprotheres</i> breeding area | Vulnerable | 3 496 | 3 496 | 100 |
| <i>Mirafra cheniana</i> | Near Threatened | 16 556 | 640 | 4 |
| <i>Podica senegalensis</i> | Vulnerable | 11 292 | 11 292 | 100 |
| <i>Sagittarius serpentarius</i> | Near Threatened | 226 962 | 94 500 | 42 |
| <i>Tyto capensis</i> | Vulnerable | 369 310 | 39 000 | 11 |

Appendix 5: Red Listed invertebrates and their targets included in C-Plan 3

| Invertebrate | Status | Area Conf (Ha) 100% Target | Habitat (ha) | Habitat Target (ha) | Habitat Target % |
|-----------------------------------|---------------|---|-------------------------|------------------------------------|---------------------------------|
| <i>Aloeides dentatis dentatis</i> | Vulnerable | 2 438 | 0 | 0 | 0 |
| <i>Chrysoritis aureus</i> | Vulnerable | 3 | 9 873 | 1 975 | 20 |
| <i>Ichneustoma stobbiai</i> | Vulnerable | 319 | 12 806 | 12 806 | 100 |
| <i>Lepidochrysops praeterita</i> | Vulnerable | 152 | 13 803 | 2 761 | 20 |

Appendix 6: Red Listed mammals and their targets included in C-Plan 3

| Mammal | Status | Area Conf (Ha) 100% Target | Habitat (ha) | Habitat Target (ha) | Habitat Target % |
|----------------------------------|-----------------|---|-------------------------|------------------------------------|-----------------------------|
| <i>Atelerix frontalis</i> | Near Threatened | | 7 391 | 3 000 | 41 |
| <i>Lutra maculicollis</i> | Near Threatened | | 53 689 | 20 300 | 38 |
| <i>Miniopterus schreibersii</i> | Near Threatened | 784 | | | |
| <i>Myotis tricolor</i> | Near Threatened | 290 | | | |
| <i>Mystromys albicaudatus</i> | Endangered | | 6 015 | 2 000 | 33 |
| <i>Neamblysomus julianae</i> | Vulnerable | 5 336 | | | |
| <i>Rhinolophus blasii</i> | Vulnerable | 473 | | | |
| <i>Rhinolophus clivosus</i> | Near Threatened | 388 | 694 | 694 | 100 |
| <i>Rhinolophus darlingi</i> | Near Threatened | 237 | | | |
| <i>Rhinolophus hildebrandtii</i> | Near Threatened | 79 | | | |

Appendix 7: Red Listed reptiles and their targets included in C-Plan 3

| Reptile | Status | Total area (ha) | Target (ha) | Target % |
|------------------------------|-----------------|------------------------|--------------------|-----------------|
| <i>Homoroselaps dorsalis</i> | Near Threatened | 10 865 | 10865 | 100 |

Appendix 8: Other biodiversity features and their targets included in C-Plan 3

| | Total area (ha) | Target (ha) | Target % |
|---|------------------------|--------------------|-----------------|
| Unique Fish (Maloney's Eye sub Catchment) | 1061 | 1061 | 100 |
| Climate change: Bioclimatic zones | 78586 | 70727 | 90 |
| Carbon sequestration: Dinokeng Scarp Woodland | 43 | 43 | 100 |
| Carbon sequestration: Magaliesberg Scarp Woodland | 1908 | 1908 | 100 |
| Carbon sequestration: Suikerbosrand Mesic Woodland | 346 | 346 | 100 |
| Carbon sequestration: Wilge Scarp Woodland | 232 | 232 | 100 |
| Pan cluster, good quality | 10382 | 10382 | 100 |
| Pan cluster within near-pristine Quaternary Catchment | 22256 | 22256 | 100 |

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