THE RED LIST OF MAMMALS
OF SOUTH AFRICA, SWAZILAND AND LESOTHO
2016

EDITED BY MATTHEW F. CHILD, LIZANNE ROXBURGH, EMMANUEL DO LINH SAN, DOMITILLA RAIMONDO AND HARRIET T. DAVIES-MOSTERT

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Roan Antelope (*Hippotragus equinus*) – Cliff & Suretha Dorse

Mammal Red List 2016:
Introduction and Methodology

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This document is Version 1 (December 2017) and provides the methodological details necessary to interpret the assessments. The text may be revised in later versions of the document, especially in preparation for a print publication. A full analysis of the status of our mammal species will be published in 2018.

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Institutional partnership

The Endangered Wildlife Trust partnered with the South African National Biodiversity Institute (SANBI), supported by collaborations with MammalMAP (a partnership between the Animal Demography Unit, University of Cape Town and the Mammal Research Institute, University of Pretoria) and the Species Survival Commission (SSC) of the IUCN. Key stakeholders and contributors also included South African National Parks (SANParks), provincial conservation agencies, universities, museums and the private sector.

Editor contributions

	Name	Institution	Role
EDITORS	Matthew Child	Endangered Wildlife Trust & South African National Biodiversity Institute	Project management, data collation, assessment design, assessment review, technical editing, writing, proof-reading
	Dr Lizanne Roxburgh	Endangered Wildlife Trust	Database management (2015–2016), map design and production, proof-reading
	Prof. Emmanuel Do Linh San	University of Fort Hare	Small carnivore lead, technical editing, assessment design, proof-reading
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	Dr Tali Hoffmann	MammalMAP	Database management (2013–2014)
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Steering Committee

The Mammal Red List Project Steering Committee assisted with project strategy, data collection advice and layout/editing recommendations. They are (listed in alphabetical order):

Name	Surname	Institution
Sam	Ferreira	South African National Parks
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Dan	Parker	Rhodes University
Michele	Pfab	South African National Biodiversity Institute
Les	Underhill	University of Cape Town

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Name	Organisation	Species supported
Julio Balona	Private	*Pipistrellus rusticus*
Liz Bath	Private	*Panthera pardus*
Rosalind Cleaver	Private	*Macroscelides proboscideus*
Di Crawley	Private	*Vulpes chama*
Mark Drutman	Private	*Amblysomus septentrionalis, Damaliscus lunatus*
Guy Ellis	X-Posé Holdings (Pty) Ltd	*Diceros bicornis, Ceratotherium simum, Lycaon pictus*
Andy and Peter Fish	Private	*Smutsia temminckii*
Walter Hirzebruch	Private	*Neoromicia zuluensis*
Jessica Knight and Ian White	Private	*Myomyscus verreauxii*
Paco and Leandra Mendes	Private	*Acinonyx jubatus*
Genevieve Pearson	Private	*Pseudorca crassidens*
James Skuse	Private	*Petromyscus collinus*
Nick Taylor	Private	*Ourebia ourebi*

Assessors, reviewers and contributors

This revision was made by possible by the input of 377 experts from across the spectrum of the conservation sector (Appendix 1). We are grateful for their contributions. Most assessments include representatives of various sectors so as to mitigate potential bias in interpretation and risk tolerance (Hayward et al. 2015), where the proportion of contribution across sector groups is equitable (Table 1). We use the IUCN Red List authorship categories of assessors, reviewers and contributors. As there were many people involved in all stages of the assessment process, determining author category and rank was based on the following heuristics:

1. All experts who contributed to the initial assessment are listed as assessors, where author order depended on the strength of one of the following:
    - Contribution to writing the assessment.
    - Contribution to providing data essential to the Red List status – evidence for population increase or decline, including specific analyses that aided the assessment.
2. Both assessors and reviewers are listed as authors, but distinguished in the expert network database. However, reviewers are only listed as authors where they contributed significantly to the writing and/or strength of logic of the assessment, not simply commenting. Otherwise, they were listed as contributors.
3. Where assessors or reviewers did not contribute significantly towards the writing or analysis of the assessment but provided comments and/or auxiliary information, they are listed as contributors.
4. Where draft assessments were compiled following key expert workshops (Cetacea, Chiroptera, Rodentia and Soricomorpha), the above rules applied but were modified by the following:
    - If post-workshop drafts were enhanced significantly by particular workshop attendees or external experts identified at the workshop, they were listed as the authors, while the remaining workshop attendees were listed as contributors.
    - If the post-workshop drafts were not modified significantly, then all workshop attendees were listed as authors in alphabetical order.
5. Where a core editing team member contributed significantly to the development of the assessment, they were listed as an author or contributor depending on the significance or time input of the contribution.

6. Where assessments drew heavily on the global assessment, the global assessment authors were listed as contributors.

For a complete list of all assessors, reviewers and contributors, please see Appendix 1.

Data providers

We are grateful to all the institutions (Table 1) and individuals who provided data for the Red List revision. This database is the foundation of the assessments and ongoing efforts to clean, integrate and build on the database will ensure future revisions run more efficiently (see Distribution and Key recommendations).

Table 1. List of data-providing institutions for the Red List revision, ranked by number of records provided. These data are unique, vetted and geo-referenced records (but see details on page 10), which underwent several rounds of data cleaning.

Institution	Number of records
South African National Parks	92,637
University of Cape Town	42,959
Eastern Cape Parks and Tourism Agency	39,803
North West Department of Economic Development, Environment, Conservation and Tourism	33,475
Ditsong National Museum of Natural History	31,966
CapeNature	28,890
Amathole Museum	22,962
Africa: LIVE	19,890
Ezemvelo KZN Wildlife	16,066
University of Pretoria	11,320
African Bats	10,622
University of Swaziland and University of Venda	9,032
Animal Demography Unit, University of Cape Town	8,829
Iziko Museum South Africa	8,402
Gauteng Department of Agriculture and Rural Development	8,169
Durban Natural Science Museum	7,635
Private contributors	7,064
Endangered Wildlife Trust	6,876
Mpumalanga Tourism and Parks Agency	5,940
E Oppenheimer & Son and De Beers Group of Companies	5,000
McGregor Museum	4,883
University of New South Wales	4,862
Free State Department of Economic, Small Business Development, Tourism and Environmental Affairs	4,532
Department of Economic Development, Tourism and Environmental Affairs	3,606
Agricultural Research Council	2,868
Limpopo Department of Economic Development, Environment and Tourism	2,670
Durham University	2,287
Rhodes University	2,269
University of the Free State	2,264
National Museum, Bloemfontein	2,098
Northern Cape Department of Environment and Nature Conservation	1,884
University of KwaZulu-Natal	1,596
KwaZulu-Natal Museum	1,346
University of the Witwatersrand	991
Nottingham Trent University	701
Gauteng and Northern Regions Bat Interest Group	625
Earthwatch	513
University of Johannesburg	479
University of Venda	444
Madikwe Private Reserve	317
Cape Leopard Trust	315
African Pangolin Working Group	311
Published literature	253
Stellenbosch University	243
Nelson Mandela Metropolitan University	212
Natural Scientific Services	207
Bangor University	127
Cardiff University	118
University of Fort Hare	117
Khamab Kalahari Reserve	42
Buffelskloof Private Nature Reserve	41
Council for Industrial and Scientific Research	38
University of Northern Colorado	32
Walter Sisulu University	27
Enviro-Insight	26
Professional Hunters' Association of South Africa and Wildlife Ranching South Africa	22
North Zululand Honorary Officers	10
Smithsonian Museum	7
South African Environmental Observation Network	7
Swaziland Game Parks	4
Total	**460,931**

Table 2. Proportion of contributions according to conservation sector type, to both the assessment process (Appendix 1) and writing, as well as providing the underlying data. Governmental institutions include provincial conservation agencies as well as parastatal institutions; research institutions refer to universities and museums; non-governmental organisations refer to any non-profit institution; private sector refers to commercial organisations, environmental impact assessment firms and private individuals who contributed independently; and citizen science refers to data records provided through citizen science data portals.

Sector	% of contribution to assessments	% of data contribution
Governmental institutions	18.2	52.3
Research institutions	55.5	34.6
Non-governmental organisations	17.1	4.0
Private sector	9.2	2.8
Citizen science	0	6.2

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Species images

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EXECUTIVE SUMMARY

Life on Earth is undergoing its sixth major extinction crisis. We must understand the risk of each species becoming extinct to prioritise conservation efforts and allocate scarce resources effectively. The International Union for the Conservation of Nature (IUCN) established the Red List in 1963 to objectively categorise the probability of extinction for every species on the planet. Assessments are carried out through extensive networks of stakeholders pooling their expert knowledge. Red Lists have become the backbone of global species conservation as a unified and standardised protocol to measure biodiversity loss and inform policy decisions. Extinctions, however, occur regionally before globally. National (or Regional) Red Lists are thus needed to help prioritise regionally threatened species and to feed into global assessments.

The Endangered Wildlife Trust (EWT) produced the previous national Red List of Mammals in 2004 (Friedmann & Daly 2004). For the 2016 revision, the EWT partnered with the South African National Biodiversity Institute (SANBI), supported by collaborations with MammalMAP (a partnership between the Animal Demography Unit, University of Cape Town and the Mammal Research Institute, University of Pretoria) and the Species Survival Commission (SSC) of the IUCN. Key stakeholders and contributors also included South African National Parks (SANParks), provincial conservation agencies, universities, museums and the private sector. The assessment region included South Africa, Lesotho and Swaziland, as well as the footprint of all transfrontier parks in these three countries.

The project began in February 2013. The first phase concentrated on networking with experts and collating empirical data on distribution and population size. We identified the initial set of assessors and data contributors from a chain referral survey, which then grew on an *ad hoc* basis. Data collation began in June 2013 and ran, in parallel with other processes, to December 2015. Data contributors included museums, university researchers, statutory conservation agencies, environmental consultancies, private protected areas, landowners and citizen scientists. Overall, we amassed 460,931 occurrence records and 41,075 population count records. Cleaning and synthesising this database is an ongoing project. In total, there were 104 primary data contributors from 60 institutions, and in their private capacity. This collated database should be maintained and updated regularly to make future Red List revisions more accurate and efficient. Formalising relationships with data-providing institutions is underway.

The strategy for soliciting assessments of species evolved from using annotated templates to preparing draft assessments (based on a scientific article format) and soliciting edits to the information. This method significantly improved contribution quality and response time. Overall, there were 357 individual assessors, reviewers and contributors to the assessments (with 12% of experts contributing to ≥ 10 assessments). Assessment authors were drawn from diverse institutions and roles to minimise bias resulting from disparate purviews (*sensu* Hayward et al. 2015). Table 2 reveals that there was a good balance between practitioner and researcher contributions, where governmental institutions provided the bulk of the data (52%) and contributed to 18% of the assessments while research institutions provided 35% of the data and contributed to 56% of the assessments.

Most assessments were revised and edited remotely, in which 3,273 documents (assessment versions) were managed and integrated by the editing team. For larger taxonomic groups (Chiroptera, Cetacea, Rodentia/ Soricomorpha), we hosted expert workshops to gather new information, update taxonomies, broaden the required assessor network and devise assessment methods for the groups. We developed a protocol to assess small mammals under the B criterion (using recent land cover data) and an expert-driven framework to estimate the number of private subpopulations that can be considered wild and free roaming. Further work is needed to refine such frameworks. Every assessment was reviewed by the Chief Editor (Matthew Child) to standardise the listing logic, approaches to uncertainty and quality of content. In total, 2,455 scientific articles and reports were integrated into the assessments to ensure that the latest information was used.

Of the 343 species, subspecies and subpopulations recorded from the assessment region, six were Not Evaluated (considered vagrant) and five are Extinct, leaving 331 taxa that were assessed. Overall, 57 taxa are threatened (six Critically Endangered, 20 Endangered, 31 Vulnerable) and 35 are Near Threatened (Table 3). Proportional to the number of taxa assessed, this yields 17% threatened and 10% Near Threatened. This compares to 19% of taxa being threatened and 32% being Near Threatened in the previous assessment (N = 295 taxa assessed). Encouragingly, the proportion of Data Deficient listings has been significantly reduced in this revision (from 18% to 7% in 2004 and 2016 respectively) due to a combination of better information and a change in risk tolerance. While it appears that there are fewer threatened species currently, most of these changes were non-genuine, involving new information, analysis or taxonomic revision. Of the genuine changes detected thus far (N = 29), 19 (66%) are uplistings (more threatened). Thus, while more work is required to determine the overall number of genuine changes so that the Red List Index (Butchart et al. 2006a) can be applied, preliminary results indicate a net worsening conservation status for mammals. Similarly, a stakeholder workshop is required to translate the Red List statuses into conservation priorities, weighing extinction risk against the context of ecological, cultural, economic and logistical factors (*sensu* Miller et al. 2007). Finally, being Least Concern does not mean of "no concern" and we developed a watch-list categorisation to flag species that do not currently meet the criteria but may do so in the near future. Continued conservation effort is needed to enhance the recovery of all species such that they comprise evolutionarily and ecologically functional populations.

This Red List revision has made the following important advancements:

- **Consolidated database**: the data collated during this project can enhance the efficiency of future revisions through good data management practices and the establishment of data-sharing agreements with partner institutions. These initiatives are

underway through the construction of the National Biodiversity Information Facility at SANBI. The current database can also form the foundation of an atlas project where data gaps are identified and systematically monitored similar to that of the Karoo BioGaps project and to the field surveys conducted for both the national butterfly and reptile assessments (Mecenero et al. 2013; Bates et al. 2014).

- **Conservation evidence**: we weighted the threats and interventions according to the evidence presented in the scientific literature so as to standardise the evaluation of severity and effectiveness, respectively. These data are being compiled into a database summarising the type and strength of evidence presented by scientific papers regarding mammal conservation and will be used as a resource for future assessments.
- **Measuring conservation value of managed subpopulations**: through a series of expert workshops, a framework was developed to objectively measure the wildness of managed subpopulations through attributes relating to evolutionary and ecological dynamics. This framework was applied to all relevant species to standardise the inclusion of private subpopulations into the Red List. Refinement of the framework is ongoing and will ultimately link to the IUCN Green List, which is also under development.
- **Watch-list categories:** we created three additional qualifying categories intended to flag species that are in urgent need of additional research or direct conservation interventions. These qualifiers complement the Red List categories and can help to prioritise assessments needing urgent revisions.
- **Information quality classifications:** we standardised the data quality used to assign Red List statuses for each taxon on a spectrum from low to high confidence. These classifications will be used to determine what data are needed to make the assessments more robust and thus will be linked to the conservation evidence framework.

This project has brought together scientists, conservation practitioners, government officials, landowners and citizen scientists to produce assessments, databases and frameworks for South Africa's sustainable future. We have created three legacies that will greatly improve the efficiency and accuracy of future revisions: 1) a synthesised occurrence and population count database; 2) referenced assessments that provide the foundation for future revising rather than recreating; and 3) frameworks that help to adapt the application and standardisation of the IUCN sub-criteria to a South African context. South Africa is a stronghold for African mammal biodiversity and keeping track of our species together through these legacies will help us to remain so.

The Mammal Red List was funded via the South African National Biodiversity Institute (through a grant by the Norwegian Government that aims to build capacity in the southern Africa region for undertaking assessments), the Endangered Wildlife Trust, the Department of Environmental Affairs, E Oppenheimer & Son and the De Beers Group of Companies.

The summary listings and links to full assessments can be accessed here.

Table 3. Summary Red List status categories per mammalian order.

Order	Taxa evaluated	Red List Category†							Percentage threatened‡	Watch-list Category*		
		CR (PE)	CR	EN	VU	NT	DD	LC		Data	Threat	CD
Afrosoricida	18	1	1	5	4	3	1	3	61%	9	2	1
Artiodactyla	33	-	-	4	4	2	-	23	24%	10	11	7
Carnivora	39	-	-	1	4	6	-	28	13%	13	9	5
Cetacea	46	-	1	3	4	1	13	24	17%	28	20	-
Chiroptera	63	-	-	1	5	11	-	46	10%	29	9	-
Eulipotyphla	17	-	1	2	3	2	-	9	35%	7	7	1
Hyracoidea	3	-	-	1	-	-	-	2	33%	2	-	1
Lagomorpha	8	-	1	-	-	-	-	7	13%	5	2	-
Macroscelidea	8	-	-	-	-	1	1	6	0%	2	1	-
Perissodactyla	7	-	1	2	1	1	-	2	57%	1	5	5
Pholidota	1	-	-	-	1	-	-	-	100%	1	1	1
Primates	9	-	-	1	1	1	1	5	22%	5	-	-
Proboscidea	1	-	-	-	-	-	-	1	0%	-	1	1
Rodentia	77	-	-	-	4	7	6	60	5%	28	15	1
Tubulidentata	1	-	-	-	-	-	-	1	0%	1	1	-
Total	**331**	**1**	**5**	**20**	**31**	**35**	**22**	**217**	**17%**	**141**	**84**	**23**

†*IUCN Red List Categories*: CR(PE) – Critically Endangered Possibly Extinct, CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened, DD – Data Deficient, LC – Least Concern

‡*Percentage threatened*: Sum of CR(PE)+CR+EN+VU species divided by total number evaluated

**Watch-list Categories*: CD – Conservation Dependent

Cape Mountain Zebra (*Equus zebra zebra*) – Emmanuel Do Linh San

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1 BACKGROUND

IUCN Red List process

Red Lists are tools to assess the extinction risk of a species and are used to evaluate conservation progress by quantifying the movement of species between threatened and non-threatened categories (Mace et al. 2008). Thus, their primary power is in standardising the measurement of biodiversity loss across the world, across taxa and across geographic and time scales. As Red Lists are focal points for collating and synthesising information regarding the threats and conservation of a species, they have an array of policy applications (Rodrigues et al. 2006). For example, as a signatory to the Convention on Biological Diversity (CBD), South Africa has a legal obligation to monitor biodiversity and report progress against the Aichi 2020 targets. The IUCN Red List Categories and Criteria were first published in 1994, following six years of research and broad consultation. Application of the criteria highlighted areas where they could be refined and the guidelines have thus evolved into their current manifestation (Version 3.1) (IUCN Standards and Petitions Subcommittee 2017).

The global IUCN Red List is produced and managed by the IUCN Species Survival Commission (SSC), the IUCN Global Species Programme and the Red List Partnership. The IUCN Red List Unit (RLU) is the gatekeeper to the IUCN Red List of Species. The majority of Red List Authorities (RLAs) (individuals that sign off on assessments) are based within IUCN SSC Specialist Groups. Assessments are conducted by expert networks (a worldwide network of over 8,000 volunteer scientists divided into over 100 SSC Specialist Groups) applying the Red List criteria to the available data and, in the absence of strong data, making decisions on their approach to uncertainty. During this current South African Mammal Red List, we have worked extensively with the various IUCN SSC Specialist Groups in sharing information between the national and global assessments and ensuring our endemic species are thoroughly reviewed by the IUCN SSC RLAs. Please visit the IUCN Red List website for further information.

Regional Red Lists

Regional Red List projects proceed in the same way as a global revision but with one added step – applying the regional criterion. The word *regional* is used to indicate any sub-global geographically defined area, such as a continent, country, state, or province. Within any region there will be taxa with different distribution histories, ranging from those that are indigenous (native to the area), and have been there since pre-human settlement, to those introduced more recently. In the current revision, only one benignly introduced taxon has been assessed: the Eastern Black Rhinoceros (*Diceros bicornis michaeli*). There may also be breeding and non-breeding taxa (those that do not reproduce in the region but may still be dependent upon its resources for their survival). There are no documented non-breeding taxa for mammals within the assessment region. There may also be formerly native taxa that are now extinct in the region, but which are still extant in other parts of the world. There are no known Regionally Extinct (RE) taxa within the assessment region that are extant elsewhere. Lichtenstein's Hartebeest (*Alcelaphus buselaphus lichtensteinii*) may be close to being RE but it is unclear whether it is a natural resident or a vagrant to the assessment region. We have not included any vagrants (determined by expert consensus) in the assessment, but have included extreme edge-of-range taxa that have at least one documented breeding population within the assessment region.

Regional Red Lists are important as they are used to: (1) inform conservation policies and legislation (both national and international); (2) identify research gaps and stimulate monitoring programs; (3) monitor the status of biodiversity and report on the state of the environment (through use of indices such as the Red List Index); (4) regulate the development and use of wildlife resources; (5) target areas for conservation planning; (6) increase public awareness of threats to biodiversity; and (7) set priorities for the allocation of limited conservation resources (Miller et al. 2007). Users include conservation planners, research scientists, managers of conservation organisations, landowners and protected area managers, environmental impact agency workers, civil servants compiling governmental reports, officials involved in land-use planning, environmental educators and concerned members of the public looking to lodge protests against damaging development applications. Within South Africa, common uses of national Red Lists include:

- Conservation planning and protected area expansion at national, provincial and local scales (Pfab et al. 2011).
- Biodiversity Management Plans (BMPs) that require multiple stakeholder coordination.
- Regulating sustainable use through permitting via the Threatened or Protected Species list (ToPS) or compiling Non-detriment Findings (NDFs) for a change of listing on the CITES (Convention on International Trade in Endangered Species of Fauna and Flora) appendices.
- Environmental impact assessments and specialist studies to guide development.
- Identifying systematic monitoring priorities for species or regions.
- Identifying potential sites for biodiversity stewardship programmes.
- Identifying corridors and flagships for urban conservation programmes.
- Gathering regional information to feed into global assessments of the species (coordinated by the IUCN Red List Unit) and to establish bi-directional information flows to align both regional and global assessments. Endemic species assessments are by definition global assessments.

Two previous mammal Red Lists have been produced in South Africa: Smithers (1986) and Friedmann and Daly (2004). As the IUCN recommends revising Red Lists every five years, the current revision was urgently needed. Now that the foundational databases and narrative-rich assessments have been produced, it should be more time-efficient to revise the mammal assessments in years to come. Ultimately, being able to apply the Red List Index to all taxonomic groups will give a comprehensive measurement of conservation progress in the country, and

enable our government to gauge our success in meeting international biodiversity targets. Regional Red Listing provides an accurate inventory of species' extinction risk and creates platforms for partnerships and conservation innovation. Our vision of the current Red List project was multipurpose:

- To compile the best data and qualitative information to accurately estimate extinction risk, conservation trends, and conservation progress within South Africa.
- To enhance functional connections between conservation NGOs, governmental departments and the private sector.
- To use evidence-based conservation science in the assessment of threats and implementation of effective interventions.
- To provide a resource for dynamic engagement with the public and citizen science projects.
- To create capacity in Red List assessing.

Thus, the national Red List is not simply a guideline but a tool to synthesise evidence on mammal conservation and to engage stakeholders. Red Lists can transcend their use as a static summary and can become a vehicle to catalyse feedbacks between various databases and to streamline the connections between policy, research and practice. Thus, revising the Red List is not a passive process, but a dynamic and goal-orientated tool to unify practitioners and policy makers in effective conservation.

However, it should be remembered that, while the Red List statuses reflect the *relative extinction risk of species* (based chiefly on geographical and population data), the process of setting priorities for conservation actions requires several additional considerations, such as ecological significance, cultural value, logistical factors in implementing conservation plans, availability of funding or capacity, and existing legal frameworks to implement conservation plans (Miller et al. 2007). Additionally, the global status of the species and the proportion of the global population that occurs within the assessment region should influence the priority list. This will also help to identify regional populations that are of global importance for the conservation of the species. Thus, Miller et al. (2007) recommend that regional assessments include three measures: (1) the regional Red List Category, (2) the global Red List Category, and (3) an estimate of the proportion (%) of the global population occurring within the region. The latter measure has been approximated as relative endemism.

Demystifying the terminology

We used Version 3.1 of the IUCN Red List Categories and Criteria (IUCN Standards and Petitions Subcommittee 2017). The categories are summarised in Figure 1 and the criteria thresholds are summarised in Table 4. Please see Appendix 2 for definition of the Red List categories and explanation of the criteria thresholds. Please see Appendix 3 for a summary of key terms, definitions and their application to the criteria. Red List parameters have specific definitions relating to their application to the Red List criteria and to biological facets of the species affecting its extinction risk. Such definitions are often not intuitive (for example, 'location') and can contradict commonly accepted biological definitions (for example, the use of 'subpopulation' versus 'population'). Table 5 clusters key Red List terms according to parameter type and classified them to how variable they are to calculate, which was used to help standardise the data quality standards in the assessments. The parameters are ranked in order of direct relevance to the criteria (most commonly quantified parameters) and consistent applicability across species (*consistently quantifiable*) compared to those parameters that need species-specific information to be quantified (*species-specific*), and are thus not necessarily standardised across species, and those auxiliary terms that are either only indirectly related to the criteria and are difficult to quantify (*auxiliary*), and are thus more likely to be inconsistently applied across species (Hayward et al. 2015).

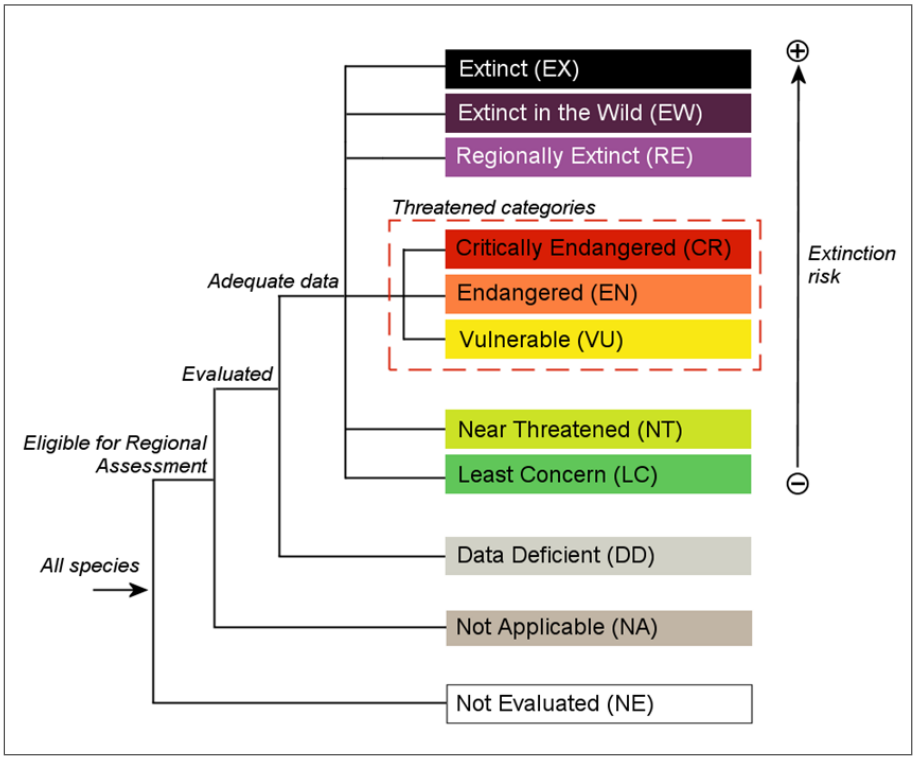

Figure 1. A hierarchical overview of the IUCN Red List extinction risk categories.

There are several Red List categories that are often misinterpreted and require further explanation, particularly in the context of this revision:

- **Not Evaluated (NE)**: A taxon is NE when it has not yet been evaluated against the criteria. In this revision, we used the category in acknowledging that the species does sometimes occur here, but it is considered vagrant and thus not assessed. Thus, this category can serve as a comprehensive checklist for taxa that occasionally occur in the assessment region but which were not considered for assessment.
- **Least Concern (LC):** Just because something is "Least Concern" doesn't mean it is of "no concern". It simply means it is of lesser concern than the rest, but

Table 4. Summary of the IUCN criteria and associated thresholds used in the assessment.

SUMMARY OF THE FIVE CRITERIA (A-E) USED TO EVALUATE IF A TAXON BELONGS IN AN IUCN RED LIST THREATENED CATEGORY (CRITICALLY ENDANGERED, ENDANGERED OR VULNERABLE).[1]

A. Population size reduction. Population reduction (measured over the longer of 10 years or 3 generations) based on any of A1 to A4

	Critically Endangered	Endangered	Vulnerable
A1	≥ 90%	≥ 70%	≥ 50%
A2, A3 & A4	≥ 80%	≥ 50%	≥ 30%

A1 Population reduction observed, estimated, inferred, or suspected in the past where the causes of the reduction are clearly reversible AND understood AND have ceased.

A2 Population reduction observed, estimated, inferred, or suspected in the past where the causes of reduction may not have ceased OR may not be understood OR may not be reversible.

A3 Population reduction projected, inferred or suspected to be met in the future (up to a maximum of 100 years) *[(a) cannot be used for A3]*.

A4 An observed, estimated, inferred, projected or suspected population reduction where the time period must include both the past and the future (up to a max. of 100 years in future), and where the causes of reduction may not have ceased OR may not be understood OR may not be reversible.

based on any of the following:

(a) direct observation *[except A3]*

(b) an index of abundance appropriate to the taxon

(c) a decline in area of occupancy (AOO), extent of occurrence (EOO) and/or habitat quality

(d) actual or potential levels of exploitation

(e) effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.

B. Geographic range in the form of either B1 (extent of occurrence) AND/OR B2 (area of occupancy)

	Critically Endangered	Endangered	Vulnerable
B1. Extent of occurrence (EOO)	< 100 km²	< 5,000 km²	< 20,000 km²
B2. Area of occupancy (AOO)	< 10 km²	< 500 km²	< 2,000 km²
AND at least 2 of the following 3 conditions:			
(a) Severely fragmented **OR** Number of locations	= 1	≤ 5	≤ 10
(b) Continuing decline observed, estimated, inferred or projected in any of: **(i)** extent of occurrence; **(ii)** area of occupancy; **(iii)** area, extent and/or quality of habitat; **(iv)** number of locations or subpopulations; **(v)** number of mature individuals			
(c) Extreme fluctuations in any of: **(i)** extent of occurrence; **(ii)** area of occupancy; **(iii)** number of locations or subpopulations; **(iv)** number of mature individuals			

C. Small population size and decline

	Critically Endangered	Endangered	Vulnerable
Number of mature individuals	< 250	< 2,500	< 10,000
AND at least one of C1 or C2			
C1. An observed, estimated or projected continuing decline of at least (up to a max. of 100 years in future):	25% in 3 years or 1 generation (whichever is longer)	20% in 5 years or 2 generations (whichever is longer)	10% in 10 years or 3 generations (whichever is longer)
C2. An observed, estimated, projected or inferred continuing decline AND at least 1 of the following 3 conditions:			
(a) **(i)** Number of mature individuals in each subpopulation	≤ 50	≤ 250	≤ 1,000
(a) **(ii)** % of mature individuals in one subpopulation =	90–100%	95–100%	100%
(b) Extreme fluctuations in the number of mature individuals			

D. Very small or restricted population

	Critically Endangered	Endangered	Vulnerable
D. Number of mature individuals	< 50	< 250	**D1.** < 1,000
D2. *Only applies to the VU category* Restricted area of occupancy or number of locations with a plausible future threat that could drive the taxon to CR or EX in a very short time.	-	-	**D2.** typically: AOO < 20 km² or number of locations ≤ 5

E. Quantitative Analysis

	Critically Endangered	Endangered	Vulnerable
Indicating the probability of extinction in the wild to be:	≥ 50% in 10 years or 3 generations, whichever is longer (100 years max.)	≥ 20% in 20 years or 5 generations, whichever is longer (100 years max.)	≥ 10% in 100 years

1 Use of this summary sheet requires full understanding of the *IUCN Red List Categories and Criteria* and *Guidelines for Using the IUCN Red List Categories and Criteria*. Please refer to both documents for explanations of terms and concepts used here.

we cannot allow ourselves to become idle (Mallon & Jackson 2017). Hence, we developed the watch-list categories to flag species that do not currently qualify for a threatened status but that need special attention.

- **Near Threatened (NT)**: The Near Threatened category always contains a level of subjectivity. However, there are several heuristics we used to standardise its application: (1) if the taxon was close to qualifying for a Vulnerable category (summarised in IUCN Standards and Petitions Subcommittee 2017); (2) If a taxon does not meet any of the criteria thresholds but is Conservation Dependent and would qualify as threatened within five years of the specific intervention ceasing (summarised in IUCN Standards and Petitions Subcommittee 2017); and (3) we used uncertainty as a key guiding principle: where there was sufficient doubt over a major variable used to determine the assessment, NT rather than LC was used (provided there was some form of quantitative evidence that the species might warrant concern). For example, while we know to a high level of certainty the minimum population size of Spotted Hyaenas (*Crocuta crocuta*) based on statistical models, we do not know the population size of Brown Hyaenas (*Parahyaena brunnea*) to any meaningful accuracy. Thus, although the Brown Hyaena has a wider extent of occurrence (EOO) than the Spotted Hyaena, the suspected continuing threat of persecution and road kill, combined with the uncertainty over how this affects recruitment and population trend, warrants a NT listing. Conversely, Spotted Hyaenas, although more confined to protected areas, are known to be stable in these areas and may be expanding in range (e.g. Waterberg) and the threats of traditional medicine or snaring, although severe, have not caused an overall population decline within the assessment region.
- **Data Deficient (DD)**: A DD listing is justified when there is no direct or indirect information about its current status or possible threats but does not imply that a taxon is not threatened (IUCN Standards and Petitions Subcommittee 2017). However, what constitutes "no information" is again partially subjective. The following heuristics were used to standardise this category: (1) If the data are so uncertain that both CR and LC are plausible categories, the taxon can be listed as DD; and (2) if plausible categories range from NT to threatened categories, DD is not the appropriate category. It is important to recognize that taxa that are poorly known can often be assigned a threat category on the basis of background information concerning the deterioration of their habitat and/or other causal factors; therefore the liberal use of Data Deficient is discouraged.

The following sections provide an annotated explanation of the assessments and the information that was used to determine the statuses.

The summary listings and links to full assessments can be accessed here.

Riverine Rabbit (*Bunolagus monticularis*) – Tony Camacho

Table 5. Key Red List parameters and definitions, categorised by whether they are: (1) quantifiable across species, (2) quantifiable according to the biology of the species, and (3) auxiliary terms that indirectly affect the thresholds and are difficult to quantify. Note that the definitions provided are from the IUCN, but please see the relevant text for how the parameters were applied during the revision. The 'term cluster' refers to the relevant text section.

Parameter/term	Term cluster	IUCN definition
		CONSISTENTLY QUANTIFIABLE
Population size	Population	Total number of mature individuals of a species.
Population reduction	Decline	The decline in the number of mature individuals of the population as a percentage of the original population size.
Continuing decline	Decline	A recent, current, or projected future decline (which may be smooth, irregular or sporadic), which is liable to continue unless remedial measures are taken.
Extent of occurrence (EOO)	Geographical	The area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred or projected sites of present occurrence of a taxon, excluding cases of vagrancy.
Area of occupancy (AOO)	Geographical	The area within its 'extent of occurrence', which is occupied by a taxon. The measure reflects that the extent of occurrence may contain unsuitable or unoccupied habitats. In some cases, (e.g., irreplaceable colonial nesting sites, crucial feeding sites for migratory taxa) the area of occupancy is the smallest area essential at any stage to the survival of existing populations of a taxon.
		SPECIES-SPECIFIC
Mature individuals	Population	Those known, estimated or inferred to be capable of reproduction.
Subpopulation	Population	Geographically or otherwise distinct groups in the (global) population between which there is little demographic or genetic exchange (typically one successful migrant individual or gamete per year or less).
Extreme fluctuations	Population	These occur where population size or distribution varies widely, rapidly and frequently, typically over an order of magnitude.
Generation length	Population	The average age of the mature individuals in the population. Generation length therefore reflects the turnover rate of breeding individuals in a population. It is greater than the age at first breeding and less than the age of the oldest breeding individual.
Location	Geographical	A geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the species present.
Severely fragmented	Geographical	Refers to a situation where the species' risk of extinction is increased because most of its individuals are found in small and relatively isolated subpopulations. Specifically, if >50% of its area of occupancy is in habitat patches that are (1) smaller than required to support a viable population and (2) separated from other habitat patches by large distances.
Rescue effect	Geographical	Process by which immigrating individuals result in lower extinction risk for the target regional population.
		AUXILIARY
Demographic sink	Population	An area where the local reproduction of a species is lower than local mortality. The term is usually used for a subpopulation experiencing immigration from a source where the local reproduction is higher than the local mortality.
Benign introduction	Geographical	An attempt to establish a species, for the purpose of conservation, outside its recorded distribution but within an appropriate habitat and eco-geographical area; a feasible conservation tool only when there is no remaining area left within its historic range.
Reintroduction	Geographical	The intentional movement and release of an organism inside its indigenous range from which it has disappeared.
Reinforcement	Geographical	The intentional movement and release of an organism into an existing population of conspecifics.
Natural range	Geographical	The range of the species, excluding any portion that is the result of an introduction to a region or neighbouring region.
Naturalised population	Geographical	A non-native species that has spread into the wild and reproduces in sufficient numbers to maintain a population. These species / subpopulations are not assessed.
Wild population	Geographical	The subpopulations within their natural range in which the individuals are the result of natural reproduction (i.e. not the result of human-mediated release or translocation).

2 EXPLAINING THE ASSESSMENTS

Summary table and rationale

The summary table contains:

- Regional Red List status as of the end of 2016.
- National Red List status of Friedman and Daly (2004).
- Reasons for change measured since last national Red List in 2004, in preparation for the national Red List Index.
- Global Red List status and relevant assessment year.
- Threatened or Protected Species listing of 2007. The results of this revision have been used to inform the upcoming TOPS revision soon to be published.
- The CITES status and relevant year of listing in a CITES appendix.
- Endemic status.
- Watch-list categories. Special categories created to highlight specific areas of action for the taxon.

Assessment Rationale

The rationale summarises the major points of the assessment, providing a transparent justification for the listing by explaining the chain of logic, as well as identifying any major threats facing the taxon and any major conservation interventions needed. It includes any inferences or uncertainties so as to be replicable and accountable for the next revision. It highlights the key issues in the other sections to summarize the reasons why the species qualifies for the assigned category. The rationales are thus intended to provide a methodological blueprint to facilitate future revisions and assist future assessors in being able to determine genuine changes. It also summarises the evidence for applying or not applying the regional criterion, as well as justifying any watch-list categories for the taxon.

Genuine versus non-genuine changes

The reason for a change in listing is important in calculating conservation progress through the Red List Index by assessing which statuses have genuinely changed (due to intensifying threats or effective interventions) since the previous assessment, and, by corollary, whether the previous assessment was incorrect and needs to be retroactively corrected to reflect the correct movement in status. Quantifying the reasons for change also helps to assess where research has made significant contributions for particular groups and thus also which groups need more research (which feeds into the Conservation Evidence framework; Figure 2). Table 6 displays the types of change possible (only relevant categories included) since either the previous national Red List of mammals (Friedmann & Daly 2004), or the previous global IUCN revision for mammals (*c*. 2008), for non-endemics and endemics, respectively. The first comprehensive Red List of South African Mammals by Smithers (1986) was not used to assess change because the terms and definitions are largely incompatible with Friedmann and Daly (2004) and the current revision due to subsequent revisions in the guidelines (IUCN Standards and Petitions Subcommittee 2017), and no data or assessment rationales are presented from which to interpret change. All genuine changes record the reason for the change in the assessment rationale.

For changes identified as potentially genuine, the following rules were applied:

- **Only one change type coded**: Genuine and non-genuine changes are mutually exclusive and are not coded simultaneously. The rules below were used to determine which type of change was more appropriate.
- **Genuine change trumps new information**: If the change is a combination of both new information and an element of genuine deterioration or improvement in status, genuine change was only coded if the magnitude of change (for example, population size, rate of decline or range change) was sufficient to cross the threshold in the absence of the new information.
- **Genuine change trumps taxonomic split**: In cases where a status change results from a combination of taxonomic splitting and genuine change, the change is coded as genuine for the new species but as a taxonomic change for the parent species (if the splitting results in a change).
- **Retroactive changes to previous assessments**: Where errors to previous assessments were identified (either through mistakes in applying the criteria or through new information), corrections were made and where information was sufficient to do so the earlier assessment was redone through backcasting, thus enabling the change to be listed as genuine. Where no information was available for the particular time period, the change remained non-genuine. (Note: this task remains to be completed).

Endemism and the regional criterion

The distribution of a species outside the assessment region is important for determining whether there is 1) potential for individuals to disperse into the assessment region and thus rescue local subpopulations from extinction; and 2) to assess the importance of the regional population in the context of the global population. Movement (or lack thereof) of individuals across borders may influence the risk of extinction within the assessment region. If the species is endemic or known to be completely isolated from populations in neighbouring countries, there is no rescue effect (Table 5) possible and thus the regional criterion will not apply. If, however, neighbouring populations are deemed to influence the extinction risk of the regional population, then the regional status may be downlisted or uplisted. If the rate or significance of immigration is negligible or unknown, then the regional status remains unchanged. However, if there is assumed to be a steady influx of individuals from neighbouring countries, and the neighbouring populations are not threatened, the regional status can be downlisted as dispersing individuals are likely to rescue subpopulations from local extinctions. Conversely, if the

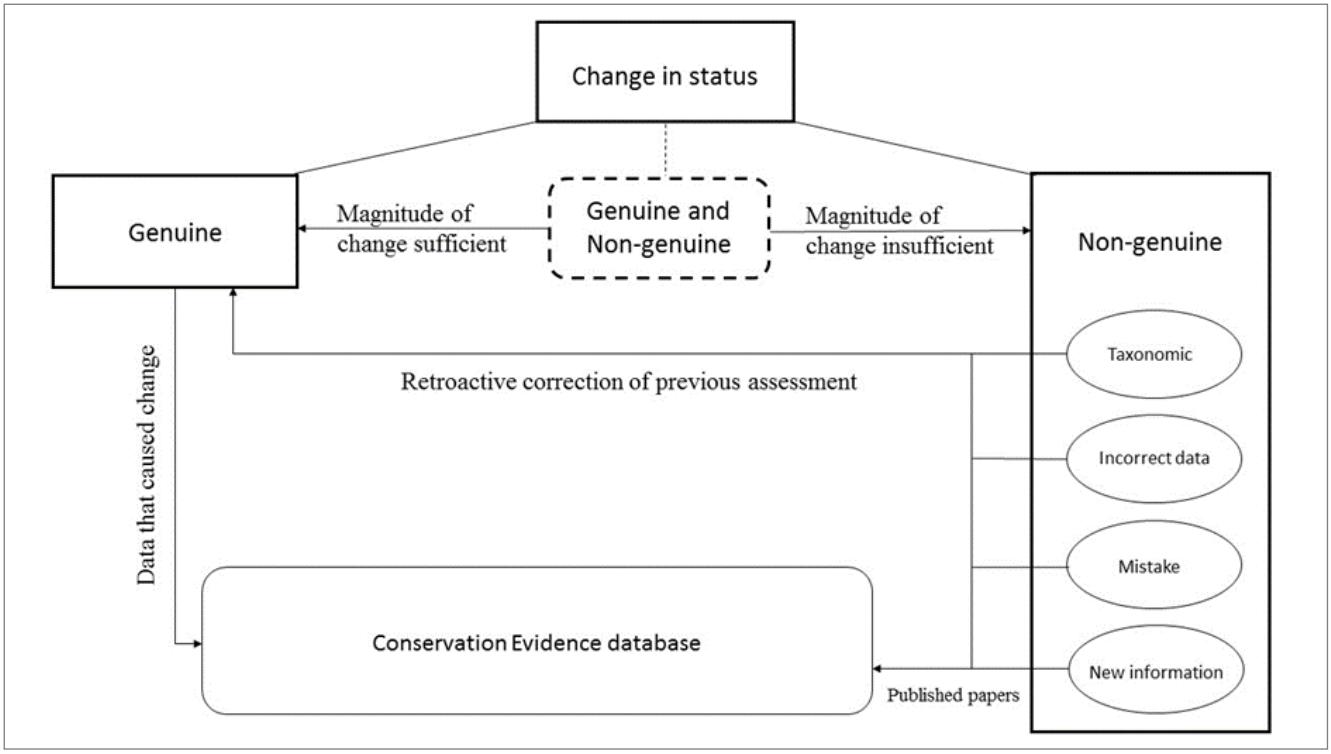

Figure 2. Flow diagram illustrating the relationship between genuine and non-genuine changes. If a combination of genuine and non-genuine changes has occurred in the assessment, a genuine change is coded only if the magnitude of change is sufficient to cross the criterion threshold in the absence of the non-genuine change. The change data should be recorded in the conservation evidence database, along with any appropriate data from recent publications that causes New Information non-genuine changes. Non-genuine changes can be changed to genuine changes if the previous assessment is retroactively corrected (if the relevant information is available).

regional population is a demographic sink that is unable to sustain itself without continual immigration from populations outside the region, and if the rate of extra-regional immigration is expected to decrease, the extinction risk of the regional population may be underestimated by the criteria. In such exceptional cases, an uplisting of the category may be appropriate. It is important to note, that both conditions must be met to use the regional criterion to uplist (Figure 3).

To avoid the potential inconsistency resulting from uncertainty over source-sink dynamics, we have attempted to simplify the application of the regional criterion until such time as information from neighbouring countries becomes available to more accurately assess rescue effects. Firstly, we classify the geographical distribution of the assessment region population in relation to the global distribution of the species according to Table 7. To standardise the bias in interpreting limited

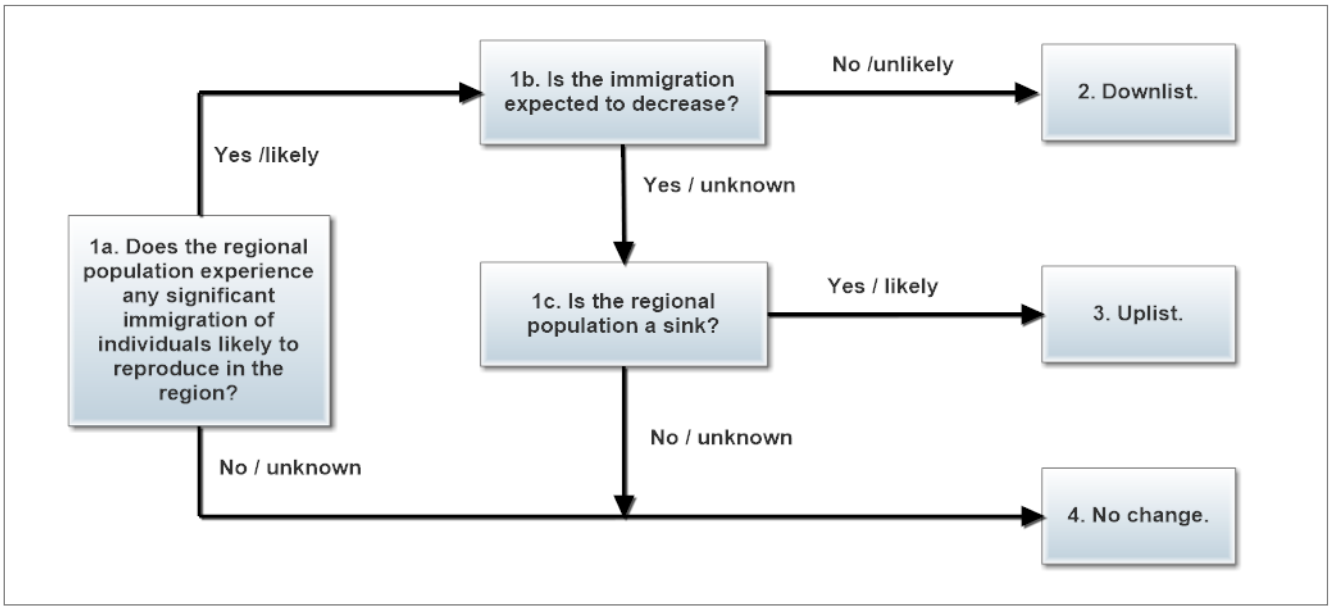

Figure 3. A flow diagram illustrating the regional criterion. If the existence and rate of immigration is unknown, the original status should remain unaltered. If, however, immigration is known to occur and expected to continue, the regional status can be down-listed. Conversely, if immigration is expected to decrease and the regional population is not demographically self-sustaining, the regional status can be uplisted.

Table 6. Description of types of change relevant to the current revision, listed in order of importance and applicability.

Type of change	Description	Examples
GENUINE	The change in category is the result of genuine deterioration or improvement in status that has taken place since the previous assessment.	The change is due to an increase in the rate of decline, a decrease in population or range size or habitat, or declines in these for the first time (owing to increasing/new threats). This relies on the data quality and uncertainty across the two assessments being congruent.
NON-GENUINE		
New information *Empirical* *Change in risk tolerance*	The change in category is the result of better knowledge about the taxon from either current research or more comprehensive data collection.	Newly synthesised information about the status of the taxon leading to better estimates for population size, range size or rate of decline. Research has generated more accurate values to apply the criteria. Data that were available for the first assessment were only collated in the current revision. The subcategories are: *empirical* (based on new data or analyses); and *change in risk tolerance* (expert experience or anecdotal evidence causes a shift between precautionary or evidentiary assessments).
Taxonomy *Newly split* *Newly described* *Newly lumped* *No longer valid*	A taxonomic change has occurred between assessments.	Molecular and genetic research has clarified taxonomic resolution or status. This applies mainly to small mammals. The subcategories are: *newly split* (newly elevated to species level); *newly described* (has been recently described as a species); *newly lumped* (following merging of two previously recognized taxa); and *no longer valid*/*recognised* (for example, now considered to a hybrid or variant, form or subspecies of another species, or the previously recognised taxon differs from a currently recognised one as a result of a split or lump).
Mistake	The previous status was applied in error because the assessor(s) misunderstood the Red List Criteria.	If the subcriteria were not supported or if the incorrect subcriterion was used.
Incorrect assessment *Data* *Analyses*	The previous status was applied in error because incorrect data or analyses were used.	The data referred to a different taxon (for example, due to a taxonomic change) or errors were made in the collection, collation or cleaning of the data that have subsequently been corrected. We extend this category to assessments where the analysis of the data was absent (for example, no analyses were performed and thus estimates were guessed) or were the analyses were incorrect.

information on regional population dynamics, we apply the regional criterion based on two questions:

1. Is the species an effective long-distance disperser?
2. Is the habitat connected across borders and largely intact in both countries?

The information to answer these questions is drawn from *regional population dynamics* subsection in the Assessment Rationale. This section is intended to describe whether this species' range is continuous with its range throughout southern Africa and Africa; whether habitat is connected; and whether the species had adequate dispersal capacity. For the Chiroptera, wing-loading was used as a proxy for dispersal capacity to standardise application of the regional criterion. The following rules were then used to apply the regional criterion:

1. If both answers are 'yes', a rescue effect is considered possible: downlist.
2. If one answer is 'no', a rescue effect is considered improbable: status remains unchanged but flagged as needing further research.
3. If both answers are 'no', a rescue effect is considered impossible: status remains unchanged.

Table 7. Categories of endemism used in the national Red List assessment and associated potential for rescue effects.

Endemic category	Definition	Rescue effect
Yes	Only occurs in the assessment region (South Africa, Swaziland and Lesotho; or any combination of those countries).	None
Near	The majority of the global population (>90%) occurs in the assessment region.	Assumed negligible
No	Between 10% and 90% of its range occurs outside the assessment region.	Potential
Edge of range	If the total portion of the range for the assessment region is <10% of its global range.	Probable

For threatened edge-of-range species, we further qualified the protocol above by the following rules:

1. Downlist automatically if range is continuous with rest of African range (for example, many Chiropteran species), thereby freeing conservation resources for threatened endemic or near-endemic species.
2. If the species is isolated from the rest of its range, the assessment is treated normally.

Watch-list categories

While the primary Red List categories measure the relative risk of extinction for taxa (Figure 1), the categories assume equal levels of knowledge about the taxa (albeit characterised by a standard lexicon for data quality, risk tolerance and uncertainty resolution – see Data Sources and Quality) and thus that the categories are robust to data paucity. The Least Concern category also implies that all such taxa are of similar conservation concern but Least Concern does not mean 'no concern'. To counteract this variance, we created three additional qualifying categories to add fine-scale detail to the assessments. These qualifiers apply to threatened, Least Concern and Data Deficient taxa.

- **Watch-list Data**. Varying data quantity and quality can influence the assessment by providing false values for the criteria thresholds, and thus confounds the standardisation between statuses. Precautionary assessments based primarily on expert experience, and thus subject to potential bias (Hayward et al. 2015), are the most likely candidates for this category. However, evidentiary assessments based on quantitative data may also qualify if the data are inadequate or insufficient to apply the Red List criteria (see **Conservation Evidence**). The following rules are used:
  - All Data Deficient listings are by definition Watch-list Data too, as new data must be collected to assign a Red List status, but not all Watch-list taxa are Data Deficient (as it may still be possible to assign a temporary status based on the information available).
  - The category is only applied to taxa where a critical piece of missing information is likely to influence the accuracy of the Red List status. Examples include field surveys to delimit geographical distribution, genetic tests to determine the extent of hybridisation in the population, and quantifying threat severity to estimate population trend.
  - It only applies to taxa where estimated, projected, inferred and suspected threshold values range across, or are close to, two status categories. For example, if the estimated population size ranges from 240 to 3,400 mature individuals, but the proportion of hybrid individuals is unknown. Or if the current estimated area of occupancy (AOO) is 435 km^2 but the range is suspected to be wider than currently known (potential for downlisting). However, a taxon with an estimated minimum AOO of 2,300 km^2 with a suspected wider range would not qualify as there is no possibility of uplisting under criterion B2.
  - The information identified by this category does not pertain to all gaps in understanding but only those directly relevant to quantifying threshold values for the Red List criteria.
  - This category can also apply to species where there is uncertainty over the validity of a subspecies or subpopulation. For example, where molecular data is needed to determine the evidence for assessing a subspecies or subpopulation separately.
  - The specific data needed to complete an accurate listing is described in the Assessment Rationale.
- **Watch-list Threat**. This category identifies a key emerging threat that will affect the taxon in the future, whereas Conservation Dependent (see below) identifies current threats with associated interventions and Watch-list Data establishes current research priorities and urgent data to be collected. The following rules are used:
  - This category applies when an emerging or previously unidentified threat may cause increasing population decline in the near future (5–20 years). It is only listed if the threat may potentially cause a change in conservation status in the near to medium future. It thus identifies the need for pre-emptive systematic monitoring frameworks.
  - It does not apply to threats previously identified that are suspected to be currently causing mortality or population decline but for which research has not quantitatively measured severity (this would be identified by the Watch-list Data qualifier).
- **Conservation Dependent**. We define this category similarly to Redford et al. (2011) as any taxon that requires specific, continual conservation intervention to prevent it from becoming more threatened. Such interventions usually mitigate extrinsic factors, such as overexploitation, but we extend this definition to include any taxon for which the long-term resilience of the population depends on some form of intensive management, such as metapopulation management or habitat restoration. It can apply to both threatened and Least Concern taxa. The following rules are used:
  - If extrinsic threats would cause (or are causing) population decline in the absence of the conservation intervention.
  - If the ability to disperse, and thus adapt to environmental change, is only possible through metapopulation management and/or the establishment of habitat corridors through protected area expansion.
  - This category does not apply to threatened taxa that are widespread and able to disperse, or to taxa where there is little evidence to rank the severity of the threat or the effectiveness of potential interventions and thus the interventions are ill-defined and not implementable.
  - If the taxon is Least Concern, but the cessation of the intervention would result in the taxon qualifying for a threatened category within five years, the taxon can be listed as Near Threatened (IUCN Standards and Petitions Subcommittee 2017).

Species qualifying as Watch List and Conservation Dependent are included as species of 'conservation concern.' As these qualifying categories cut across threatened and non-threatened categories, the number of species of 'conservation concern' is larger than the number of threatened species. Unlike the Butterfly Atlas and Red List (Mecenero et al. 2013) and the Red List of South African Plants (SANBI 2017), we did not use the 'Rare' status to qualify assessments because there have been no national systematic surveys for most species. The taxa of conservation concern thus include both Near Threatened and Data Deficient statuses, similar to the Orange List proposed by Victor and Keith (2004), but eschew 'rarity' in favour of qualifiers that speak directly to missing information that might influence the listing and taxa that require continual conservation intervention. We feel this is more appropriate for mammals, which are not as localised as other taxa and for which habitat fragmentation necessitates intensive management.

Taxonomy

In general the Red List criteria can be applied to any unit at or below the species level except microorganisms (IUCN Standards and Petitions Subcommittee 2017), which includes species (including newly described or undescribed species), subspecies and subpopulations. The following units are not eligible for Red List assessments: hybrids, infraspecific ranks (for example, forms, morphs, cultivars etc.), domesticated species and species that went extinct before 1500 AD.

Conservation assessments are relevant to the degree that they reflect real entities. We recognise that there are many definitions of a species and that the boundaries between a species, subspecies and subpopulation are not set but are continually in flux and overlapping. After a century of research, the major conclusion is that species are "poorly differentiated way-stations in a continuous hierarchy of biodiversity" (Mallet 2005). Thus, although the consensus is that species are real in some sense, there is no consensus on when a group of individuals should classified as one or many species (Fitzpatrick et al. 2015).

For the purposes of this revision, we use the Biological Species Concept because it is more conservative than the Phylogenetic Species Concept and thus less likely to dilute conservation resources. In general, we follow the IUCN in using Wilson and Reeder (2005) as the overarching systematic framework, both for the assessments to be congruent between regional and global scales and to be consistent with stable nomenclature (Asher & Helgen 2010). At the order level, we differ from the IUCN only in splitting Cetartiodactyla into Cetacea and Artiodactlya so as to make the assessment strategy and subsequent analyses more tractable, as well as being more intuitive to a general readership. We realise that there are many advances in mammalian systematics but the Red List is not a synthesis of phylogenetics. Rather it is a practical tool to measure the conservation status of species and important subspecies or subpopulations. As such, there may be discrepancies between the higher-order classification and the actual units assessed, as flexibility was given to assessors at the unit level to include new species, subspecies or evolutionarily significant units (subpopulations). This again follows the IUCN model where the specific taxonomy of the order is entrusted to the relevant SSC Specialist Group. However, we use standardised rules for inclusion for each unit to control the bias resulting from different sets of assessors' using higher or lower taxonomic thresholds (Table 8). Taxonomic status included the following units: species, subspecies, species complex (where there is a high likelihood of the taxon comprising cryptic species) or subpopulation.

When compiling the assessments, if a subspecies or subpopulation qualified to be assessed separately (Table 8), but the descriptive text did not differ significantly between subspecies or between the subpopulation and the parent species, the listings were made separately but the descriptive text was merged into one assessment for the species (for example, the *Cercopithecus albogularis* subspecies). This was also done when species did not significantly differ in information content (for example, the *Rhabdomys* and Ziphiidae assessments). In time, we hope enough ecological and conservation data will be generated to warrant describing such taxonomic units separately in their own documents. Generally, if there was only one subspecies recognised for the region, the assessment was performed at the species level for simplicity (as the data used in the analysis were not different). For utilised species at risk of hybridisation, assessments were also at the subspecies level to highlight this potential threat. The taxonomic notes include a summary of recent taxonomic changes or any current taxonomic debates about the validity or identity of the taxon.

Distribution

A paragraph detailing global range, current distribution range within the assessment region, and any recent range shifts. The section describes the engine room of the assessments because producing the distribution maps necessitated collating and cleaning the underlying data.

Data sources, collation and curation

Mammal data in South Africa exists in numerous, often fragmented, sources. To consolidate these data, we initiated a data collection process that first identified potential contributors using a chain-referral survey. We collected additional datasets in an *ad hoc* manner from additional experts. We began data collection in June 2013. From these contributors we requested information on species distribution patterns, population sizes and population trends, and the types and severity of the threats facing each species. The contributors collected these data using a variety of methods, such as field surveys (ground, aerial and acoustic), traps (camera, Sherman and mist nets), informal geo-referenced sightings (direct observations or spoor), and mortalities (for example, road kills). Provincial conservation authorities were requested to share their data via the Department of Environmental Affair's Working Group 1. A full list of all data-providing institutions is provided in Table 1. We converted game count data received from protected areas into distribution points by taking the centroid of the reserve for each count year per species. We also stored these data in a relational database so that we could analyse national population trends for the relevant species. We also solicited data from all major museums and national parks authorities. Overall, we synthesised 460,931 data-points between June 2013 and December 2016. Of these, the large majority (99%) were

Table 8. Description of taxonomic units assessed in the revision, with corresponding decision protocols used to standardise their inclusion.

Taxonomic unit	Definition	Rules for inclusion
Species	We use the biological species concept with the qualifier that only individuals that actually or potentially interbreed in naturally functioning ecosystems are included (in other words, subpopulations that are not intensively managed ecosystems, see wild and free-roaming definition).	All native species within South Africa, Swaziland and Lesotho that reproduce within the assessment region (whether over the entire reproductive cycle or any essential part of it). Vagrants (found only occasionally within the assessment region and which do not reproduce here) are not included. Species-level assessments are not necessary if the relevant subspecies have been assessed (in contrast to the IUCN global assessments). However, a species-level assessment is still required if a subpopulation has been
Species complex	A species that is suspected to comprise several distinct species but for which conclusive data are lacking. Relevant for small mammal assessments.	Included and assessed as a species in the current revision but flagged for further taxonomic delineation. Unpublished genetic or molecular evidence must be described in the text. Preliminary geographical distributions must be included if possible. If there is a particularly putative species within the complex that is at immediate risk of extinction before being described, this can be assessed sepa-
Newly described / undescribed species	See definition above. Also includes units for which the taxonomic resolution is unclear, but the consensus is that it is a species. Critically, research must be ongoing to clarify taxonomic status (to limit taxonomic sprawl).	Newly described species included if based on published research and widely accepted by relevant experts. The minimum requirements are 1) a peer-reviewed paper describing the new species (as long as falls under the Biological Species Concept) and 2) consensus at expert workshops. Assessing undescribed species is discouraged but will be accepted if 1) existing research demonstrates the biological significance of the species; and 2) the putative species is threatened (thus there is conservation value in its assessment). Undescribed species listed as Least Concern or Data Deficient can only be included if work is underway to describe the species and the new species will be widely accepted. Clear distribution information must
Subspecies	A genetically, and often phenotypically, distinct population of a species, which is geographically delineated with limited gene flow between subspecies. Where overlapping (for example, hybrid zones), the subspecies are capable of interbreeding, but the subspecies must express adaptations characteristic of a significantly different ecological niche or physiological adaptations characteristic of a different habitat.	As there are often many informally described subspecies for each species, assessments are only performed at the subspecies level if the following requirements are met: 1) the subspecies is biologically distinct, based on published molecular research or unpublished results (corroborated and accepted by the Red List Authority of the relevant IUCN SSC Specialist Group); and 2) there is conservation value in assessing at the subspecies level due to the relevant subspecies being threatened by qualitatively distinct threats (such as potential hybridisation with exotic subspecies). If the subspecies does not meet the requirements above, the assessment is conducted at the species level but putative subspecies are described in the text. If the subspecies requirements are met, all subspecies occurring within the assessment region are assessed, with the corollary being only the subspecies that occurs within the assessment region is assessed. For regional-scale assessments, it suffices to assess the relevant subspecies and thus we do not assess the species as a whole (for example, we assess Cape *Equus zebra zebra* and Hartmann's Mountain Zebra *Equus zebra hartmannae* but not Mountain Zebra *Equus zebra*).
Subpopulation	Geographically or otherwise distinct groups in the (global) population between which there is little demographic or genetic exchange (typically one successful migrant individual or gamete per year or less), which are adapted to specific environmental conditions and/or represent important evolutionary lineages. This category thus includes units described as ecotypes and evolutionarily significant units (ESUs).	To limit the number of subpopulations assessed to only those that require urgent conservation action, the following requirements must be met: 1) the subpopulation must be biological (as opposed to be defined by political or geographical boundaries) for which there are published or unpublished results available to demonstrate its uniqueness; and 2) the subpopulation must be facing a qualitatively distinct and identified threats. Subpopulations assessed as Least Concern or Data Deficient are not included but maybe mentioned on the text. If future research elevates the subpopulation to a subspecies or species, future assessments should reflect the new taxonomic status. Assessing subpopulations can be used to identify potentially novel species that are undescribed but that may become extinct in the absence of conservation

either geo-referenced, or could be geo-referenced based on the locality information provided.

When problems with data records were identified, they were vetted by returning to the source to check information accuracy. Records that could not be vetted were not used in the assessments or maps. Verifying such records remains to be fully completed. As it is a labour-intensive process to check geo-referencing of records and to update taxonomy of older specimens or records, we prioritised records for threatened species. For threatened species, out-of-range records were identified based on the most recent available IUCN distribution maps, and the georeferencing was either checked and corrected, or these records were flagged as problematic and excluded from the maps as well as the assessments. However, these records are retained in the database for future verification.

The database is not an atlas. Records reflect only verifiable presence and not absence, thus problems with false negatives are probably geographically biased and indices of abundance cannot be calculated as the database contains no measurement of observer effort. Field surveys are not standardised thus precluding diversity analyses. However, this database represents the first attempt to consolidate South African mammal data from multiple sources into a central database. No data will be made publically available unless explicitly condoned by the contributors. All data remain the property of the contributors. Centralising the data ensures that future revisions have a baseline to compare against and is an important foundation on which further national biodiversity assessments can be built.

Map production

The assessment region includes South Africa, Swaziland and Lesotho, as well as all transfrontier conservation areas. This is intended to display distribution across functional and connected landscapes and not simply within arbitrary political boundaries (Figure 4). Due to data resolution varying from point to quarter degree grid cell, most maps have been plotted at the quarter degree grid scale (QDGC level 2). Plotting at QDGC scale was also to protect sensitive species information. It is important to note that the taxon may not occur throughout the QDGC but only at one site. Caution should thus be used in interpreting fine-scale distribution within the QDGC. Planners and managers must therefore combine the distribution maps with data at finer resolutions to improve conservation planning, or request the point data from the data providers. For the Chiroptera, because all data are at point scale, these maps have been plotted as such. The distribution maps follow a data-driven approach and are based on multiple sources of empirical, expert-reviewed data and thus represent the verified minimum range of the species free from false positives. False negatives need to be rectified through further field surveys. The establishment of the central database and identification of survey gaps that need to be filled will provide the first a useful national overview to plan a systematic monitoring programme. When assessments are migrated to an online system, the underlying datasets will be linked to the assessment, thus enabling a more rapid determination of genuine versus non-genuine changes. Explanation of the terms used in the maps follows:

- **Historical (pre-2000) records**: Please note that what we define as "historical" is not what is normally understood by the term (i.e. pre-anthropogenic disturbance/transformation) but simply refers to data collected before 2000 or before the first national Red List assessment, which was conducted from 2002-2004 using data from prior to 2002. Thus, the 'historical' distribution in the current maps is only to mark recent changes in distribution between the 2004 and current Red List projects. However, direct comparisons between Friedmann and Daly (2004) and the current maps must be interpreted carefully, as it is likely that differences reflect the underlying data used in the assessments and not genuine range expansions. Specifically, the maps display the following layers:
- **Current (post-1999) distribution**. All distribution records collected after the year 2000. For ranched species, all available records pertaining to game farms, wildlife ranches, conservancies or private game reserves were included on the maps to represent the extent of homogenisation (Spear & Chown 2008, 2009).
- **Overlap records**. A grid cell in which there are both pre-2000 and post-1999 records.
- **Undated records**. This layer represents all the distribution records for which no date of collection was provided or for which no date can be found. Although the majority of these records are likely to be pre-2000, they are assigned their own category on a precautionary basis until they can be further investigated.
- **Formally protected areas**. This layer includes all provincial, national and Transfrontier protected areas from the 2011 National Biodiversity Assessment (Driver et al. 2012) and thus represents the minimum protected area coverage within the assessment region. Private protected areas are not displayed as the complete dataset is not available yet. The layer was not used for any analyses of the data, but simply to provide context, and broadly show the protected area network in the country. The available information on protected areas is being regularly updated and more up-to-date layers are now available.
- **Global range**. The global distribution range of the species, using the latest IUCN Red List data, is shown as an inset in the map to situate the regional distribution within a global context.

In addition to the layers above, for a subset of 23 ranched and utilised large mammal species, an additional layer was displayed:

- **Natural distribution range**. This layer, produced for the Department of Environmental Affairs by an Intergovernmental Task Team comprising scientists from all provinces from 2012–2015 (Birss et al. 2015), recreated the historical natural distribution of the relevant species over the period 500 years before present to *c.* 1930 based historical accounts, confirmed archaeological records, and records of current distribution (generally up to 1930, as it is assumed that up till this time distributions were relatively unchanged by translocation) where there is good evidence that the species occurs in the same place as during the historical period. Negative records (confirmed absences) were also used to help define distribution ranges. These data were then overlaid with vegetation types (Mucina &

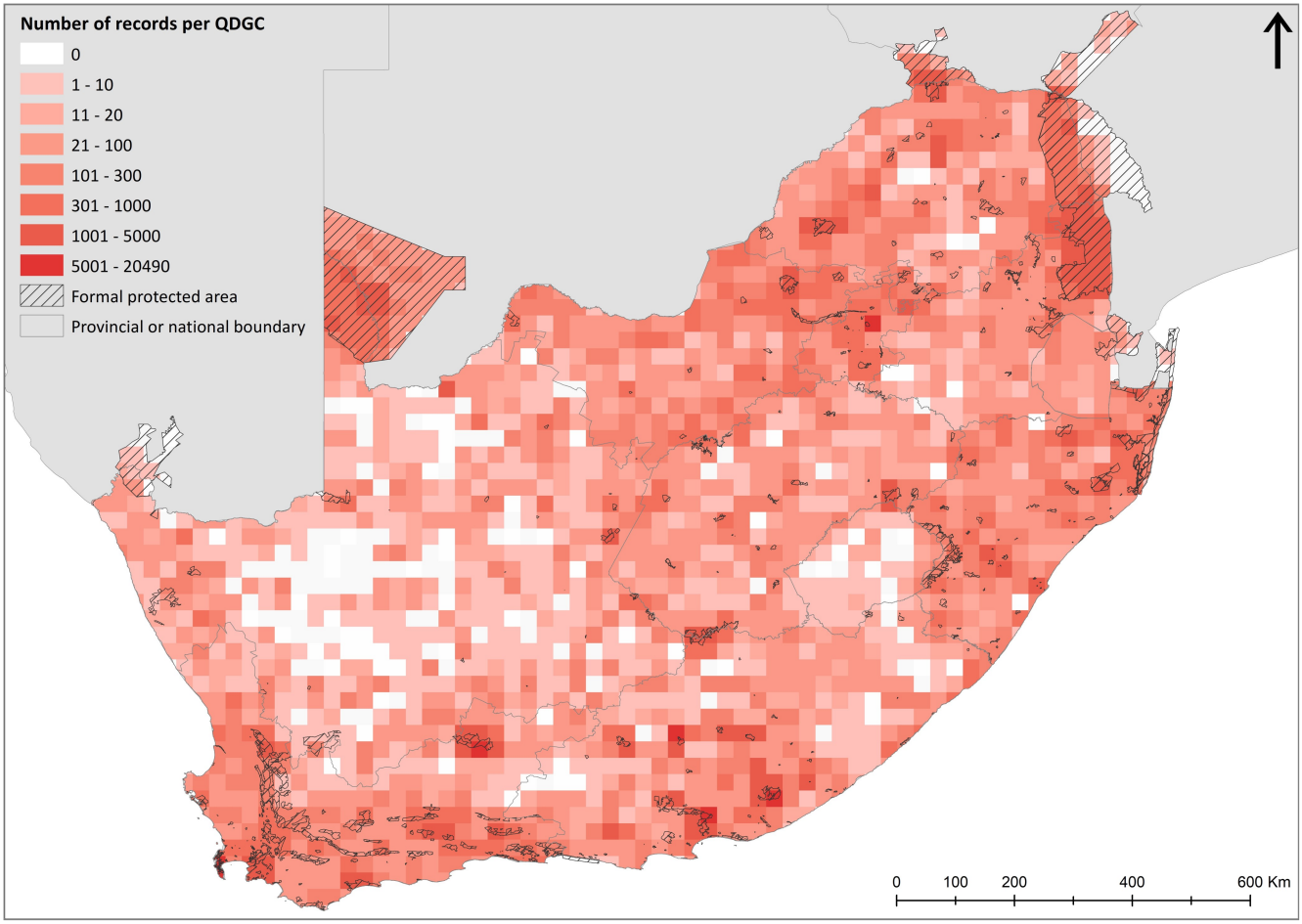

Figure 4. The assessment region comprises South Africa, Swaziland and Lesotho, as well as transfrontier conservation areas. The number of mammal records per quarter degree grid cell (QDGC) used in the assessment are displayed. The highest densities of records are typically found in protected areas, while the lowest densities of records are found in the Northern Cape and Lesotho.

Rutherford 2006) to create a historical or natural range. However, this is layer is not the same as a habitat suitability map. The maps will be continually refined as new data become available.

The following are recommendations for future Red List mapping efforts:

- Maintain the centralised mammal distribution database by collating additional datasets at they are produced. This will significantly reduce the time needed to conduct future revisions.
- Continue vetting the records to correct errors and to reflect recent taxonomic changes.
- Source funding to perform systematic mammal surveys, much like what was done in the Butterfly and Reptile Red Lists and Atlas projects (Mecenero et al. 2013; Bates et al. 2014), as small mammals are particularly reliant on museum records at present.

Geographical parameter protocol

Estimating geographical parameters and patterns is one of the main ways to list species, especially small mammals. The extent of occurrence (EOO) (Figure 5) was calculated as the minimum convex polygon around all compiled geo-referenced records (IUCN Standards and Petitions Subcommittee 2017). This measure may exclude discontinuities or disjunctions within the overall distribution of a species. Area of occupancy (AOO) (Figure 5) is the area within a species' extent of occurrence that is occupied. This measure reflects the fact that a species will not usually occur throughout the area of its extent of occurrence, which may, for example, contain unsuitable habitats. The AOO is the smallest area essential at any stage to the survival of existing populations of a species. The size of the AOO should be at a scale appropriate to relevant biological aspects of the species. We estimated AOO by calculating the amount of natural habitat remaining within the EOO using a national land cover dataset from 2013 (GeoTerraImage 2015a) where we used the following heuristics:

- If the species is not a habitat specialist, AOO was estimated as all remaining natural habitat within the EOO.
- If the species is a habitat specialist (for example, grassland or forest specialists), the relevant vegetation types (Mucina & Rutherford 2006) within the EOO were clipped to the land cover layer (GeoTerraImage 2015a) and the remaining natural habitat was calculated.
- For wetland specialists, the following method was used:
  - Where a home range size or maximum dispersal distance is available, we used this value to buffer wetland patches
  - In the absence of such ecological information, we buffered the wetlands by both 500 m (strip width used to assess habitat condition around wetlands in the National Biodiversity

Assessment, as it provides a good proxy for wetland condition; Driver et al. 2012) and 32 m (minimum buffer zone of no development around waterbodies, as set in the National Environmental Management Act, Activity 9 and 11 listing 1 of Government Notice R544 and Activity 16 Listing 3 of Government Notice R546 of 2010).

- The buffer strips around the wetlands were summed and overlaid with the land cover layer to calculate the remaining natural vegetation around wetlands.

For species heavily impacted by the traditional medicine trade, we used rural area expansion between 2000 and 2013 (GeoTerraImage 2015b), which is approximately the 10 year duration recommended for small mammals in the Red List guidelines (IUCN Standards and Petitions Subcommittee 2017), as a proxy for population decline from harvesting. Additionally, we calculated the effective intact AOO as the proportion of the AOO unaffected by harvesting. If home range or dispersal ability was known, this value was used to buffer distribution points (as a radius). If not, both distribution points and "huts" (as a proxy of rural development; Eskom Spot Building Count Eskom, 2011) were buffered by a radius of 10 km (feasible walking distance from villages). We then used current land cover data to subtract the amount of transformed land currently contained within the AOO. Finally we subtracted the area of the natural AOO that intersects the buffered rural villages and thus within harvesting distance, which left an estimate for AOO that contains natural land at least 10 km away from potential harvesting threats.

A location is a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the species present. The size of the location depends on the area covered by the threatening event (for example, an entire river might be one location if it was all threatened by the construction of a dam upstream). A location may include part of one subpopulation or many subpopulations. For example, if two or more subpopulations occur within an area that may be threatened by one such event, they must be counted as a single location. Conversely, if a single subpopulation covers an area larger than may be affected by any single event, it must be counted as more than one location. Where a species is affected by more than one threatening event, a location should be defined by considering the most serious plausible threat. For example, where the most serious plausible threat is habitat loss, a location is an area where a single development project can eliminate or severely reduce the population (Figure 6). Note:

- Locations will not be applicable to widespread, un-fragmented species or to all types of threat; and, in many cases, it is not possible to estimate the number of locations for a species.
- Locations must be defined by plausible or imminent threats, *not* all possible future threats (for example, a possible meteorite crash is not a plausible threat).

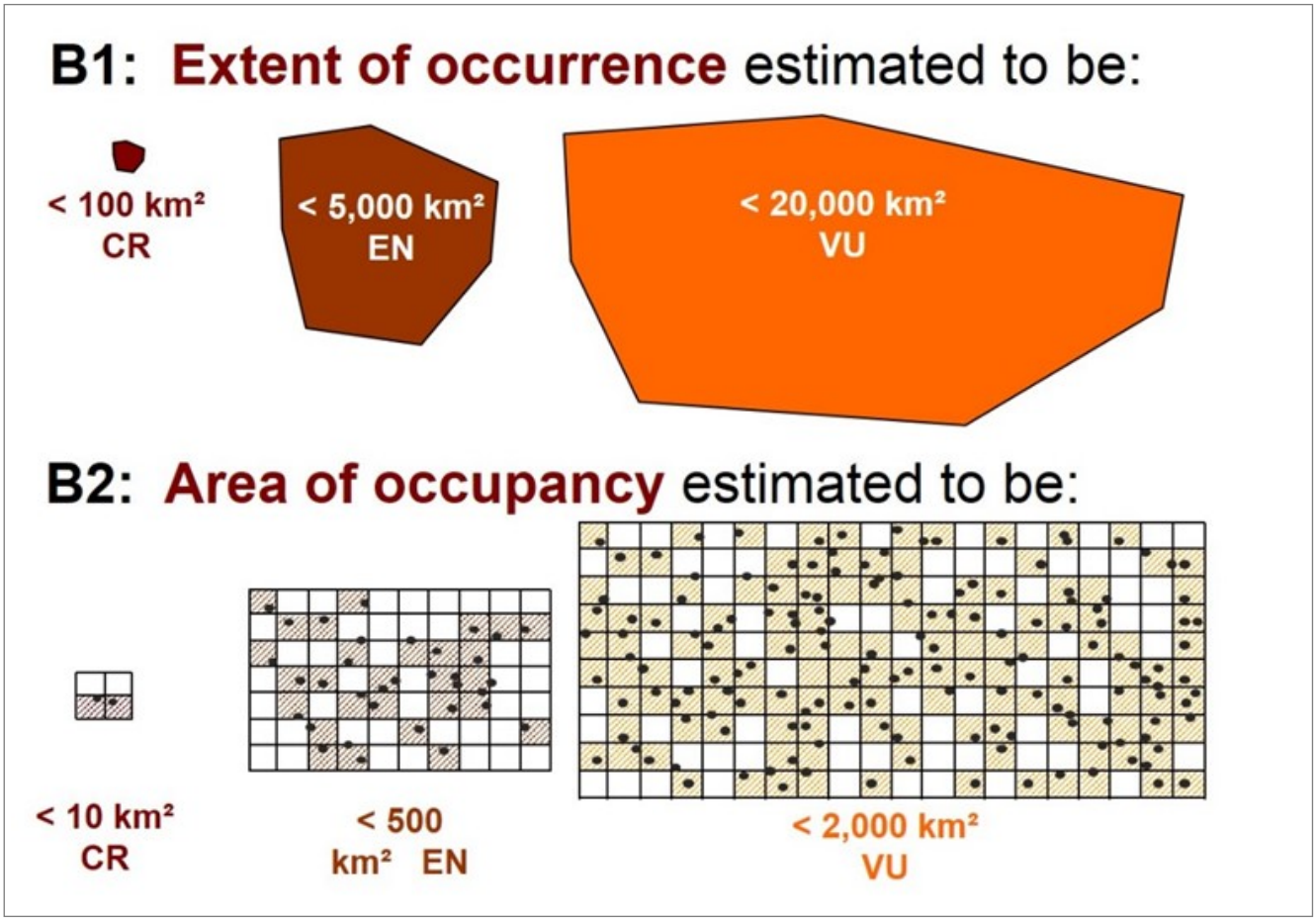

Figure 5. The EOO, or range, is important in applying sub-criterion B1 and is calculated through a minimum convex polygon, while the AOO can be used to apply sub-criterion B2 and can be calculated through occupied grid cells, both in conjunction with other sub-criteria.

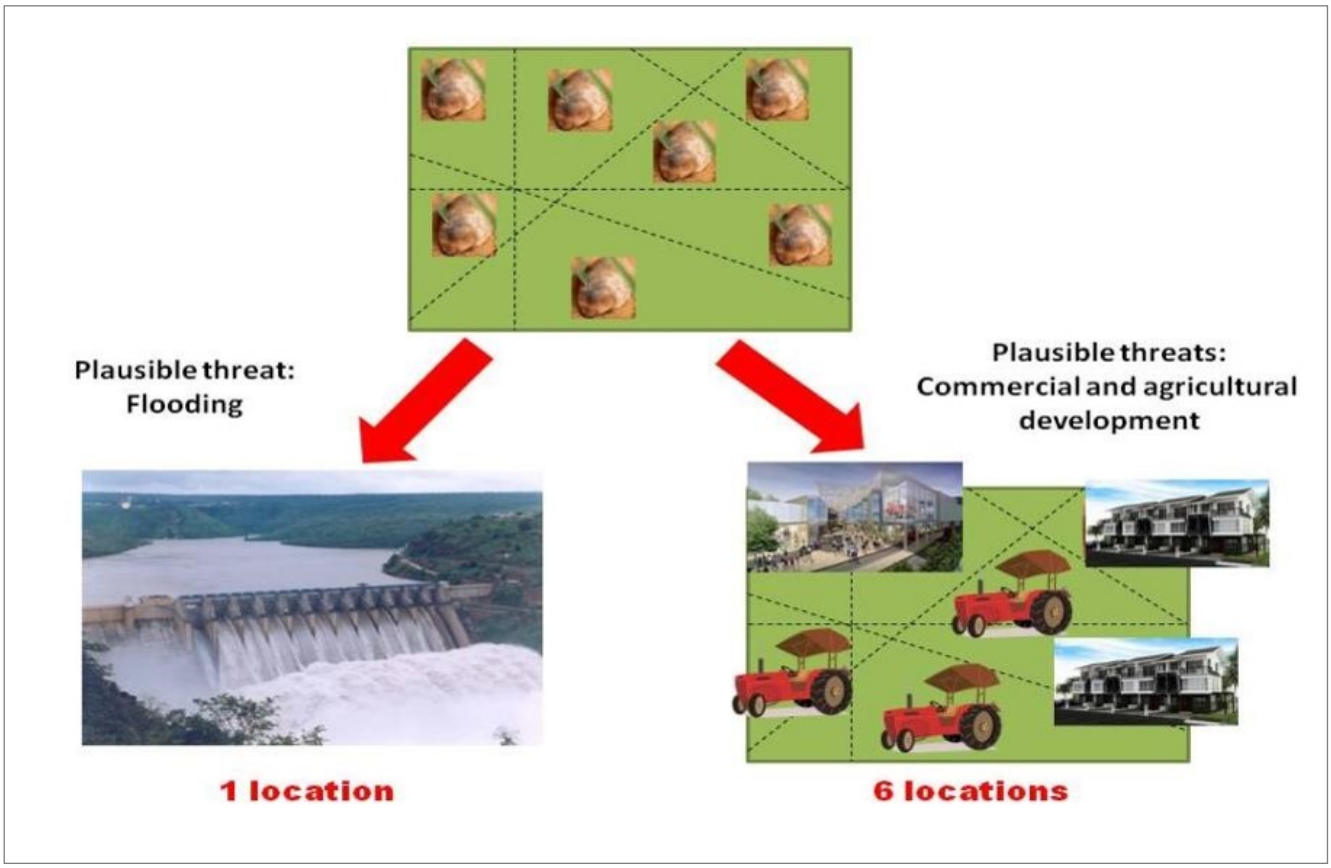

Figure 6. The last seven remaining subpopulations of a golden gole species exist in fields within the same region (< 100 km^2) but isolated from each other by a matrix of unsuitable habitat (which continues to increase due to inappropriate land-use expansion). If the most plausible threat is a dam that will flood the region and drown all subpopulations, this is considered one location and may qualify for Critically Endangered under B1ab(i). If the most plausible threats are a combination of commercial development and agricultural development, the area of which only affects 1–2 subpopulations each, then the number of locations would be six, corresponding to Vulnerable under B1ab(i).

Table 9. Definition of presence terms

Term	Definition
Extant	The species is known or thought very likely to occur presently in the area, usually encompassing current or recent localities where suitable habitat at appropriate altitudes remains.
Probably Extant	The species' presence is considered probable, either based on extrapolations of known records, or realistic inferences (e.g., based on distribution of suitable habitat at appropriate altitudes and proximity to areas where it is known or thought very likely to remain Extant). 'Probably Extant' ranges often extend beyond areas where the species is Extant, or may fall between them.
Possibly Extant	The species may possibly occur, based on the distribution of suitable habitat at appropriate altitudes, but where there are no known records. 'Possibly Extant' ranges often extend beyond areas where the species is Extant (see definition of "Extant" above) or Probably Extant (see definition of "Probably Extant" above), or may fall between them.
Absent	Although surveys have been conducted in the country, no records exist for the species. Habitat is largely unsuitable for the species.
Possibly Extinct	The species was formerly known or thought very likely to occur in the area, but it is most likely now extirpated from the area because habitat loss/other threats are thought likely to have extirpated the species and/or owing to a lack of records in the last 30 years.
Extinct	The species was formerly known or thought very likely to occur in the area, but there have been no records in the last 30 years and it is almost certain that the species no longer occurs, and/or habitat loss/other threats have almost certainly extirpated the species.
Presence Uncertain	A record exists of the species' presence in the area, but this record requires verification or is rendered questionable owing to uncertainty over the identity or authenticity of the record, or the accuracy of the location.

Table 10. Definitions of origin terms.

Term	Definition
Native	The species is/was native to the area.
Reintroduced	The species is/was reintroduced through either direct or indirect human activity.
Introduced	The species is/was introduced outside of its historical distribution range through either direct or indirect human activity.
Vagrant	The species is/was recorded once or sporadically, but it is known not to be native to the area.
Origin Uncertain	The species' provenance in an area is not known (it may be native, reintroduced or introduced).

Table 9 and Table 10 provide definitions for the terms used in the Occurrence section.

Population

This section describes recent population trends and current population size. Please note, Red List criteria relating to population trends refer only to the number of mature individuals. **Mature individuals** are the number of individuals known, estimated or inferred to be capable of reproduction. When estimating this quantity for each species, the following points were considered:

- Mature individuals that will never produce new recruits were not counted (for example, densities are too low for fertilization).
- In the case of populations with biased adult or breeding sex ratios, it is appropriate to use lower estimates for the number of mature individuals.
- Where the population size fluctuates, a lower estimate was used.
- Re-introduced individuals must have produced viable offspring before they are counted as mature individuals.

The proportion of mature individuals was, in the absence of other information, calculated by analysing the proportion of reproductive individuals within a typical group for the species and extrapolating this proportion across the total population size. Where such information was lacking, a range in the proportion of mature individuals is used, based on similar species, to test whether the listing is sensitive to the parameter. For utilised species, the proportion of private subpopulations eligible for inclusion in the mature population estimates was determined by quantifying wildness.

Generation length reflects the turnover rate of breeding individuals in a population. Generation length is greater than the age at first breeding and less than the age of the oldest breeding individual. It can be defined as any of the following: average age of parents of the current cohort (i.e., newborn individuals in the population); age at which 50% total reproductive output is achieved; mean age of parents in a population at the stable age distribution; and time required for the population to increase by the replacement rate. All of these definitions of generation length require age- and sex-specific information on survival and fecundity, and are best calculated from a life table (IUCN Standards and Petitions Subcommittee 2017). In the absence of specific estimates, we used the data from Pacifici et al. (2013) to set generation length.

A continuing decline is a recent, current or projected future decline (which may be smooth, irregular or sporadic) which is liable to continue unless remedial measures are taken. Fluctuations will not normally count as continuing declines, but an observed decline should not be considered as a fluctuation unless there is evidence for this (IUCN Standards and Petitions Subcommittee 2017). The current population trend may be stable or increasing, with a continuing decline projected in the future. If the current population trend is declining, then there is continuing decline, but only if the trend is liable to continue into the future and it is not the declining phase of a fluctuation. We calculated continuing declines through rates of habitat loss or through analysing population trends based on the collated population count dataset.

Subpopulations are defined as geographically or otherwise distinct groups in the population between which there is little demographic or genetic exchange (typically one successful migrant individual per year or less). Where there is evidence to delineate between subpopulations, this is justified here. For utilised species, individual fenced populations were mostly considered separate subpopulations in the absence of a metapopulation plan.

The definition of '**severely fragmented**' is if >50% of its area of occupancy is in habitat patches that are 1) smaller than required to support a viable population, and 2) separated from other habitat patches by large distances. In the absence of such information, we interpreted 'severely fragmented' as the distinction between a habitat specialist or generalist and considered the dispersal ability of the species. If the species can survive in agricultural or degraded land, it was assumed not to be fragmented.

Wild and free framework

The Red Listing procedure should only be applied to wild subpopulations inside the natural range of the taxon (IUCN Standards and Petitions Subcommittee 2017). The definition of wild may be based on the intensity of management, and the expected viability of the subpopulation without management intervention, where the IUCN states that subpopulations dependent on direct intervention are not considered wild if they would go extinct within 10 years without "intensive" management (IUCN Standards and Petitions Subcommittee 2017). Acceptable management actions include those that counteract threats, such as anti-poaching patrols, habitat restoration, installing nest boxes; while unacceptable actions are providing most of the food needs of the subpopulation, controlling breeding and providing intensive veterinary care (IUCN Standards and Petitions Subcommittee 2017).

However, a standardised definition of what constitutes a wild population remains unclear. Wildness varies along a spectrum from captive-bred to completely free-roaming. As such, decision-makers need a measurable framework for wildness that can incorporate both short-term impacts on subpopulation survival (for example, food and water provision) and long-term impacts on population resilience (for example, disease resistance and dispersal), thereby reflecting functioning ecological and evolutionary processes. The foundation for such a framework originated when Redford et al. (2011) asked what it means

to successfully conserve a vertebrate species and defined five wildness nodes: Captive Managed; Intensively Managed; Lightly Managed; Conservation Dependent and Self-sustaining. However, these nodes lack empirical and quantifiable thresholds to be able to practically measure differences between subpopulations. Ultimately the framework should allow practitioners to measure the wildness of a subpopulation of a particular species on a particular property by evaluating a core set of management variables. This is driven by the need to evaluate how the private wildlife sector contributes to conservation, and ensure that the Red List assessment reflects as accurately as possible this conservation contribution.

To lay the foundation for such a framework, two expert workshops were convened by the South African National Biodiversity Institute at the Pretoria National Botanical Gardens (10th of December 2014 and 24th February 2015). The workshops laid the foundation for a practical framework to measure wildness by identifying six attributes relating to ecological and evolutionary processes with measurable thresholds to distinguish between five wildness nodes. The framework was piloted by using a wildlife ranch dataset (Taylor et al. 2015) and represents a tool for identifying wild subpopulations scaled by the area requirements and social dynamics of the species. We applied the framework to key utilised species to quantify the proportion of privately managed populations that could be considered wild and thus be incorporated into national population size estimates. For example, the framework was applied to a recent survey to evaluate the total wild number of Cape Mountain Zebra (*Equus zebra zebra*) (Hrabar & Kerley 2015), which helped support a downlisting from Vulnerable to Least Concern (Hrabar et al. 2016). This, following a downlisting proposal, ultimately led to the downlisting of the subspecies on CITES from Appendix I to Appendix II at the CoP17 in 2016. This demonstrates the mutual benefit of private-public partnerships and of having a framework that objectively measures conservation value.

Feedback between practice and theory needs to be implemented such that the framework is refined to the point where it is practical, intuitive and reflects the important evolutionary and ecological aspects of the relevant species. Ultimately, we hope this framework provides a foundation to institute more quantitative and explicit sub-criteria that will help to reduce assessor bias and inconsistency in the Red List guidelines (Hayward et al. 2015).

Habitats and Ecology

This section includes information on the essential habitats and ecological conditions required by the taxon that are relevant to the species' risk of extinction. Importantly, this section also outlines whether the taxon has been recorded from human-modified landscapes, which we inferred to influence its severely fragmented status. In future revisions, we hope to develop this section as an engine to gather ecological parameters to develop standardised protocols for the taxon or taxon group, such as home range and subpopulation size estimates in various habitats and information relating to the dispersal ability of the taxon. The *ecosystem and cultural services* section lists any services the species might provide. For example, pest control, seed dispersal, ecological engineer, key forage species, flagship species, or being the subject of local folklore. For most species, this is a generalised section relating to common functions across the group.

Use and Trade

This section is used to describe what the animal is used for. This includes food, medicine, cosmetics, clothes, accessories, pets, trophy hunting, museum or collection specimens and research purposes. If trade is a significant threat, it is listed in the threats table. The "use and trade summary table" summarises the information currently available for any utilization and/or trade of the species (including legal and illegal hunting and collection for local, national and international trade). This table is useful for evaluating the driver of the trade and thus to design appropriate conservation interventions. The indented section describes commercial use sub-categories.

The "effects of wildlife ranching table" only applies to species that are commercially utilised (both consumptive and non-consumptive). This section describes the positive and negative effects of wildlife ranching management strategies on the population (for example, extra-limital translocation, domestication or hybridisation, persecution), including notes on the extent and quality of habitat being protected, and present and future impacts of these changes on the wild population. It is important to note that this section is not intended to be conclusive but rather to generate hypotheses for further investigation pending data collection from the private sector, with the long-term aim of being able to consistently integrate private populations into conservation assessments.

Threats

One of the aims of the Mammal Red List is to gather evidence that will be useful to conservation managers, landowners and other practitioners. In general, only major threats that are/could cause decline in the population were listed. However, this is largely subjective in the absence of evidence. Attempts were made to rank the severity of threats according to their quantified impact (see Conservation Evidence). Assessors were encouraged to also list specific descriptions of the local threat. These were then linked to the IUCN threats classification system (Salafsky et al. 2008). Threats for Least Concern species were also listed to standardise the threat weighting across species and inform watch-list qualifiers. The threats were then classified by the type of evidence associated with it (Table 13):

- **Empirical** if actual mortality/decline data is presented;
- **Simulation** if the mortality levels have been modelled;
- **Attitudinal** if mortality is suspected based on stakeholder perceptions;
- **Indirect** if mortality is suspected based on indirect evidence such as the rate of habitat loss (based on remote sensing); or
- **Anecdotal** if this is the assessors' opinion and currently has no empirical evidence.

Note this categorisation is different from the data quality definitions because we are ranking the quality of evidence associated with individual published sources and not the aggregate quality of the information used for the assessment. However, the key data from these sources

may contribute to an aggregate minimum and maximum data quality for the assessment if directly relevant to the listing. The scale of the study presenting the evidence was further classified as:

- **Local** – study undertaken at one site.
- **Regional** – study undertaken at multiple sites within a predefined area.
- **National** – study undertaken at multiple sites nationwide or extrapolated to the national scale.
- **International** – study performed somewhere else in the world or is a review of evidence.

In future revisions, a hierarchically organised threats scheme should be developed that nests threats according to ultimate and proximate drivers and their associated severity based on population decline evidence.

Current habitat trend

Habitat loss and degradation is the greatest threat facing most South African mammals (Driver et al. 2012). This section in the assessment summarises the state of habitat extent and quality as well as the rate of habitat loss relevant to the species. Mammals are expected to be the most impacted group by projected scenarios of natural habitat loss in southern Africa over the next century (Biggs et al. 2008). We quantified habitat loss to measure *population reduction* and *continuing decline* (Table 5) in a standardised manner across assessments. Currently, at the national scale, the most comprehensive data available constitutes a 1990 and 2013 land cover dataset (30 m resolution Landsat 8 satellite imagery) (GeoTerraImage 2015a). We used this layer to estimate the amount of remaining natural habitat within area of occupancy parameters and to estimate rates of habitat loss for particular habitat types. This was supplemented by data on rates of urban and rural settlement expansion per province (Table 11) (GeoTerraImage 2015b), which we also used to infer increased rates of illegal harvesting. Specific rates of provincial loss were used to supplement these data and to infer regional levels of population decline and habitat status (Table 12).

Wetlands are the country's most threatened ecosystem, with 65% of wetland ecosystem types threatened (48% of all wetland types Critically Endangered, 12% Endangered and 5% Vulnerable) because they are highly productive and hence become transformed for agriculture (Driver et al. 2012). Nationally, there has been a 32.8% decrease in the wetland extent between 1990 and 2013/14 (GeoTerraImage 2015a). However, this must be interpreted with caution due to the generally drier conditions of 2013/2014 compared to 1990, which has affected the ability to detect wetlands. Overall, 45% of our remaining wetland area exists in a heavily modified condition, due primarily to onsite modification from crop cultivation, coal mining, urban development, dam construction, and overgrazing (and thus erosion) and off-site modifications from disruptions to flow regime and deterioration of water quality (Driver et al. 2012).

The condition of terrestrial habitats is not only influenced by outright loss of habitat but also vegetation and soil degradation from overgrazing, invasive species, and incorrect fire regimes. For example, the area infested by invasive plants in South Africa doubled between 1995 and 2007, with around R6.5 billion of ecosystem services lost annually (Driver et al. 2012). However, patterns of habitat degradation were not possible to consistently quantify for this revision. Similarly, the effects of climate change are unknown for most species, but models project a possible eastwards range shift (reflecting the east-west aridity gradient) for most taxa and an absolute reduction in range, where highest species losses occur in the west of the country (Erasmus et al. 2002; Thuiller et al. 2006). Rates of habitat loss from climate change projections were incorporated when there were species-specific information to do so.

Conservation

Similarly to the Threats section, we aim to gather evidence for the effectiveness of interventions that will be useful to conservation managers, landowners and other practitioners. This section describes, with references where appropriate, what actions are in place to protect this species and what actions are needed. This can range from specific landowner actions, such as adjusting electric fence structure to reduce pangolin mortality, reintroducing species to their former range, to legislative and policy-based actions at provincial, national or international

Table 11. Summary of rural and urban area expansion per province (GeoTerraImage 2015). Rural areas are villages, while urban areas comprise the following classes: commercial, industrial, residential, township, informal, smallholding, sport and golf, school and sportsground, mine buildings and built-up. These data have been used to infer continuing decline for small mammal assessments.

	Rural area (km²)			Urban area (km²)			Rural expansion (%)		Urban expansion (%)	
Province	*1990*	*2000*	*2013*	*1990*	*2000*	*2013*	2000–2013	1990–2013	2000–2013	1990–2013
Eastern Cape	4927	5180	5219	733	860	914	0.8	5.9	6.3	24.7
Free State	18	19	21	773	899	994	7.0	17.2	10.6	28.6
Gauteng	27	40	55	2832	3194	3454	38.7	102.4	8.1	22.0
KwaZulu-Natal	6436	6654	6730	1103	1229	1298	1.1	4.6	5.6	17.7
Limpopo	2748	3344	3640	552	621	714	8.8	32.5	14.9	29.4
Mpumalanga	912	1101	1181	738	895	989	7.2	29.4	10.5	34.0
North West	1204	1386	1476	517	622	706	6.5	22.5	13.5	36.7
Northern Cape	159	186	203	232	274	315	9.0	27.6	15.0	36.1
Western Cape	0	0	0	878	1029	1118	N/A	N/A	8.6	27.3

Table 12. Summary of provincial and local scale rates of habitat loss from provincial conservation agencies and the literature.

Province	Habitat type	Proportion of loss (%)	Time period (years)	Rate of loss (%) per annum	Reference
Eastern Cape	All	2	2007–2015 (8)	0.3	Berliner & Desmet 2007
Eastern Cape	All	12	2015–2045 (30)	0.4	Extrapolated from number of development proposals
Free State	All	6	1994–2009 (15)	0.4	N. Collins, unpubl. data
Free State	All	2.4	2000–2009 (9)	0.3	N. Collins, unpubl. data
Free State	Grassland	4	1994–2009 (15)	0.3	N. Collins, unpubl. data
Free State	Grassland	2.3	2000–2009 (9)	0.3	N. Collins, unpubl. data
Free State	Nama Karoo	2.9	1994–2009 (15)	0.2	N. Collins, unpubl. data
Free State	Nama Karoo	2.7	2000–2009 (9)	0.3	N. Collins, unpubl. data
Free State	Savannah	0.5	1994–2009 (15)	0.03	N. Collins, unpubl. data
Free State	Savannah	5.1	2000–2009 (9)	0.6	N. Collins, unpubl. data
Gauteng	All	13	1995–2009 (14)	0.9	Driver et al. 2012
KwaZulu-Natal	All	20.4	1994–2011 (17)	1.2	Jewitt et al. 2015
KwaZulu-Natal	All	7.6	2005–2011 (6)	1.3	Jewitt et al. 2015
KwaZulu-Natal (Karkloof)	Forest	5.7	1944–1996 (52)	0.1	Lawes et al. 2004
Limpopo (Soutpansberg)	Woodland	20	1990–2006 (16)	1.2	Munyati & Kabanda 2009
Limpopo / Mpumalanga (Kruger to Canyons)	All	7	1993–2006 (13)	0.5	Coetzer et al. 2010
North West	All	10	1994–2006 (12)	0.8	NW READ 2014
North West	All	2	2006–2010 (4)	0.5	Desmet & Schaller 2015
Western Cape	All	0.4	2006–2011 (5)	0.1	Pence 2014
Western Cape	Wetlands	0.7	2006–2010 (4)	0.2	Pence 2012

scales. These were then linked to the IUCN actions classification system (Salafsky et al. 2008). This section also lists and describes the key protected areas for the species, either in terms of resilient subpopulations, genetically pure subpopulations or key potential sites for reintroductions. The *Current Conservation Projects* tab describes any existing conservation projects ongoing for this species (for example, the Wild Dog Metapopulation Strategy run by the Wild Dog Advisory Group; or the Black Rhino Range Expansion Project run by the World Wildlife Fund for Nature – South Africa). This section will need further work to comprehensively populate and will form a valuable database when completed. It will also form the foundation of a gap analysis for conservation action.

The *recommendations for land managers and practitioners* subsection describes practical management recommendations for the conservation of the species. For example, recommendations on a monitoring scheme (what scale and institutions) and/or the development of a management plan. It also advises whether this species would benefit from captive breeding programmes or other *ex situ* management strategies and whether there are specific land management practices that would benefit the species.

The *research priorities* subsection lists specific research projects that are a priority for the species. The section attempts to be as detailed as possible to generate specific research projects needed to make the assessments more comprehensive and accurate and thus links to the data quality section. For example, we did not simply list "taxonomic research" but "research into the genetic structure of the southern African Leopard (*Panthera pardus*) population and connectivity between subpopulations".

The *encouraged citizen actions* subsection describes any citizen science schemes that might benefit this species (for example, uploading sightings records onto MammalMAP), or any citizen-funded projects that would help to raise the profile of this species (for example, the APOPO mine and tuberculosis detection projects, HeroRATS, for the Giant Rat *Cricetomys ansorgei*). It also includes any practical actions that citizens can perform to conserve this species (primarily orientated towards species that occur in urban and peri-urban settings). For example, planting particular types of trees to provide nest sites, or avoiding consumption of certain products with known negative effects on the species.

Conservation evidence paradigm

We standardised the weighting of listed threats and interventions by detailing the evidence for the effects of the proposed threat on the species and the effectiveness of proposed interventions. The threats and intervention tables within the assessments classify data quality at the level of the scientific article. These are (in descending order of evidence strength) (Table 13): 1) empirical, 2) simulation, 3) attitudinal, 4) indirect, and 5) anecdotal. These classifications are different from the data sources

Table 13. Description of data qualifiers for individual articles in the Threats and Interventions tables.

Article data quality	Description		Examples
	Threat	Intervention	
Empirical	Relevant biodiversity variable decreased	Relevant biodiversity variable increased	Articles presenting mortality data or evidence for population size increase. The responses of directly relevant variables are real.
Simulation	Relevant biodiversity variable decrease modelled	Relevant biodiversity variable increase modelled	Articles where mortality levels/increase in numbers have been modelled. The responses of directly relevant variables are hypothetical.
Attitudinal	Relevant biodiversity variable decrease determined through stakeholder perception	Relevant biodiversity variable increase determined through stakeholder perception	Articles where potential threat level/intervention effectiveness is determined through surveys. The responses of directly relevant variables are potential.
Indirect	Indirect or tangential biodiversity variables decreased	Indirect or tangential biodiversity variables increased	Articles where data on indirect/tangential variables are interpreted to influence the primary biodiversity variable. For example, remote sensing studies to quantify rate of habitat loss / condition as a proxy for population decline. Or population decline based on the removal of old-growth trees needed for nesting sites. Similarly, the decrease in livestock mortalities from the implementation of livestock guarding dogs could be construed to decrease persecution rates of predators and thus increase population size.
Anecdotal	Direct, indirect, or tangential biodiversity variables thought to be decreasing	Direct, indirect, or tangential biodiversity variables thought to be increasing/could increase	Articles that describe a threat or intervention but present no data, analyses or models. Also includes personal communications based on expert knowledge or experience (unpublished).

classification because, while the classification of the individual peer-reviewed articles are meant to justify and quantify the severity of threats and effectiveness of interventions relevant to the species, the data sources and quality section categorises the aggregated information relevant to the Red List status. Thus, the articles described in the threats and interventions tables may or may not influence the Red List assessment and thus may or may not be aggregated into the general data source used to make the Red List assessment (Figure 6). For example, an article describing the negative attitudes of rural communities towards Leopards would help to quantify the severity of the threat of persecution, but it would not be incorporated as a data source for the Red List assessment itself as there are no data from which a criterion threshold could be quantified. However, an article providing empirical data on actual or potential population decline from persecution would help to quantify population reduction or continuing decline and thus be used to apply criteria A, B or C, and would be incorporated as a data source and thus general data quality for the assessment. In summary, while the data sources and quality classifications describe the aggregated information that directly influences the application of the Red List criteria, the classification of individual articles in the threats and interventions tables weigh up the strength of evidence as represented in the scientific literature to rank specific threats and interventions, thus allowing the reader to interpret what kinds of studies have been performed that are relevant to conservation status of the species. The resources in the tables are meant to relate directly to the relevant species, but often this is not possible as little research has been conducted that directly assesses mortality or recovery (*sensu* Balme et al. 2014; M.F. Child unpubl. data). Articles that contain empirical data will then be further categorised and synthesised to develop a Conservation Evidence database by summarising the type of experimental evidence they provide (for example, whether the experiment is controlled, replicated, randomised, paired or a systematic review summarising effect size). This initiative is recommended as a spin-off project to enhance the efficacy and efficiency of future revisions.

Data Sources and Quality

Data quality refers to the information used to assign a Red List status and not to the general quality of information about the species (for example, there may be good ecological studies on the species but few studies assessing population trends or threat levels). It refers specifically to the data that can be used to assign a parameter value relevant to the criteria thresholds. There are five types of data quality defined by the IUCN (IUCN Standards and Petitions Subcommittee 2017). From strongest to weakest: Observed, Estimated/Projected, Inferred and Suspected. These are described in Table 14. As many assessments, particularly for small mammals, relied on determining the geographical range and habitat occupancy of the species, we adapted the IUCN terminology to standardise our use of EOO/AOO estimates across species (Table 14), and are defined below:

- *Observed*: extensive field surveys (past and present) for the species leave little uncertainty over distribution. Very few or no false negatives in distribution. Most often relevant to species with extremely restricted ranges and/or restricted to fenced protected areas; or species that are widespread and easily encountered.
- *Estimated*: EOO based on both historical and recent records (not necessarily surveys) but potential for false negatives (and thus underestimation of area), due to lack of systematic surveys, and false positives if local extinctions have occurred at historical sites

(which may overestimate area). If the species is a habitat specialist (for example, only occurs in forests, grasslands or wetlands), AOO was estimated using the remaining natural vegetation of the key habitat type (see habitat trend subsection). This may overestimate occupancy as presumably not all habitat patches will be occupied.

- *Projected*: Future estimates of EOO and AOO cannot be used as proxies for current distribution, but can be used to infer a continuing decline or suspect a population reduction using A3 or A4.
- *Inferred*: EOO based mostly or solely on museum records and thus false negatives (and potential underestimation of area), due to lack of systematic surveys, and false positives (and thus potential overestimation), if local extinctions have occurred at historical sites, are highly probable. AOO is calculated using the amount of remaining natural habitat (not habitat specific) within the EOO, relevant to either habitat generalists or species for which we do not know the habitat requirements or niche. This approach may overestimate occupancy.
- *Suspected*: EOO /AOO cannot be suspected.

As the above shows, EOO and AOO may have different data qualities for the same species. For example, a species may have an inferred EOO based on a smattering of historical and recent records (but no systematic surveys), but an estimated AOO based on specific habitat types to which the species is restricted.

The use of a data quality category also depends on the Red List parameter being calculated. Suspicion differs from inference because, while evidence of qualitative habitat loss can be used to infer that there is a qualitative (continuing) decline, evidence of the amount of habitat loss can be used only to suspect a population reduction at a particular rate (IUCN Standards and Petitions Subcommittee 2017). Thus, while continuing decline can be inferred from any rate of habitat loss, a particular rate of population reduction can only be suspected from a particular rate of habitat loss (A1-4). For this revision, we translated all data and information sources used to make the listing into maximum and minimum levels of data quality:

- *Maximum data quality* describes the most relevant and strongest evidence used in the listing. This refers to describing the main parameters for each criterion: Population reduction for A, EOO/AOO for B, and population size for C and D.
- *Minimum data quality* describes the level of uncertainty in the supporting information. This typically refers to the sub-criteria thresholds that use continuing decline (criteria B and C). Three special uses of the *suspected* data quality category (Table 14) have been implemented:
  - It describes high levels of uncertainty and assumptions, caused either by lack of Red List relevant information or lack of applied ecological information for the species, in the following parameters or terms (Table 5): *mature population size*, *severely fragmented*, *location*, *subpopulation*, and *extreme fluctuations*.
  - For precautionary assessments, it has been used to qualify continuing decline in the absence of any empirical evidence but strong anecdotal information. For example, if poaching is thought to be a major threat to the species, a continuing decline can be inferred if there are sufficient empirical data to justify the severity of the threat, but suspected if no formal research has documented the impact of the threat. Note that the use of suspected for this aspect of minimum data quality refers both to direct, indirect and tangential variables (Table 14).
  - *Least Concern listings:* We also use suspected data quality for species which are 'clearly' not threatened but for which there are no actual data to evaluate any criterion thresholds. For example, while there is an observed minimum population size for Impala (*Aepyceros melampus*) there are no such estimates for Aardvark (*Orycteropus afer*) in which the population size and trend is *suspected* not to fall in a threatened category.

Thus, whereas maximum data quality describes the data used to conduct the Red Listing, minimum data quality can be used to describe potential decline from threats for which there are no data (including Least Concern species), or from uncertainty surrounding the ecological definition of certain terms, and is thus used to inform the watch-list categories. In other words, inference implies relevant data but suspicion implies a threat that is thought to be potentially causing decline but for which no empirical evidence exists. Using the maxima / minima helps to bound the uncertainty surrounding the Red List assessment. For example, a species may have an observed population number of mature individuals but only an inferred continuing decline from habitat loss. For good-quality assessments, maximum and minimum data quality will be synonymous as observed or estimated, or range from observed to inferred. The lowest quality assessments will be suspected for both maximum and minimum data qualities, while intermediate quality assessments will have suspected as the minimum data quality.

Corresponding to the data quality categories are the data source categories. Data sources describe the format in which the information is presented, the degree of its scientific rigour, and the relative accessibility of the information. Categorising the data sources will help to quantify how much of the information relevant to the assessments is based on published data compared to unpublished reports and anecdotal information. Data sources are defined by the following categories (from strongest to weakest) (Table 15):

1. *Census*: any systematic survey or total count that does not rely on statistical models to estimate population size.
2. *Field study*: any survey that samples the relevant species and measures a parameter of interest; for example, population size, relative abundance, mortality rate, subpopulation trend. If field studies have been conducted across all known sites where the species occurs or across the representative range of the species, this is estimated data quality. If the field studies are localised and have not been replicated across the representative range, this is inferred data quality (see Table 15).
3. *Indirect information:* field studies that do not sample the species directly but generate data indirectly or tangentially relevant to the species but still in the same general type of units. Such studies could be on

Table 14. Description and examples of data quality categories used to classify the strength of the information relevant to Red List criteria. Examples for key criteria parameters are provided.

Data quality category	Description	Relevant criteria	Rationale and examples
Observed	Information that is directly based on well-documented observations of all or nearly all known individuals in the population (*direct variables*).	A1,2,4a (*population reduction*) B1,2b(v),c(iv) (*EOO, AOO, continuing decline*) C1,2a(i,ii),b (*population size and continuing decline*) D (*population size*), D2 (*AOO*)	*Population size*: A total count or census of all or most individuals within the population. For example, through aerial surveys of the entire EOO or AOO. If values from known subpopulations are extrapolated across other subpopulations, then the data quality becomes estimated. *Population reduction*: Based on two or more censuses on, or close to, the 3 generation or 10 year period. If not close to the time period, it becomes estimated (see below). *Continuing decline*: Based on empirical data where the level of mortality to recruitment is known to be causing a net decline. *Area*: Certainty over the geographical range (extensive surveys or restricted to fenced / isolated areas). No false negatives.
Estimated	Based on calculations that include statistical assumptions about sampling, or biological assumptions about the relationship between a measured variable to the criterion variable (*direct variables*).	A1-4b (*population reduction*) B1,2b(v),c(iv) (*EOO, AOO, continuing decline*) C1, 2a(i,ii),b (*population size and continuing decline*) D (*population size*) E	*Population size* Any index of abundance to calculate population size. For example, mark-recapture or distance sampling studies. Model assumptions must be stated. If estimates from known subpopulations are extrapolated across other subpopulations, then the data quality becomes inferred. *Population reduction*: Based on two or more statistical estimates on, or close to, the 3 generation or 10 year period. Includes interpolation in time to calculate a parameter for a particular time step (for example, from census data). *Continuing decline*: Based on empirical data where statistical models (for example, confidence intervals) indicate a decline. *Area*: EOO based on both historical and recent records but potential for both false negatives (and thus underestimation of area) and false positives (and thus overestimation of area). AOO based on amount of specific habitat type (may overestimate if not all habitat patches occupied).
Projected	Same as "estimated", but the criterion variable is extrapolated in time (*direct variables*).	A1-4b (*population reduction*) B1,2b(i,ii,iii,v) (*continuing decline*) C1,2 (*continuing decline*) E	*All parameters:* Any statistical model that predicts parameter values in the future. For example, niche modelling. Model assumptions must be stated. The extrapolation of current or potential threats into the future, including their rates of change, must be included. Determining future EOO/AOO parameters can only be used to infer a continuing decline or suspect a population reduction.
Inferred	Information that is based on indirect evidence, on variables that are indirectly related to the criterion variable, but in the same general type of units. Inferred values rely on more assumptions than estimated values. For example, area or number of subpopulations (*indirect variables*).	A1-4d (*population reduction*) B1,2b(i,ii,iii,iv,v) (*EOO, AOO, continuing decline*) C2a(i,ii),b (*population size and continuing decline*) D (*population size*)	*Population size*: Calculated from density estimates in localised or clustered areas of the EOO. Inference thus involves extrapolating an observed or estimated quantity from known subpopulations to calculate the same quantity for other subpopulations. *Population reduction*: Based on, for example, decrease (%) in catch-per-unit-effort or illegal trade / harvesting estimates on, or close to, the 3 generation or 10 year period. *Continuing decline*: Based on, for example, data from catch-per-unit-effort, illegal trade / harvesting estimates or decline in habitat. Only one time-point needed. Any rate of decline. *Area*: EOO based only on historical (museum) records. Potential for false negatives and positives due to lack of recent systematic surveys. AOO based on amount of natural habitat remaining (not habitat specific and thus may overestimate occupancy).
Suspected	Information that is based on circumstantial evidence, or on variables in different types of units (*tangential variables*).	A1-4c,e (*population reduction*) *B1,2b(i,ii,iii,iv,v) (*continuing decline*) *C2	*Population size*: Cannot be suspected. *Population reduction*: Based on decline in habitat quality or on incidence of a disease. In general, a suspected reduction can be based on any factor related to population abundance or distribution, including the effects of (or dependence on) other species, as long as the relevance of these factors can be supported. **Continuing decline*: For precautionary assessments only. In the absence of empirical data that can be used for inference, suspected is used when expert experience strongly suggests a decline. Only used in minimum data quality for direct, indirect and tangential variables. *Area*: *EOO* / *AOO* cannot be suspected. *Least Concern species*: Suspected is used as the data qualifier for any variable for which there are no empirical data.

catch per unit effort or observed reduction in key habitats – as long as the relationship between the indirect variable and the population is known or correlated. This represents *inferred* data quality. However, information based on indirect variables where the relationship with the population is unknown but reasonably connected is *suspected* data quality. For example, levels of illegal harvests based from port impoundments, decrease in habitat quality (from, for example, invasive species) rather than habitat loss outright, or the prevalence of disease.

4. *Museum records:* where the majority of the data for the species is from museum or historical records (in the absence of new field studies), which is defined as pre-2000 for this revision, and refers to *suspected* data quality.

Data sources 1–3 are further qualified by the information type format: 1) *literature* (peer-reviewed scientific articles); *unpublished* (for example, provincial reports, unpublished theses or reports; this includes analyses performed by Red List core editors specifically for the assessment); or *expert knowledge* (which includes informal sightings of the species and personal observations or experience). The Data Sources and Quality section in the assessments lists only the sources of information used to make the listing (Table 15). Ideally, these should be fewer categories of high-quality information here. For example, an assessment based on field studies published in the literature with minimal reliance on indirect or anecdotal information is a robust assessment.

Categorising uncertainty

Uncertainty caused by inconsistent data quality and interpretation can cause bias in Red List assessment (Hayward et al. 2015), and reduces the efficacy of measuring conservation trends. Non-genuine changes are mostly the result of 'new information', which are often the result of disparate or incomplete datasets being analysed by different assessors. The IUCN encourages assessors to list taxa irrespective of the data quality, and have developed a standardised terminology to categorise information most relevant to Red List assessments. We have linked the data quality classifications to a standardised classification of data sources, both to aid readers in quickly identifying the type of data used in the assessment and to assist in quantifying the proportion of the scientific literature that contributes to Red List assessments (see conservation evidence).

However, the availability of appropriate data to conduct an assessment is different to the uncertainty in interpreting the data. Whereas data quality refers to the available information *per se*, data uncertainty refers to its interpretation. Interpreting the available information may

Table 15. The relationship between data quality and data sources used in the mammal Red List revision.

Data quality category	Data sources applicable	Data source description	Data source examples
Observed	Census – literature Census – unpublished	Total counts of the animals over the entire area.	Systematic surveys in protected area reports or published in peer-reviewed articles. No statistical models or extrapolation necessary.
Estimated	Field study – literature Field study – unpublished (across all known sites where species occurs or a representative range of sites for the species)	Field work at sampled sites that use statistical models to estimate relevant parameters using direct variables. The field study / studies should cover or sample the entire range of the species (otherwise, inferred).	Statistical models published in peer-reviewed articles or analyses based on underlying population data contained in unpublished theses or reports.
Projected	Field study – literature Field study – unpublished	Simulations based on field data and/or museum records and environmental variables that estimate parameter values in the future.	Ecological niche models, population viability analyses or other statistical models published in peer-reviewed articles, unpublished theses or reports.
Inferred	Indirect information – literature Indirect information – unpublished Field study (extrapolated from local studies across range of species)	Field studies at sampled sites to estimate relevant parameters using indirect variables. Direct and indirect variables should be correlated. Census extrapolation: density from census area applied across subpopulations/area. Field study extrapolation: estimates from sampled site (s) applied across subpopulations/area.	Statistical models or estimates based on variables indirectly related to (but correlated with) the population in peer-reviewed articles, unpublished theses or reports.
Suspected	Indirect information – literature Indirect information – unpublished Indirect information – expert knowledge Museum records	Field studies at sampled sites to estimate relevant parameters using tangential variables. Direct / indirect and tangential variables may not be correlated and the relationship is thus unknown but they should be reasonably connected. Museum records refer to assessments heavily or solely influenced historical distribution records (main data source for many small mammals). This pertains mainly to minimum data quality.	Estimates based on variables indirectly related to the population, but the causal relationship is unknown, in peer-reviewed articles, unpublished theses or reports, as well as anecdotal expert opinion for which no empirical data exist.

be influenced by small sample size confounded by natural variability in the phenomenon being measured (for example, natural population fluctuations misinterpreted as decline); semantic uncertainty arising from vagueness in the criteria or lack of consistency in different assessors' usage of them (Hayward et al. 2015); and measurement error in parameter estimates through poor statistical methods, ineffective sampling or measuring incorrect variables. Measurement error can only be counteracted by collecting additional data in the right areas (Akçakaya et al. 2000), which is why the conservation evidence framework is so important.

The terminology used in the Threats and Interventions tables is different to those used in Data Quality and Sources because one addresses the level of a data source (more specifically, a scientific document) in ranking threats and interventions, while the other addresses the composite information used to conduct the assessment. There is overlap between these systems, particularly in the use of 'Indirect information', and it is possible that the sources from the tables directly influence the Red List assessment and thus are transcribed to the Data Quality and Sources table. However, more often than not, the literature (or lack thereof) used to quantify evidence for threats and interventions do not provide appropriate data to conduct a Red List assessment (which may rely more on unpublished field studies and expert opinion). The comprehensive assessment of the scientific literature for conservation evidence will provide a platform to streamline and connect the information generated by research to that available for incorporation in Red List assessments. A simple schematic illustrating how these terms interlink is shown in Figure 7.

The best way to counteract uncertainty over interpreting the data or mistakes arising from measurement error hidden in the information is by producing a range of plausible values and including a best estimate within that range. Uncertainty is most likely to affect the assessment when based on expert opinion alone (without parameter estimates to anchor the assessment). We characterise uncertainty resolution by the following terms, which are linked to (Table 15) in descending order of certainty:

1. **Total count**: little uncertainty, corresponds to Census data source. This is for assessments based on high levels of certainty for which there is no documented decline or ambiguity in population parameters.
2. **Confidence intervals**: based on statistical models. Refers to objective approaches to uncertainty and should generally correspond to evidentiary risk tolerance.
3. **Maximum** / **minimum values**: range of parameter estimates. No statistical model but based on available data and thus generated objectively**.**
4. **Best estimate**: a point estimate provided for the main criterion where there are too few data to estimate a range in parameter values.
5. **Consensus**: congruent expert opinion of those involved in the assessment, often based on experience. This generally lacks quantitative estimates and rely heavily on expert knowledge, which will likely correspond to low risk tolerance (precautionary assessments, see below).

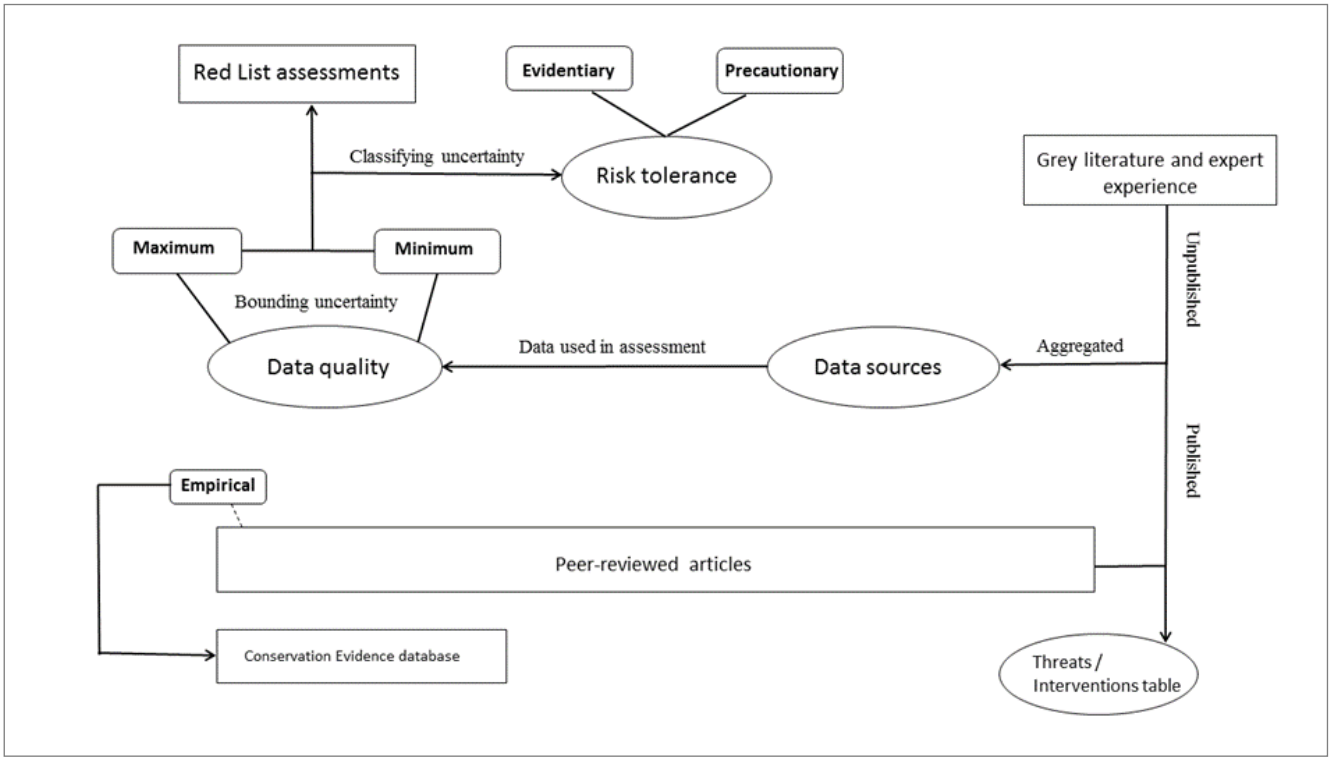

Figure 7. Flow diagram to illustrate the hierarchically nested use of individual data sources translated into data quality and categorisations of uncertainty. Rectangles represent databases, ovals represent clusters of definitions, and rounded rectangles represent key terms. Peer-reviewed articles are categorised according to their strength of evidence and relevance to the species in the Threats and Interventions tables. Empirical papers are then fed into the Conservation Evidence database. Information from published sources are assessed together with that of unpublished sources to categorise the aggregated data sources most relevant to determining the Red List status. The relevant data sources are then classified according to the maximum and minimum quality (and thus certainty) they represent, from which the risk tolerance can be assessed to help interpret the assessment.

When the parameter estimates, or the uncertainty over interpreting the information, crosses one or more thresholds for the Red List criteria, assessors can either take an *evidentiary* or *precautionary* approach to deciding on the status (risk tolerance) (IUCN Standards and Petitions Subcommittee 2017). A precautionary attitude (low risk tolerance) will classify a species as threatened unless it is highly unlikely that it is not threatened, whereas an evidentiary attitude will classify a species as threatened only when there is strong evidence to support a threatened classification. It is recommended that the assessments should be more evidentiary than precautionary but use the lower bounds of any estimates to make the listing. To standardise the use of precautionary and evidentiary, we define an evidentiary assessment as one in which all the parameter estimates fall within criterion threshold (Figure 8) or where there is no evidence / expert experience to suggest that taxon is threatened. A precautionary assessment is where the range of estimates or interpretations crosses between two or more criteria thresholds (however, if all thresholds are crossed as they are all plausible, the species is Data Deficient). Here, the lower estimate, and thus the more threatened status, is chosen (Figure 8). An evidentiary attitude can still be taken when the values cross between two thresholds if it is very unlikely that the lower estimate is closer to reality (for example, the worst case scenario is not used). The range of possible statuses should be documented to enhance transparency and facilitate repeatability of the assessment process. This will also help to sift between genuine versus non-genuine changes in later revisions of the assessment.

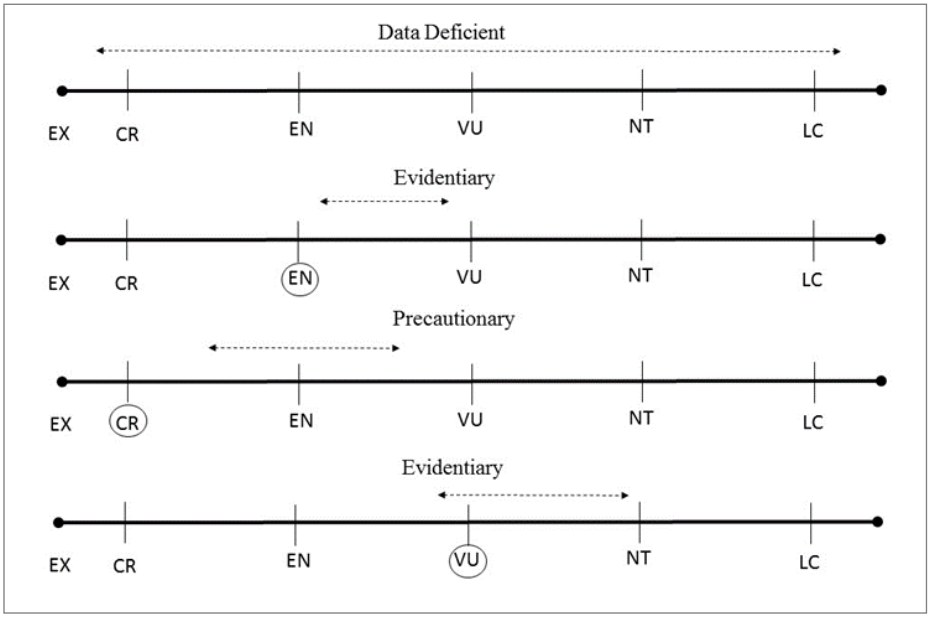

Figure 8. Illustration of how a range in parameter estimates or uncertainty in interpretation influences evidentiary versus precautionary assessments.

Blue Duiker (*Philantomba monticola*) – Yvette Ehlers-Smith

3 KEY RECOMMENDATIONS AND FUTURE WORK

The project has underscored several areas where future revisions could become more efficient and beneficial for all stakeholders, and has highlighted opportunities for synergy with parallel programmes of work and initiatives. Our vision is for the assessments to become focal points to integrate the relevant literature about each species into a coherent and continually updated narrative of its conservation status. Similarly, as the logic of each assessment is transparent and open to scrutiny, we hope it will encourage the development of research projects to test the implicit hypotheses and ultimately improve the accuracy and robustness of the listings, as well as generating the conservation evidence needed to evaluate the effectiveness of interventions. Updating even the Least Concern species will allow us to keep track of variables such as abundance and distribution, which will then allow a more accurate estimation of other indicators, such as the Protection Level indicator, and indices, such as the Living Planet Index. Similarly, synthesising the information available for each species, including its ecological role and its effects on other species and ecosystems, will enable novel applications/syntheses of the species assessments, such as linking species Red Lists to ecosystem Red Lists and creating Red List assessments of functional types, thereby providing another method to measure ecosystem service capacity across the assessment region. National Red Lists can transcend their use as a static summary and can become a vehicle to catalyse feedbacks between various databases and a platform to streamline the connections between policy, research and practice (Figure 9). Key recommendations for future work are summarised below:

Online revisions and working groups

Through the planned National Biodiversity Information System (NBIS) development at SANBI, a specialised Red List interface will be built to facilitate real-time revision of the assessments. The current assessments will be transferred from the Species Information Status (SIS) system of the IUCN to the SANBI platform, thus enabling more rapid online editing of assessments in future. This system will work similarly to the global Red List website where assessors and reviewers are credited for their contributions. As such, the establishment of national species working groups (comprised of multiple stakeholders), linked to the IUCN SSC Specialist Groups, is encouraged. This will enable assessment methodologies to be standardised and taxonomic revisions to be coordinated. It will also provide a central forum through which experts can request permission to make edits to the assessments and provide evidence to change the listing. The development of an online system will also enable the assessments to be directly linked to the underlying datasets supporting the assessment. This will ensure that datasets are cited directly in the assessments, that data contributors are directly acknowledged, and will create a versioning history so that genuine changes are more easily detected (rather than changes resulting from different underlying datasets being used). It will also enable the automation of Red Listing from the underlying data once protocols have been standardised.

Develop standardised protocols for assessment

Lack of standardised methods for assessing different groups of species between revisions severely hampers being able to detect genuine changes and apply the Red List Index. We developed protocols to assess certain groups of species (such as using the latest land cover data to estimate area of occupancy for small mammal assessments) and an expert-derived framework to estimate the number of private subpopulations that can be considered wild and free roaming (M. F. Child unpubl. data). Further work is needed to refine such protocols and to automate the process as new field data enter the NBIS. For example, analysing the national land cover dataset for 2000 will allow us to calculate standardised EOO and AOO estimates for both 2000 and 2014 (GeoTerraImage 2015a), enabling us to more accurately correct previous assessments and determine genuine versus non-genuine changes for more species. Additionally, vetted workflows for each taxonomic group should be established to facilitate standardisation of the assessments despite expert turnover with each revision. Plans are also in motion to link the Mammal Red List to the IUCN Green List of species, which is currently under development, such that the level of species recovery and conservation success can be quantified.

Prioritise and plan

A prioritisation workshop (*sensu* Miller et al. 2007) should be held to identify key species for systematic conservation planning. Stakeholder workshops should also be convened to identify data collection strategies for data deficient species and areas (such as that being done by the Karoo Biogaps Project), establish research priorities to inform a conservation evidence database and design a set of incentives to stimulate stakeholder engagement with the Red List. For example, work is underway to explore options for developing the Red List assessments as peer-reviewed papers or as products that contribute towards stakeholders' publication count. Data-sharing agreements with key institutions should also be established such that new field data are integrated into the central database, thus facilitating more cost-effective revisions in the future.

Ongoing database curation and integration

Ongoing data cleaning efforts, in collaboration with the data holders, should continue to be conducted to further build on the foundational mammal database established for the first time as part of this project. For example, small mammal museum records need to be comprehensively re-vetted and re-organised following recent molecular and taxonomic revision. Citizen science records also need vetting and quality control. Currently, all out-of-range records for threatened species have been flagged in the database, for future verifying, either of locality information or, when physical specimens or photographs or other media are available, for confirming the identity of the species record. We excluded these records from the Red List maps, but the records are retained in the database.

The importance of having a collated population count database is demonstrated by the Mountain Reedbuck (*Redunca fulvorufula fulvorufula*) assessment where its threatened status was revealed by being able to show nationwide declines. As such:

- Each protected area should publish revised mammal check-lists, especially for small mammals, such as Watson (2006) for Tussen-die-Riviere Nature Reserve, Free State Province, so that these can be collated into the central database to calculate the proportion of overall populations under formal protection for each species.
- Visual records from historical surveys, such as from Lynch (1983, 1989, 1994), should be collated from the original sources to add to the historical distribution data.
- Further collation of game count data from wildlife areas (national, provincial, private) from across the country should be comprehensively undertaken to ensure accurate and standardised calculation of population trends and population reduction, thus making the A criterion more robust. This will also help to estimate private landowner contribution to conservation progress.
- Collection of long-term data will help to resolve the problem of shifting baseline syndrome where the Red List status can be combined with alternative metrics, such as the Living Planet Index, to track loss of abundance and thus provide a holsitic view of species status.
- Improved data management capacity of protected area managers through skills training and access to database management tools is needed.

Consistency of data flow from primary data holding institutions is needed to enable better comparison between revisions, thus generating more genuine change assessments and more accurate trends through the Red List index. Currently, the patchwork approach to data collection and analysis hinders continuity of conservation measurement. The advancement of the National Science Collections Facility and SANBI's mandate as the Global Biodiversity Information Facility (GBIF) focal point will help to coordinate such efforts. This coordination should be extended to include field researchers and the private sector. For example, very few data were collected from ecological consultancies conducting ecological impact assessments (EIAs), which highlights the problem identified by King et al. (2012).

To encourage data submission and attribution, our medium- to long-term goal is to publish each dataset used in the assessments either through GBIF or as a data paper that would enable individual datasets to have a citation or digital object identifier (DOI) number and list these datasets in the references for each relevant assessment. This will allow assessors to very easily see what datasets have been used in each assessment version over time, to track the type of change in status (i.e. based on new information or a genuine change in status), and to allow data contributors to be directly credited. This will be facilitated by the migration of assessments to an online database (described above).

Conservation evidence as a national research framework

Although the amount of land under protection is increasing, our ability to monitor the effectiveness of conservation is not, which necessitates incorporating outcomes of evidence-based processes in management (Legge 2015). This is especially important in South Africa, where wildlife ranches and private protected areas constitute a huge total of the potential conservation estate (Taylor et al. 2015). The conservation evidence initiative is a framework to collate evidence for the effectiveness of interventions and to summarise the evidence into synopses for land managers, practitioners and policy makers. The Red List can be used to organise a research agenda that would summarise the evidence that decision and policy makers need, as well as aligning data standards to research quality.

While many species in the current Red List have detailed threat sections, this is not counterbalanced by evidence for the effectiveness of counterpart interventions (M.F. Child unpubl. data). Most assessments make management recommendations that could be formulated into testable hypotheses for researchers to generate the evidence needed for effective conservation and policy. Creating an evidence database will also help to enhance the narrative of the assessments. While we have attempted to cite the relevant literature in each of the assessments, it is too scattered at present to comprehensively extract the relevant information for each assessment. A completed conservation evidence database will allow assessors to quickly pull up the literature relevant to the species and integrate the information into a narrative. The assessment can then become a dynamic repository for all scientific information relevant to the conservation of the species, integrating all studies that have sampled the species. This work is the subject of planned future project.

Capacity building

Capacity building for fellow African institutions is going to be put in place so that regional Red List initiatives can be established and strategic conservation objectives can be aligned. For example, it is recommended that South Africa, Swaziland and Lesotho coordinate revisions and extend the programme to southern Africa through Red List training workshops and the development of open-access databases. A step towards this goal was achieved when a training workshop was held at the EWT head office from 27–31 July 2016 to equip two participants from Swaziland, four participants from Lesotho and one participant from the Free State Province, South Africa, with the skills to manage and clean Red List data correctly, apply the Red List criteria and plan the national Red List projects of Swaziland and Lesotho efficiently. In the long-term, such capacity building initiatives should be used to:

- Coordinate future Red List revisions between the three countries to maximise the efficiency of data-sharing and expertise.
- Establish a central regional Red List database from which to periodically pool data, making future revisions easier.
- Establish a regional network of Red List experts who can help with information regarding Red Listing in their respective host countries.

Ultimately, coordinating Red List revisions amongst Swaziland, Lesotho and South Africa will ensure more accurate regional and national Red Lists (allowing the application of the regional criterion to be based on better information; and allowing the aggregation or disaggregation of Red List data at regional or national scales) and ensure funding achieves the greatest impact by enabling assessments of functional landscapes rather than arbitrary political boundaries (while also providing national-specific metrics by which to measure conservation progress).

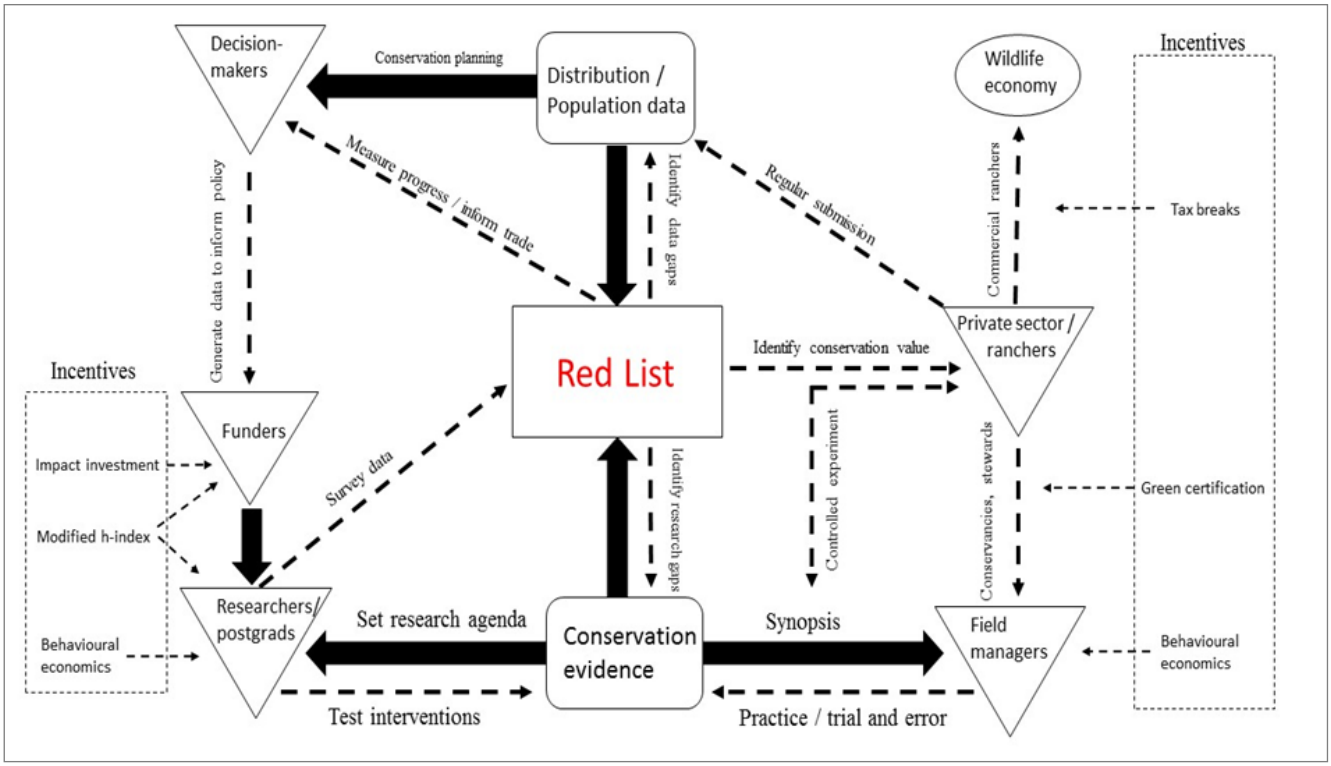

Figure 9. Schematic diagram to illustrate the potential relationship and feedbacks between the Red List (solid arrows represent primary relationships while dotted arrows represent potential feedbacks or incentive mechanisms), research institutions, government agencies and the private wildlife sector. At the centre is the Red List project (RL) and associated data. Two primary feeder databases are needed to inform Red List statuses (rounded rectangles): a distribution and population size (DP) database and a conservation evidence (CE) database (to assess the relative severity of threats and relative impact of interventions), where there is feedback between both databases, and the Red List assessments are used to identify survey and research gaps, and the resultant information generated can create more accurate RL assessments. The threats identified during the RL form the framework to organise interventions in the CE. The CE is crucial to link and coordinate two critical stakeholder groups (triangles): researchers and practitioners. Resulting feedbacks enhance the CE by both groups testing interventions identified by the RL: field managers can generate data through adaptive management and publish results in the Conservation Evidence journal, while researchers can conduct more rigorous replicated and controlled experiments to increase the strength of evidence. Researchers and field managers would also submit their survey data to the DP database. More accurate RL assessments are then fed into decision-making institutions for national planning and reporting, who in turn should encourage national funding bodies to fund research needed to produce conservation evidence. RL assessments can also be used to identify private populations that possess biodiversity value, and thus can be used by decision makers to inform conservation planning (e.g. biodiversity stewardship) and create relevant incentives for private landowners wanting to contribute to biodiversity or promote socio-economic resilience through the wildlife economy. Focused surveys and workshops are needed to identify incentives and mechanisms that would promote the feedbacks identified in the diagram, so that future RL assessments will be both more resource-efficient and more accurate and relevant to stakeholders.

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Short-eared Trident Bat (*Cloeotis percivali*) – Merlin Tuttle

5 APPENDICES

Karoo Rock Sengi (*Elephantulus pilicaudatus*) – Galen Rathbun © California Academy of Sciences

Appendix 1. List of experts were provided input into the assessments, either as assessors, reviewers or contributors.

Name	Institution	Assessments	Reviews	Contributions	Data provider?
Ada Natoli	UAE Dolphin Project	3			
Adrian Shrader	University of KwaZulu-Natal	2			
Akhona Mbatyoti	North-West University	2			
Aletris Neils	Conservation CATalyst	1			
Alex Sliwa	Cologne Zoo	2			
Alexei Abramov	Zoological Institute Russian Academy of Sciences			1	
Alicia Linzey	Indiana University of Pennsylvania	2			
Aliza Le Roux	University of Free State	2			Yes
Amanda Jones	University of KwaZulu-Natal			2	Yes
Amy-Leigh Wilson	University of KwaZulu-Natal	1			
Andre Boshoff	Nelson Mandela Metropolitan University	1			
Andrei Snyman	Northern Tuli Predator Project	1			
Andrew Skowno	South African National Biodiversity Institute			1	
Andrew Smith	Arizona State University		4	4	
Andrew Taylor	Endangered Wildlife Trust	3	25		Yes
Andrew Turner	Western Cape Nature Conservation Board				Yes
Andri Marais	Giraffe Conservation International			1	
Andy Tutchings	Giraffe Conservation International			1	
Angela Gaylard	South African National Parks	2	1	2	
Ant Maddock	Joint Nature Conservation Committee	3	1		
Antoinette Kotze	National Zoological Gardens of South Africa	3			
Anton Walker	Lapalala Wilderness			1	
Ara Monadjem	University of Swaziland	75	4	70	Yes
Armand Kok	Rhodes University				Yes
Armin Seydack	South African National Parks	1	1		
Athol Marchant	Ezemvelo KwaZulu-Natal Wildlife			1	
Aviwe Nquinana	University of Fort Hare		1		
Axel Hunnicutt	University of Pretoria	1	1		
Ayabulela Yokwana	University of Fort Hare	1			
Ben Okita	Save the Elephants			4	
Bentley Kaplan	University of Cape Town	1			
Beryl Wilson	McGregor Museum	17	1	78	Yes
Bester Marthán	University of Pretoria	1			
Bettine van Vuuren	University of Johannesburg				Yes
Birthe Linden	University of Venda	3			Yes
Boris Kryštufek	Slovenian Museum of Natural History	2			Yes
Brendan Whittington-Jones	Endangered Wildlife Trust	1			Yes
Brent Coverdale	Ezemvelo KwaZulu-Natal Wildlife	3			
Brian Kuhn	University of the Witwatersrand				Yes
Camille Fritsch	University of KwaZulu-Natal			1	
Carl Havemann	University of Pretoria			1	
Carlien Esterhuizen	North West Parks and Tourism Board			1	Yes
Carlo Rondinini	International Union for the Conservation of Nature			4	

Appendix 1. (continued)

Name	Institution	Assessments	Reviews	Contributions	Data provider?
Carly Cowell	South African National Parks	4			
Caroline Howlett	Durham University	3			
Carolyn Baker	South African Sugarcane Research Institute	1			
Carsten Schradin	University of the Witwatersrand	2			
Catharine Hanekom	Ezemvelo KwaZulu-Natal Wildlife		1		
Chanel Rampartab	University of Cape Town	2			
Charl Senekal	Zimanga Private Nature Reserve	1			
Charlene Bissett	South African National Parks	2	1		Yes
Cheryl Tosh	University of Pretoria			1	
Chris Hootan	Tshwane University of Technology			1	
Chris Kelly	WildlifeACT			1	
Chris Oosthuizen	University of Pretoria	1			
Chris Stuart	African-Arabian Wildlife Research Centre	13			
Christiaan Blignaut	Department of Economic Development, Environment and Tourism Limpopo			1	Yes
Christine Kraft	Department of Environment and Nature			3	Yes
Christy Bragg	Endangered Wildlife Trust	3			
Claire Relton	Endangered Wildlife Trust	13	2	127	
Colleen Begg	Niassa Carnivore Project, The Ratel Trust	1			
Colleen Downs	University of KwaZulu-Natal	2	2		Yes
Conrad Matthee	Stellenbosch University	4		4	
Coral Birss	Western Cape Nature Conservation Board	9	1	4	Yes
Corne Anderson	DBCM Ecology Division, Kimberley	2			
Corrie Schoeman	University of KwaZulu Natal	69		1	Yes
Craig Hilton-Taylor	International Union for the Conservation of Nature		1	4	
Craig Mulqueeny	Ezemvelo KwaZulu-Natal Wildlife			1	Yes
Craig Tambling	University of Fort Hare	2		1	
Craig Widdows	University of KwaZulu-Natal	1			
Daan Buijs	North West Department of Rural, Environment & Agricultural Development	1			Yes
Damian Ponsonby	University of the Witwatersrand	2			
Dan Parker	Rhodes University	3			
Danie Pienaar	South African National Parks			1	
Daniel Kuun	Gauteng Department of Agriculture and Rural Development				Yes
Danielle Conry	Nelson Mandela Metropolitan University	1			
Darren Pietersen	University of Pretoria	1			Yes
Daryl Codron	National Museum, Bloemfontein	1			
Dave Balfour	Eastern Cape Parks and Tourism Agency		5		
Dave Druce	Ezemvelo KwaZulu-Natal Wildlife			2	
Dave Rushworth	Trackers Nature Reserve			1	
David Camps	Department of Environmental Affairs	1			
David Cumming	University of Cape Town		1		

Appendix 1. (continued)

Name	Institution	Assessments	Reviews	Contributions	Total
David Jacobs	University of Cape Town	60			Yes
David Mallon	Manchester Metropolitan University		9	1	
David Marneweck	Endangered Wildlife Trust	1	1		Yes
David Rowe-Rowe	Private	4			Yes
Dean Peinke	Eastern Cape Parks and Tourism Agency	5	1	1	Yes
Dean Ricketts	Department of Economic, Developmental and Environmental Affairs			1	Yes
Debbie Jewitt	Ezemvelo KwaZulu-Natal Wildlife	3			
Deon Cilliers	Cheetah Outreach	1			
Derek van der Merwe	Endangered Wildlife Trust	1			
Desire Dalton	National Zoological Gardens of South	3			
Dewald Badenhorst	Department of Environment and Nature Conservation, Northern Cape				Yes
Domitilla Raimondo	South African National Biodiversity		64		
Doug Butterworth	University of Cape Town		2		
Duane Schlitter	Texas A&M University	3			
Duncan MacFadyen	E Oppenheimer & Son	18		74	Yes
Dusty Joubert	Selati Game Reserve			1	
Elsa Bussière	University of Cape Town	1			Yes
Emmanuel Do Linh San	University of Fort Hare	3	26	4	Yes
Eric Herrmann	Department of Environment and Nature Conservation, Northern Cape				Yes
Erika Mias	Iziko Museums of South Africa				Yes
Erika Schulze	Department of Economic, Small Business Development, Tourism and	5	1	1	Yes
Esme Beamish	University of Cape Town	1			
Fabien Génin	University of Fort Hare	3			
Federica Chiozza	International Union for the Conservation of Nature				Yes
Filipe Carvalho	University of Évora	2			
Findlay Ken	University of Pretoria	1			
Fiona Preston-Whyte	University of the Witwatersrand			4	
Francesca Cassola	International Union for the Conservation of Nature	1		1	
Francesca Parrini	University of the Witwatersrand	5	1		
Francisco Palomares	Estacion Biologica de Doñana CSIC		1		
Francois Deacon	University of the Free State	1			Yes
Frans Radloff	Cape Peninsula University of Technology	1			
Fredrik Dalerum	University of Pretoria	3		1	
Galen Rathbun	California Academy of Sciences	8			
Gareth Mann	Rhodes University				Yes
Gary Bronner	University of Cape Town	11	7		Yes
Genevieve Pence	Western Cape Nature Conservation Board	4		1	
Gerard Malan	Tshwane University of Technology	1			
Gerrie Camacho	Mpumalanga Tourism and Parks Agency	6		3	Yes
Gill Braulik	Wildlife Conservation Society			1	

Appendix 1. (continued)

Name	Institution	Assessments	Reviews	Contributions	Total
Graham Kerley	Nelson Mandela Metropolitan University	5	3		
Greg Canning	Limpopo Lipadi			1	
Greg Coates	University of KwaZulu-Natal	1			
Greg Hofmeyr	Port Elizabeth Museum at Bayworld	4	9		
Guila Ganem	Université Montpellier	1			
Guin Zambatis	South African National Parks				Yes
Gus Mills	Private	4			Yes
Gus van Dyk	Tswalu Kalahari Reserve			1	
Guy Balme	Panthera		1		
Guy Castley	Griffith University	2	1		
Guy Palmer	Western Cape Nature Conservation Board	12	1	80	
Gwenaëlle Delcros	University of KwaZulu-Natal				Yes
Gwenith Penry	University of Pretoria	2			
Halszka Hrabar	Nelson Mandela Metropolitan University	1			
Hannah Thomas	University of Pretoria	1			
Hanneline Smit-Robinson	BirdLife South Africa	8			
Hanno Killian	Khamab Nature Kalahari Reserve	1			
Harriet Davies-Mostert	Endangered Wildlife Trust		1	12	
Hennie Butler	University of the Free State	1			
Herman Oosthuizen	Department of Environmental Affairs	12		35	
Ian Craigie	Ezemvelo KwaZulu-Natal Wildlife				Yes
Ian Gaigher	University of Venda	1			
Ian Little	Endangered Wildlife Trust	1			
Ian Rushworth	Ezemvelo KwaZulu-Natal Wildlife			7	
Ian Whyte	South African National Parks	1	1		
Inês Carvalho	University of Aveiro	2	2		
Ingrid Peters	University of Pretoria	1			
Ingrid Wiesel	Brown Hyena Research Project Trust Fund		1		
Isa-Rita Russo	University of Cardiff	5			Yes
Jaco Barendse	University of Pretoria	2	3		
Jaco Vivier	The Vale Farm			1	
Jacobus Du Toit	Private			1	
Jacobus Visser	University of Johannesburg	5			Yes
James Brink	National Museum, Bloemfontein	1			
James Harvey	Private	1	5		Yes
James Hendry	Unearth International			1	
James Marshall	Unearth International			1	
Jan Kamler	University of Oxford	3			
Jan Venter	Nelson Mandela Metropolitan University	7			Yes
Jane Hoepfl	African–Arabian Wildlife Research Centre	1			
Jane Waterman	University of Manitoba	1			
Janice Britton-Davidian	University of Montpellier	2			
Jason Riggo	University of California, Davis	1			Yes
Jean-Charles Perquin	University of Fort Hare	1			
Jeanetta Selier	South African National Biodiversity	3	2	15	Yes

Appendix 1. (continued)

Name	Institution	Assessments	Reviews	Contributions	Total
Jeff Muntifering	Ministry of Environment and Tourism, Namibia		1		
Jenny Currie	Private			1	
Jenny Jarvis	University of Cape Town	6			
Jeremy Anderson	International Conservation Services	2		1	
Jeremy Midgley	University of Cape Town	1			
Jessica Light	University of the Witwatersrand	1			Yes
Jim Feely	Nelson Mandela Metropolitan University		1		Yes
Jo Shaw	Word Wide Fund for Nature - South Africa			1	
Joan Isham	Word Wide Fund for Nature - South Africa			1	
Johan Du Toit	Utah State University		1		
Johan Eksteen	Mpumalanga Tourism and Parks Agency	2		4	Yes
Johan Kruger	Department of Economic Development, Environment and Tourism Limpopo Province	2			Yes
Johan Watson	Department of Economic, Small Business Development, Tourism and Environmental Affairs, Free State	4			
Johannes Le Roux	University of Stellenbosch	1			
John Craigie	Ezemvelo KwaZulu-Natal Wildlife				Yes
John Llewellyn	Ingwelala Game Reserve			1	
John Power	North West Provincial Government	15	1	6	Yes
Jonathan Swart	Welgevonden Game Reserve	1			
Josef Bryja	The Czech Academy of Sciences	1			
Judith Masters	University of Fort Hare	2	1		
Juith Botha	South African National Parks				Yes
Julia Zemouche	University of the Witwatersrand	2			
Julian Bayliss	Oxford Brookes University	1			
Julian Fennessy	Giraffe Conservation Foundation		1		
Julie Kern	University of Bristol	1			
Julio Balona	Gauteng & Northern Regions Bat Interest Group	3			Yes
Julius Koen	Department of Environment and Nature Conservation, Northern Cape	2			
Jurie du Plessis	National Museum, Bloemfontein	6	1		Yes
Justin O'Riain	University of Cape Town	2			
Justina Ray	Wildlife Conservation Society,			1	
Kai Collins	University of Pretoria	2			
Katarina Medger	University of Pretoria		1		Yes
Kate MacEwan	Inkululeko Wildlife Services	59			Yes
Kath Potgieter	University of Pretoria			1	
Katy Williams	Durham University	1			Yes
Keafon Jambum	University of the Free State			1	Yes
Keenan Stears	University of KwaZulu-Natal	1			
Keith Begg	Niassa Carnivore Project, The Ratel Trust	1			
Kelly Marnewick	Endangered Wildlife Trust	2			Yes
Ken Findlay	University of Pretoria	14		28	
Kenneth Uiseb	Ministry of Environment and Tourism, Namibia		1		

Appendix 1. (continued)

Name	Institution	Assessments	Reviews	Contributions	Total
Keryn Adcock	Wild Solutions (Ecological Research)	4			
Keshni Gopal	South African National Biodiversity Institute	1			
Kevin Emslie	University of Venda	1			
Kirsten Wimberger	University of Cape Town	4			
Kirsty Brebner	Endangered Wildlife Trust			1	
Kristin Nowell	Species Survival Commission Cat Specialist Group		3		
Leigh Richards	Durban Natural Science Museum	64	1		Yes
Leith Meyer	University of Pretoria	1			
Liaan Minnie	Nelson Mandela Metropolitan University	1			Yes
Lientjie Cohen	Mpumalanga Tourism and Parks Agency	61		2	Yes
Lihle Dumaliisile	Gauteng Department of Agriculture and Rural Development				Yes
Lindsay Patterson	University of KwaZulu-Natal	1			Yes
Lisa Lerm	Tshwane University of Technology	1			
Lizanne Nel	SA Hunters and Game Conservation Association	1			
Lizanne Roxburgh	Endangered Wildlife Trust			37	Yes
Llewellyn Foxcroft	South African National Parks	1			
Lloyd Lowry	University of Pretoria		1	3	
Louisa Richmond-Coggan	Nottingham Trent University	1			
Lourens Swanepoel	University of Venda	5			Yes
Louw Hoffman	Stellenbosch University	1			
Low De Vries	University of Pretoria	2			
Lynda Sharpe	Eastern Cape Parks and Tourism Agency	1			
Maartin Strauss	University of South Africa	2			
Marc Stalmans	Gorongosa National Park			1	
Margaret Avery	Iziko Museums of South Africa	3		84	Yes
Marine Drouilly	University of Cape Town	4			Yes
Mario Cesare	Greater Olifants River Conservancy			1	
Marion Garai	Elephant Specialist Advisory Group – SA	1			
Markus Gusset	World Association of Zoos and Aquariums			1	
Markus Hofmeyr	South African National Parks			1	
Marna Herbst	South African National Parks	1			
Marnus Smit	Department of Environmental Affairs and Nature Conservation, Northern Cape			1	Yes
Marthán Bester	University of Pretoria	1	2		
Mathilde Stuart	African-Arabian Wildlife Research Centre	13			
Matt Hayward	Bangor University			2	Yes
Matt Pretorius	Endangered Wildlife Trust			1	
Matthew Child	Endangered Wildlife Trust	1	169	125	
Matthew Lewis	University of Cape Town	1			
Mbulelo Xalu	University of Fort Hare	1			
Mduduzi Seakamela	Department of Environmental Affairs	1		3	
Melissa Petford	University of the Witwatersrand	1			
Mfundo Bizani	Nelson Mandela Metropolitan University,	1			
Mia Wege	University of Pretoria	2		1	

Appendix 1. (continued)

Name	Institution	Assessments	Reviews	Contributions	Total
Michael Hoffmann	International Union for the Conservation of Nature		13	6	
Michael Meÿer	Department of Environmental Affairs	12		35	
Michael Mills	University of Cape Town	1		1	
Michael Somers	University of Pretoria	3	2	2	
Michele Pfab	South African National Biodiversity Institute		1		
Michelle Henley	Save the Elephants – South Africa	1			Yes
Michelle Thorn	Private	1			
Mike Knight	South African National Parks		4		Yes
Mike Maguranyanga	University of the Witwatersrand	1			
Mike Peel	Agricultural Research Council	3			Yes
Mike Perrin	University of KwaZulu-Natal	4	1	1	
Molly McDonough	National Museum of Natural History	1			
Monlee Swanepoel	Stellenbosh University	1			Yes
Morris Gosling	Newcastle University			1	
Nacelle Collins	Department of Economic, Small Business Development, Tourism and Environmental Affairs, Free State				Yes
Neil Jordan	Botswana Predator Conservation Trust	1			
Neville Pillay	University of the Witwatersrand	7			
Nico Avenant	National Museum, Bloemfontein	7	5	91	Yes
Nico de Bruyn	University of Pretoria	4			
Nicola Okes	University of Cape Town	1			Yes
Nigel Bennett	University of Pretoria	10	5	1	
Nigel Fernsby	Private	1			
Nina du Toit	Stellenbosch University	1			Yes
Nkabeng Maruping	Tshwane University of Technology			1	
Nkosinathi Babu	University of Fort Hare	1			
Nokuthula Kom	University of Fort Hare	1			
Olivia Stone	University of New South Wales	1			
Pamela Amiard	Mogalaknewa Research Centre	1			
Paolo Cavallini	FAUNALIA		3		
Patricia Moehlman	EcoHealth Alliance		2		
Patrick O'Farrel	Council for Scientific and Industrial Research				Yes
Paul Funston	Panthera		1		
Paul Grobler	University of the Free State	1			
Paulette Bloomer	University of Pretoria	2		1	
Peter Best	University of Pretoria		3		
Peter Goodman	Private	2			Yes
Peter Novellie	South African National Parks	2		1	
Peter Roberts	Oxford Brookes University	1			
Peter Taylor	University of Venda	91		62	Yes
Petri Viljoen	International Conservation Services	4			
Pfitzer Silke	Private	1			
Philippe Gaubert	Institut de Recherche pour le Développement	2	1		
Pierre Pistorius	Nelson Mandela Metropolitan University	2	1		

Appendix 1. (continued)

Name	Institution	Assessments	Reviews	Contributions	Total
Pieter Nel	North West Parks and Tourism Board	1			Yes
Quinton Martins	Cape Leopard Trust	2			
Raymond Jansen	Tshwane University of Technology	1			
Rebecca Lewison	San Diego State University		1		
Rebecca Welch	Rhodes University	1			
Resit Akcakaya	Stony Brook Univesity		2	2	
Riashna Sithaldeen	University of Cape Town	1			
Richard Emslie	Ecoscot Consultancy Services	4			
Richard Sowry	South African National Parks			1	
Richard Yarnell	Nottingham Trent University	2			Yes
Richard Young	Durrell Wildlife Conservation Trust			2	
Ricky Taylor	Ezemvelo KwaZulu-Natal Wildlife		1		
Rion Lerm	South African Environmental Observation Network				Yes
Robert Asher	University of Cambridge		5		
Robert Brett	Fauna & Flora International			4	
Rod Baxter	University of Venda	29		60	
Roger Uys	Greater Wellington Regional Council		1		
Rosemary Groom	African Wildlife Conservation Fund		1	1	
Ross Kettles	Private			1	
Rouxlyn Roux	University of South Africa	1			
Ruan de Bruin	University of the Free State			1	Yes
Rus Hoezel	Durham University	3			
Russell Hill	Durham University	1			
Ruth Leeney	Benguela Research & Training, Walvis Bay, Namibia	1			
Ryan Reisinger	University of Pretoria	4			Yes
Sam Ferreira	South African National Parks			8	Yes
Sam Laurence	Enviro-Insight		1		Yes
Sam Williams	University of Durham	2			Yes
Samantha Mynhardt	University of Pretoria	3			
Samantha Page-Nicholson	Endangered Wildlife Trust	1		61	
Sandi Willows-Munro	University of KwaZulu-Natal	5			Yes
Sandrine Le Gars	University of Fort Hare	1			
Sarah Durant	Zoological Society of London		1		
Sarah King	Colorado State University	2	1		
Sarita Maree	University of Pretoria	7	3		
Savvas Vrahimis	Department of Economic, Small Business Development, Tourism and		1		
Scott Kyle	Ezemvelo KwaZulu-Natal Wildlife			1	
Sean West	Gauteng Department of Agriculture and Rural Development	1			
Shanan Atkins	Private	4		13	
Sharon Louw	Ezemvelo KwaZulu-Natal Wildlife	2			
Simon Bearder	Oxford Brookes University		1		
Simon Elwen	University of Pretoria	14	3	26	
Simon Todd	University of Cape Town		1		
Simone Blomsterberg	University of Pretoria	1			

Appendix 1. (continued)

Name	Institution	Assessments	Reviews	Contributions	Total
Siviwe Lamani	University of Stellenbosch	2			
Stefan Cilliers	South African National Parks	1			
Stephanie Plön	Nelson Mandela Metropolitan University	32		14	
Stephen Kirkman	Department of Environmental Affairs	1		3	
Steve Dell	North West Parks and Tourism Board			2	
Susan Miller	Tshwane University of Technology	1			
Susanne Schultz	University of Manchester			1	
Tali Hoffman	University of Cape Town	1		1	Yes
Tamanna Patel	University of KwaZulu-Natal	1			
Tarik Bodasing	Ezemvelo KwaZulu-Natal Wildlife				Yes
Tembisa Matolengwe	University of Fort Hare	1			
Teresa Kearney	Ditsong Museums of South Africa	3			Yes
Terry Robinson	University of Stellenbosch	8			
Tharmalingam Ramesh	University of KwaZulu-Natal	1		2	Yes
Theoni Photopoulou	Nelson Mandela Metropolitan University		1		
Theresa Sethusa	South African National Biodiversity Institute	58			
Thomas Lehmann	Senckenberg Research Institute		1		
Tim Collins	Wildlife Conservation Society		2		
Tracy Rehse	Pan-African Association of Zoos and Aquaria	1			
Trudy Turner	University of Wisconsin-Milwaukee	1			
Vaino Prinsloo	Mpumalanga Tourism and Parks Agency				Yes
Vicky Nel	Private			1	
Victor Cockcroft	Nelson Mandela Metropolitan University	20	6		
Vincent van der Merwe	Endangered Wildlife Trust	1			Yes
Vivienne Williams	University of the Witwatersrand	1		1	Yes
Vusumzi Martins	University of Fort Hare	1			
Wanda Markotter	University of Pretoria	1			
Wayne Matthews	University of South Africa	1	1		
Wendy Collinson	Endangered Wildlife Trust			1	Yes
Wendy White	The Bat Interest Group of KwaZulu Natal	10			
Will Duckworth	IUCN SCC Small Carnivore Specialist Group			1	
William Coetzer	University of KwaZulu-Natal	1			
Woody Cotterill	University of Stellenbosch	1			
Yolan Friedmann	Endangered Wildlife Trust			1	
Yolanda Pretorius	University of Pretoria	1			
Yvette Ehlers-Smith	University of KwaZulu-Natal	7		1	Yes
Zimkitha Madikiza	University of the Witwatersrand	4		3	
Zoe Balmforth	Fauna and Flora International	2			

Appendix 2. IUCN Red List categories, thresholds and qualifiers used in this revision.

Category	**Critically Endangered (CR)**
Definition	A taxon is Critically Endangered when the best available evidence indicates that it meets any of the criteria A to E for Critically Endangered, and it is therefore considered to be facing an extremely high risk of extinction in the wild.
Criterion A **Reduction in population size based on any of the following (measured over the longer of 10 years or 3 generations)**	1. An observed, estimated, inferred or suspected population size reduction of **≥90%** over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are clearly reversible AND understood AND ceased, based on (and specifying) any of the following: (a) direct observation (b) an index of abundance appropriate to the taxon (c) a decline in area of occupancy, extent of occurrence and/or quality of habitat (d) actual or potential levels of exploitation (e) the effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites. 2. An observed, estimated, inferred or suspected population size reduction of **≥80%** over the last 10 years or three generations, whichever is the longer, where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1. 3. A population size reduction of **≥80%,** projected or suspected to be met within the next 10 years or three generations, whichever is the longer (up to a maximum of 100 years), based on (and specifying) any of (b) to (e) under A1. 4. An observed, estimated, inferred, projected or suspected population size reduction of **≥80%** over any 10 year or three generation period, whichever is longer (up to a maximum of 100 years in the future), where the time period must include both the past and the future, and where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.
Criterion B **Geographic range in the form of either B1 (extent of occurrence) OR B2 (area of occupancy) OR both**	1. Extent of occurrence estimated to be less than **100 km²**, and estimates indicating at least two of a–c: a. Severely fragmented or known to exist at only a single location. b. Continuing decline, observed, inferred or projected, in any of the following: (i) extent of occurrence (ii) area of occupancy (iii) area, extent and/or quality of habitat (iv) number of locations or subpopulations (v) number of mature individuals. c. Extreme fluctuations in any of the following: (i) extent of occurrence (ii) area of occupancy (iii) number of locations or subpopulations (iv) number of mature individuals. 2. Area of occupancy estimated to be less than **10 km²**, and estimate indicating at least two of a–c: a. Severely fragmented or known to exist at only a **single location**. b. Continuing decline, observed, inferred or projected, in any of the following: (i) extent of occurrence (ii) area of occupancy (iii) area, extent and/or quality of habitat (iv) number of locations or subpopulations (v) number of mature individuals. c. Extreme fluctuations in any of the following: (i) extent of occurrence (ii) area of occupancy (iii) number of locations or subpopulations (iv) number of mature individuals.
Criterion C **Small population size and decline**	Population size estimated to number fewer than **250** mature individuals and either: 1. An estimated continuing decline of at least **25%** within three years or one generation, whichever is longer, (up to a maximum of 100 years in the future) OR 2. A continuing decline, observed, projected, or inferred, in numbers of mature individuals AND at least one of the following (a–b): a. Population structure in the form of one of the following: (i) no subpopulation estimated to contain more than 50 mature individuals, OR (ii) at least 90% of mature individuals in one subpopulation. b. Extreme fluctuations in number of mature individuals.

Appendix 2. (continued)

Category	**Critically Endangered (CR) (continued)**
Definition	A taxon is Critically Endangered when the best available evidence indicates that it meets any of the criteria A to E for Critically Endangered, and it is therefore considered to be facing an extremely high risk of extinction in the wild.
Criterion D **Very small or restricted population**	Population size estimated to number fewer than **50** mature individuals.
Criterion E **Quantitative Analysis**	Quantitative analysis showing the probability of extinction in the wild is at least **50%** within **10 years** or **three generations**, whichever is the longer (up to a maximum of 100 years).

Category	**Endangered (EN)**
Definition	A taxon is Endangered when the best available evidence indicates that it meets any of the criteria A to E for Endangered , and it is therefore considered to be facing a very high risk of extinction in the wild.
Criterion A **Reduction in population size based on any of the following (measured over the longer of 10 years or 3 generations)**	1. An observed, estimated, inferred or suspected population size reduction of ≥70% over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are clearly reversible AND understood AND ceased, based on (and specifying) any of the following: (a) direct observation (b) an index of abundance appropriate to the taxon (c) a decline in area of occupancy, extent of occurrence and/or quality of habitat (d) actual or potential levels of exploitation (e) the effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites. 2. An observed, estimated, inferred or suspected population size reduction of ≥50% over the last 10 years or three generations, whichever is the longer, where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1. 3. A population size reduction of ≥50%, projected or suspected to be met within the next 10 years or three generations, whichever is the longer (up to a maximum of 100 years), based on (and specifying) any of (b) to (e) under A1. 4. An observed, estimated, inferred, projected or suspected population size reduction of ≥50% over any 10 year or three generation period, whichever is longer (up to a maximum of 100 years in the future), where the time period must include both the past and the future, AND where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.
Criterion B **Geographic range in the form of either B1 (extent of occurrence) OR B2 (area of occupancy) OR both**	1. Extent of occurrence estimated to be less than **5,000 km²**, and estimates indicating at least two of a-c: a. Severely fragmented or known to exist at no more than five locations. b. Continuing decline, observed, inferred or projected, in any of the following: (i) extent of occurrence (ii) area of occupancy (iii) area, extent and/or quality of habitat (iv) number of locations or subpopulations (v) number of mature individuals. c. Extreme fluctuations in any of the following: (i) extent of occurrence (ii) area of occupancy (iii) number of locations or subpopulations

Appendix 2. (continued)

Category	**Endangered (EN)** (continued)
Definition	A taxon is Endangered when the best available evidence indicates that it meets any of the criteria A to E for Endangered , and it is therefore considered to be facing a very high risk of extinction in the wild.
Criterion C **Small population size and decline**	Population size estimated to number fewer than 2,500 mature individuals and either: 1. An estimated continuing decline of at least 20% within five years or two generations, whichever is longer, (up to a maximum of 100 years in the future) OR 2. A continuing decline, observed, projected, or inferred, in numbers of mature individuals AND at least one of the following (a-b): a. Population structure in the form of one of the following: (i) no subpopulation estimated to contain more than 250 mature individuals, OR (ii) at least 95% of mature individuals in one subpopulation. b. Extreme fluctuations in number of mature individuals.
Criterion D **Very small or restricted population**	Population size estimated to number fewer than **250** mature individuals.
Criterion E **Quantitative Analysis**	Quantitative analysis showing the probability of extinction in the wild is at least **20%** within **20 years or five generations**, whichever is the longer (up to a maximum of 100 years).

Category	**Vulnerable (VU)**
Definition	A taxon is Vulnerable when the best available evidence indicates that it meets any of the criteria A to E for Vulnerable , and it is therefore considered to be facing a high risk of extinction in the wild.
Criterion A **Reduction in population size based on any of the following (measured over the longer of 10 years or 3 generations)**	1. An observed, estimated, inferred or suspected population size reduction of ≥50% over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are clearly reversible AND understood AND ceased, based on (and specifying) any of the following: (a) direct observation (b) an index of abundance appropriate to the taxon (c) a decline in area of occupancy, extent of occurrence and/or quality of habitat (d) actual or potential levels of exploitation (e) the effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites. 2. An observed, estimated, inferred or suspected population size reduction of ≥30% over the last 10 years or three generations, whichever is the longer, where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1. 3. A population size reduction of ≥30% projected or suspected to be met within the next 10 years or three generations, whichever is the longer (up to a maximum of 100 years), based on (and specifying) any of (b) to (e) under A1. 4. An observed, estimated, inferred, projected or suspected population size reduction of ≥30% over any 10 year or three generation period, whichever is longer (up to a maximum of 100 years in the future), where the time period must include both the past and the future, AND where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.

Appendix 2 (continued)

Category	**Vulnerable (VU) (continued)**
Definition	A taxon is Vulnerable when the best available evidence indicates that it meets any of the criteria A to E for Vulnerable , and it is therefore considered to be facing a high risk of extinction in the wild.
Criterion B **Geographic range in the form of either B1 (extent of occurrence) OR B2 (area of occupancy) OR both**	1. Extent of occurrence estimated to be less than **20,000 km²**, and estimates indicating at least two of a-c: a. Severely fragmented or known to exist at no more than 10 locations. b. Continuing decline, observed, inferred or projected, in any of the following: (i) extent of occurrence (ii) area of occupancy (iii) area, extent and/or quality of habitat (iv) number of locations or subpopulations (v) number of mature individuals. c. Extreme fluctuations in any of the following: (i) extent of occurrence (ii) area of occupancy (iii) number of locations or subpopulations (iv) number of mature individuals. 2. Area of occupancy estimated to be less than **2,000 km²**, and estimates indicating at least two of a-c: a. Severely fragmented or known to exist at no more than **10 locations**. b. Continuing decline, observed, inferred or projected, in any of the following: (i) extent of occurrence (ii) area of occupancy (iii) area, extent and/or quality of habitat (iv) number of locations or subpopulations (v) number of mature individuals. c. Extreme fluctuations in any of the following: (i) extent of occurrence (ii) area of occupancy (iii) number of locations or subpopulations (iv) number of mature individuals.
Criterion C **Small population size and decline**	Population size estimated to number fewer than **10,000** mature individuals and either: 1. An estimated continuing decline of at least **10%** within **10 years or three generations**, whichever is longer, (up to a maximum of 100 years in the future) OR 2. A continuing decline, observed, projected, or inferred, in numbers of mature individuals AND at least one of the following (a-b): a. Population structure in the form of one of the following: (i) no subpopulation estimated to contain more than 1,000 mature individuals, OR (ii) all mature individuals in one subpopulation.
Criterion D **Very small or restricted population**	1. Population size estimated to number fewer than **1,000** mature individuals. 2. Population with a very restricted area of occupancy (typically less than **20 km²**) or number of locations (typically five or fewer) such that it is prone to the effects of human activities or stochastic events within a very short time period in an uncertain future, and is thus capable of becoming Critically Endangered or even Extinct in a very short time period.
Criterion E **Quantitative Analysis**	Quantitative analysis showing the probability of extinction in the wild is at least **10%** within **100** years.

Appendix 2 (continued)

Category	**Near Threatened (NT)**
Definition	A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.
Criterion A **Reduction in population size based on any of the following (measured over the longer of 10 years or 3 generations)**	EXAMPLE: Population has declined by an estimated 20-25% in the last three generations.
Criterion B **Geographic range in the form of either B1 (extent of occurrence) OR B2 (area of occupancy) OR both**	EXAMPLE: The taxon meets the area requirements under criterion B for threatened (EOO <20,000 km^2 and/or AOO <2,000 km^2) and is declining, but the population is not severely fragmented, occurs at twelve locations, and there are no extreme fluctuations. EXAMPLE: The taxon meets the area requirements under criterion B for threatened (EOO <20,000 km^2 and/or AOO <2,000 km^2) and is severely fragmented, but the population is not declining, occurs at more than 10 locations, and there are no extreme fluctuations. EXAMPLE: The taxon is declining and severely fragmented, but has an EOO of 22,000 km^2 and/or an AOO of 3,000 km^2, which are highly certain estimates.
Criterion C **Small population size and decline**	EXAMPLE: Population has declined by an estimated 10% in the last three generations, and is continuing to decline, and has about 15,000 mature individuals. EXAMPLE: The taxon exists in a single subpopulation of about 15,000 individuals and is declining.
Criterion D **Very small or restricted population**	EXAMPLE: The population has about 1,500 mature individuals. EXAMPLE: The best estimate of population size is 2,000 mature individuals, but this estimate is very uncertain, and may be as low as 1,000 mature individuals cannot be ruled out.
Criterion E **Quantitative Analysis**	N/A

NON-THREATENED CATEGORIES	
Extinct (EX)	A taxon is Extinct when there is no reasonable doubt that the last individual has died. A taxon is presumed Extinct when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.
Extinct in the Wild (EW)	A taxon is Extinct in the Wild when it is known only to survive in cultivation, in captivity or as a naturalized population (or populations) well outside the past range. A taxon is presumed Extinct in the Wild when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.
Least Concern (LC)	A taxon is Least Concern when it has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are included in this category.
Data Deficient (DD)	A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. A taxon in this category may be well studied, and its biology well known, but appropriate data on abundance and/or distribution are lacking. Data Deficient is therefore not a category of threat. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate. It is important to make positive use of whatever data are available. In many cases great care should be exercised in choosing between DD and a threatened status. If the range of a taxon is suspected to be relatively circumscribed, and a considerable period of time has elapsed since the last record of the taxon, threatened status may well be justified. **If the data are so uncertain that both CR and LC are plausible categories, the taxon can be listed as DD.**
Not Evaluated (NE)	A taxon is Not Evaluated when it has not yet been evaluated against the criteria. For example, if the taxon has been recorded from a country but is considered a vagrant.

Appendix 2 (continued)

QUALIFIERS	
Possibly Extinct	The tag of 'Possibly Extinct' has been developed to identify those Critically Endangered species that are likely already Extinct, but for which confirmation is required. Taxa tagged as Possibly Extinct would then be included within bounded estimates of the number of recent extinctions to indicate plausible uncertainty in contemporary rates of extinction. Note that 'Possibly Extinct' is a tag, and not a new Red List Category.
Watch-list Data	All Data Deficient listings are by definition Watch-list Data too, as new data must be collected to assign a Red List status, but not all Watch-list taxa are Data Deficient (as it may still be possible to assign a temporary status based on the information available). The category is only applied to taxa where a critical piece of missing information is likely to influence the accuracy of the Red List status. Examples include field surveys to delimit geographical distribution, genetic tests to determine the extent of hybridisation in the population, and quantifying threat severity to estimate population trend. It only applies to taxa where estimated, projected, inferred and suspected threshold values range across, or are close to, two status categories. The information identified by this category does not pertain to all gaps in understanding but only those directly relevant to quantifying threshold values for the Red List criteria.
Watch-list Threat	This category identifies a key emerging threat that will affect the taxon in the future. This category applies when a novel threat (for example, not identified in previous assessments) may cause increasing population decline in the near future (5-20 years). It is thus only listed if the threat may potentially cause a change in conservation status in the near to medium future. It does not apply to threats previously identified that are suspected to be currently causing mortality or population decline but for which research has not quantitatively measured severity (this would be identified by the Watch-list Data qualifier).
Conservation Dependent	We define this category as any taxon that requires specific, direct and continual conservation intervention to prevent it from becoming more threatened. Such interventions usually mitigate extrinsic factors, such as overexploitation, but we extend this definition to include any taxon for which the long-term resilience of the population depends on some form of intensive management, such as metapopulation management or habitat restoration. This category does not apply to threatened taxa that are widespread and able to disperse, or to taxa where there is little evidence to rank the severity of the threat or the effectiveness of potential interventions and thus the interventions are ill-defined and not implementable. It applies if extrinsic threats would cause (or are causing) population decline in the absence of the conservation intervention or if the ability to disperse, and thus adapt to environmental change, is only possible through metapopulation management and/or the establishment of habitat corridors through protected area expansion.

Appendix 3. IUCN Red List terms and their relevance to the criteria.

Terms	Definitions	Criterion*				
		A	B	C	D	E
Population and Population Size (Criteria A, C and D)	The term 'population' is used in a specific sense in the Red List Criteria that is different to its common biological usage. Population is here defined as the total number of individuals of the taxon. For functional reasons, primarily owing to differences between life forms, population size is measured as numbers of mature individuals only. In the case of taxa obligately dependent on other taxa for all or part of their life cycles, biologically appropriate values for the host taxon should be used.	X		X	X	
Subpopulations (Criteria B and C)	Subpopulations are defined as geographically or otherwise distinct groups in the population between which there is little demographic or genetic exchange (typically one successful migrant individual or gamete per year or less).		X	X		
Mature individuals (Criteria A, B, C and D)	The number of mature individuals is the number of individuals known, estimated or inferred to be capable of reproduction. When estimating this quantity, the following points should be borne in mind: 1. Mature individuals that will never produce new recruits should not be counted (e.g. densities are too low for fertilisation). 2. In the case of populations with biased adult or breeding sex ratios, it is appropriate to use lower estimates for the number of mature individuals, which take this into account. 3. Where the population size fluctuates, use a lower estimate. In most cases this will be much less than the mean. 4. Reproducing units within a clone should be counted as individuals, except where such units are unable to survive alone (e.g. corals). 5. In the case of taxa that naturally lose all or a subset of mature individuals at some point in their life cycle, the estimate should be made at the appropriate time, when mature individuals are available for breeding. 6. Re-introduced individuals must have produced viable offspring before they are counted as mature individuals.	X	X	X	X	
Generation (Criteria A, C and E)	Generation length is the average age of parents of the current cohort (i.e. newborn individuals in the population). Generation length therefore reflects the turnover rate of breeding individuals in a population. Generation length is greater than the age at first breeding and less than the age of the oldest breeding individual, except in taxa that breed only once. Where generation length varies under threat, the more natural, i.e. predisturbance, generation length should be used.	X		X		X
Reduction (Criterion A)	A reduction is a decline in the number of mature individuals of at least the amount (%) stated under the criterion over the time period (years) specified, although the decline need not be continuing. A reduction should not be interpreted as part of a fluctuation unless there is good evidence for this. The downward phase of a fluctuation will not normally count as a reduction.	X				
Continuing decline (Criteria B and C)	A continuing decline is a recent, current or projected future decline (which may be smooth, irregular or sporadic) which is liable to continue unless remedial measures are taken. Fluctuations will not normally count as continuing declines, but an observed decline should not be considered as a fluctuation unless there is evidence for this.		X	X		
Extreme fluctuations (Criteria B and C)	Extreme fluctuations can be said to occur in a number of taxa when population size or distribution area varies widely, rapidly and frequently, typically with a variation greater than one order of magnitude (i.e. a tenfold increase or decrease).		X	X		
Severely fragmented (Criterion B)	The phrase 'severely fragmented' refers to the situation in which increased extinction risk to the taxon results from the fact that most of its individuals are found in small and relatively isolated subpopulations (in certain circumstances this may be inferred from habitat information). These small subpopulations may go extinct, with a reduced probability of recolonisation. A taxon can be considered to be severely fragmented if most (>50%) of its total area of occupancy is in habitat patches that are (1) smaller than would be required to support a viable population, and (2) separated from other habitat patches by a large distance.		X			

* Definitions for criteria:

A – Reduction in population size based on any of the following (measured over the longer of 10 years or 3 generations)
B – Geographic range in the form of either B1 (extent of occurrence) OR B2 (area of occupancy) OR both
C – Small population size and decline
D – Very small or restricted population
E – Quantitative Analysis

(Table continues overleaf)

Appendix 3. (continued)

Terms	Definitions	Criterion*				
		A	B	C	D	E
Location (Criteria B and D)	The term 'location' defines a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present. The size of the location depends on the area covered by the threatening event and may include part of one or many subpopulations. Where a taxon is affected by more than one threatening event, location should be defined by considering the most serious plausible threat.		X		X	
Extent of occurrence (Criteria A and B)	Extent of occurrence is defined as the area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred or projected sites of present occurrence of a taxon, excluding cases of vagrancy. This measure may exclude discontinuities or disjunctions within the overall distributions of taxa (e.g. large areas of obviously unsuitable habitat) (but see 'area of occupancy'). Extent of occurrence can often be measured by a minimum convex polygon (the smallest polygon in which no internal angle exceeds 180 degrees and which contains all the sites of occurrence).	X	X			
Area of Occupancy (Criteria A, B and D)	ea of occupancy is defined as the area within its 'extent of occurrence', which is occupied by a taxon, excluding cases of vagrancy. The measure reflects the fact that a taxon will not usually occur throughout the area of its extent of occurrence, which may contain unsuitable or unoccupied habitats. The size of the area of occupancy will be a function of the scale at which it is measured, and should be at a scale appropriate to relevant biological aspects of the taxon, the nature of threats and the available data. For example, AOO = no. occupied cells x area of an individual cell.					

* Definitions for criteria:

A – Reduction in population size based on any of the following (measured over the longer of 10 years or 3 generations)
B – Geographic range in the form of either B1 (extent of occurrence) OR B2 (area of occupancy) OR both
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E – Quantitative Analysis