A National Strategy for Zoological Taxonomy (2013-2020)

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Summary

Governments, through the Convention on Biological Diversity (CBD), have acknowledged the existence of a "taxonomic impediment" to the sound management of biodiversity. This refers to the knowledge gaps in our taxonomic system, the shortage of trained taxonomists and curators, and the impact these deficiencies have on our ability to conserve, use and share the benefits of our biological diversity. The strategy presented here examines the current situation in terms of knowledge of animal diversity, existing capacity and resources for zoological taxonomy, and current trends in research outputs, identifies the challenges and makes recommendations for objectives that are required to address these challenges in the short to medium term.

Animal diversity. South Africa has over 65,000 described species of animals but it is recognised that as many as 80,000 remain to be discovered and described. Most of these animals are invertebrates, with the greatest species richness being represented by insects (>44,000 species). New animal species continue to be described at an increasing rate with 2,566 new species described in the last decade.

Research capacity. Ninety-two researchers / academics contribute to animal taxonomy / systematics research in South Africa, and an additional 14 retired researchers continue to publish in the field. There is a marked skew in terms of taxonomic focus, with more taxonomists working on the <4,000 vertebrates species than on the >44,000 insect species. This translates to a ratio of taxonomists : known species number for vertebrates of 1:28, and for Lepidoptera (butterflies and moths), of 1:7,000. The number of taxonomists based at museums has declined to 23, down from 62 in 1991. Age distribution of taxonomists indicates that there will be at least 15 vacancies from retirements in the next five years. The workforce is well qualified, with almost all individuals having at least a MSc and 81% with a PhD, and 52 of the taxonomists have an NRF rating, including 1 A, 11 Bs, 36 Cs and 5 Ys. There has been little transformation of the workforce with 86% of the employed taxonomists categorised as white, and 7% black, with 38% female. A major concern is that there will potentially be only a single entomologist at a university to train postgraduates in insect taxonomy with the next five years.

Research collections. South Africa has vast research collections comprising over 15 million animal specimens in 23 institutions and 75 collections. While there are a few collections that are well resourced and used, many of the collections are at high risk of deterioration / neglect and in some cases, even of being lost in the near future. Major challenges relate to i. the governance of the collections, with most of the large institutions falling under national and provincial departments of arts and culture which have no mandate for the curation of biological collections, and ii. to the use and accessibility of the collections. The collections are viewed as being of value only to a small group of specialists, while the data and specimens could be used for a range of decision-making and research activities.

Databases. The data associated with more than 6 million specimens in the research collections remain to be captured on databases, and a relatively small amount of data (approximately 600,000 records) from the collections has been provided to the South African Biodiversity Information Facility (SABIF) for dissemination and application in spatial planning.

DNA barcoding is a technique which helps taxonomists with hard-to-identify specimens, and is an innovative way for non-experts to identify biological material. Barcode sequences are lodged and made accessible through the Barcode of Life Database, or BOLD. By July 2012 8,499 records of animals from South Africa were included in the BOLD database, but only 834 of these were identified to species level which somewhat limits the current usefulness of the system.

Funding. Over the past eight years an estimated R100 million was allocated through SABI and SABIF to systematics capacity development and research and the databasing of collections (this includes all taxa and not just animals).

Research publications. An analysis of research publications over the last 31 years by animal taxonomists nationally shows they have been responsible for less than a third of the new species described from South Africa, and that each taxonomist has described less than one new species per year on average. There has been a solid output in terms of publishing high quality molecular phylogenetic studies and this area could be considered a current strength. The bulk of this type of research, however, does not directly address the taxonomic impediment.

Challenges presented by current trends. The main challenges relate to a disjoint between what is needed from taxonomists to address the taxonomic impediment and what research is done by taxonomists, lack of access to taxonomic information in a format and medium that serves a broad community of users of such information, lack of appropriate capacity, especially at museums, and a lack of co-ordination of taxonomic activities and outputs for animals in South Africa.

What is needed from taxonomists? In most needs assessments done globally and nationally, the following are regarded as the main requirements by users of taxonomic data:

1. Identification of material / specimens (either as a service, or enabling this through the provision of user-friendly identification keys / resources) (What is it?).

2. Accurate species occurrence and abundance data sets (Where does it occur and how many are there and how is this changing / has this changed over time?).

3. Co-ordinated information about species, including classification and nomenclature (What is it called?).

These needs are directly in line with the definition of taxonomy. They are, in broad terms, required to enable countries / regions / organisations to manage and conserve biodiversity, which in turn will enable people to have sustainable livelihoods, and so they must be seen as priorities. Appropriate human capacity, access to collecting permits, and the maintenance of collections are supporting activities essential to the delivery of these three main needs and for future research.

Given the diversity of animals in South Africa, and the financial and capacity constraints, it is completely unrealistic to ever expect delivery on the three needs for all animal species, and prioritization, based on feasibility, (including expertise available, the current state of knowledge relative to the diversity) and the rationale (ie. is the taxon of major importance in ecosystem functioning, or a keystone taxon, or is it of economic value) is critical.

What is the required to deliver the priority taxonomic products? Over the next seven years the focus will be on consolidation, co-ordination and dissemination of comprehensive taxonomic information for use by a wide range of stakeholders. Continued generation of new knowledge is equally important, and for this there needs to be an alignment with higher level agendas beyond those of taxonomy. Research where systematics enhances larger research projects or is firmly embedded in a broader context is a priority.

Four Strategic Objectives that relate directly to the core work of taxonomists have been identified:

SO 1. To develop and make accessible accurate and comprehensive primary data sets for specimens of selected taxa for use in spatial planning, species threat assessments, biodiversity monitoring and research relating to global change impacts on biodiversity.

SO 2. To carry out taxonomic research which is aligned with the needs of major initiatives and that is integrated into broader research programmes to ensure that taxonomy delivers useful and used knowledge.

SO 3. To develop identification tools for taxa of major concern for conservation, sustainable use and the management of invasive, disease vector and pest species. This includes the development of a DNA barcode reference library for the priority species.

SO 4. To develop capacity to enable taxonomists to contribute to the broad dissemination of their outputs, and to develop new capacity in line with identified priorities.

Four additional objectives deal with outputs which may not be considered as being the primary work of taxonomists, but the contribution and participation in the activities by taxonomists are essential. These objectives underpin much taxonomic research and so they are relevant in the strategy, even if they are not considered to be research.

SO5. To provide a complete and regularly updated checklist of animals in South Africa, including classification, synonyms and local names which is publically accessible through the internet.

SO6. To co-ordinate and disseminate existing foundational information for priority species (including distribution, habitat, threat status).

SO 7. To initiate discussions on the recommendations made in the NRF report on the status of biodiversity collections in South Africa.

SO 8. To explore mechanisms for enabling access to collecting permits so that this is not a major impediment to the exploration of animal diversity in South Africa.

The strategy presented here will require regular review, and implementation according to a detailed plan which allocates responsibilities, sets targets and identifies resource needs.

Preface

The strategy document is divided into three parts:

1. Background material which explains the context of the Strategy.

2. An overview of the current situation in terms of animal diversity, taxonomic capacity in South Africa, trends in research outputs including publications and databases, funding trends and the scope, scale and state of zoological collections.

3. The Strategy, which includes the aim, objectives, and actions required to achieve the Strategy.

Methods and resources used

The Zoological Record database provided by Ovid was used extensively for information about trends in publications by taxon and taxonomist. References and abstracts for all publications by South African taxonomists, and by all taxonomists for taxa in South Africa were extracted, and analysed. Websites of universities and research institutions were used to compile a list of taxonomists based in South Africa. Various documents and websites were used to access information and these are cited in the relevant places in the document.

Between 2009 and 2010 90% of the zoological taxonomists and collections were visited to get input on the state of taxonomy / systematics in South Africa and on priority needs and actions, and for the assessment of zoological collections which was done as part of a broader assessment of natural science research collections commissioned by the NRF.

The identification of priority actions was done through discussion with a range of stakeholders and from international documents, trends and priorities.

Part 1: Background for the Zoological Taxonomy Strategy

i. Context of the Strategy

The Strategy presented here focuses mainly on activities aligned with the aim of the Global Taxonomy Initiative (GTI):

To address the lack of taxonomic information and expertise in order to improve decision-making and management in conservation, sustainable use and relevant economic sectors.

ii. Taxonomic and geographic scope of the Strategy

Taxonomic scope: All animals, from the Porifera (sponges) to the Mammalia (mammals) are covered in the Strategy.

Habitats: Animals in all habitats (terrestrial, freshwater and marine) are included.

iii. Who is responsible for implementing the strategy?

SANBI is, according to the National Environmental Management Biodiversity Act, responsible for co-ordinating taxonomy in South Africa. SANBI has a Biosystematics and Research Collections Division, but this is currently focused on plants, and currently only one staff member is involved in aspects of animal taxonomy. SANBI has adopted a "managed network" approach for ensuring the expansion of its mandate beyond plants. This approach requires the participation of taxonomists and institutions nationally and internationally, which will be critical for the implementation of the Strategy.

iv. Aim and objectives of the Strategy document

In line with the GTI objectives, those of the Strategy document for Zoological Taxonomy in South Africa are:

1. To assess the current situation in terms of i. existing knowledge about animal diversity in South Africa, ii. trends in knowledge generation iii. human capacity for zoological taxonomy, iv. zoological research collections.

2. To prioritise those knowledge gaps for attention in line with the CBD objectives.

3. To make recommendations for addressing the priority gaps in knowledge and capacity and to address the challenges identified for zoological collections.

Part 2: Review of existing knowledge, capacity, infrastructure and research trends

A. South Africa's animal diversity

A count of known or described South African animals totalled 65,571 species. It is likely this total is higher because no comprehensive checklist or catalogue of South African animal species exists and there are gaps in the species counts that have been done. There are certainly also many undiscovered and undescribed species of animal, especially invertebrates in South African habitats, but estimating the extent of this knowledge gap is problematic. Scholtz & Chown (1995)[1], based on the extent of semi-desert, savanna and forest (considered to be species poor) in South Africa, and the fact that taxonomists were not finding many new species in the region, estimated that the actual number of insect species was likely to be two to three times the known number of species (45,000 to 90,000 undiscovered species), but they cautioned that this was probably an overestimate. Scholtz (1999)[2] suggested that the insect fauna is likely to be twice as rich as was known at the time (estimated 45,000 undiscovered species). Other figures for estimates of the total richness of the insect fauna have been given as 250,000 (more than 200,000 undiscovered species)[3]. In a recent publication Costello *et al*. (2012)[4] calculated the following figures for species remaining to be discovered: 24-31% for marine, and 21-29% for terrestrial taxa. This would mean that for South African animals, at least 2,640 marine species and 11,466 terrestrial species remain to be described but these figures would certainly be disputed by most invertebrate taxonomists in South Africa. If all invertebrate groups are considered, including in the little

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1 Scholtz, C.H. & Chown, S.L. (1995) Insects in southern Africa: How many species are there? S Afr J Sc 91: 124-126

2 Scholtz, C.H. (1999) Review of insect systematics research in South Africa. Trans Roy Soc S Afr 54: 53-63

3 Samways MJ (1994) Insect Conservation Biology. Chapman and Hall, London.

4 Costello MJ, Wilson S, Houlding B. (2012) Predicting total global species richness using rates of species description and estimates of taxonomic effort. Syst Biol. Oct;61(5):871-83. doi: 10.1093/sysbio/syr080. Epub 2011 Aug 18

explored habitats of soil and marine sediments, caves and underground water systems, and cryptic species were included, then 80,000 undiscovered animal species within South Africa's borders would be a conservative estimate.

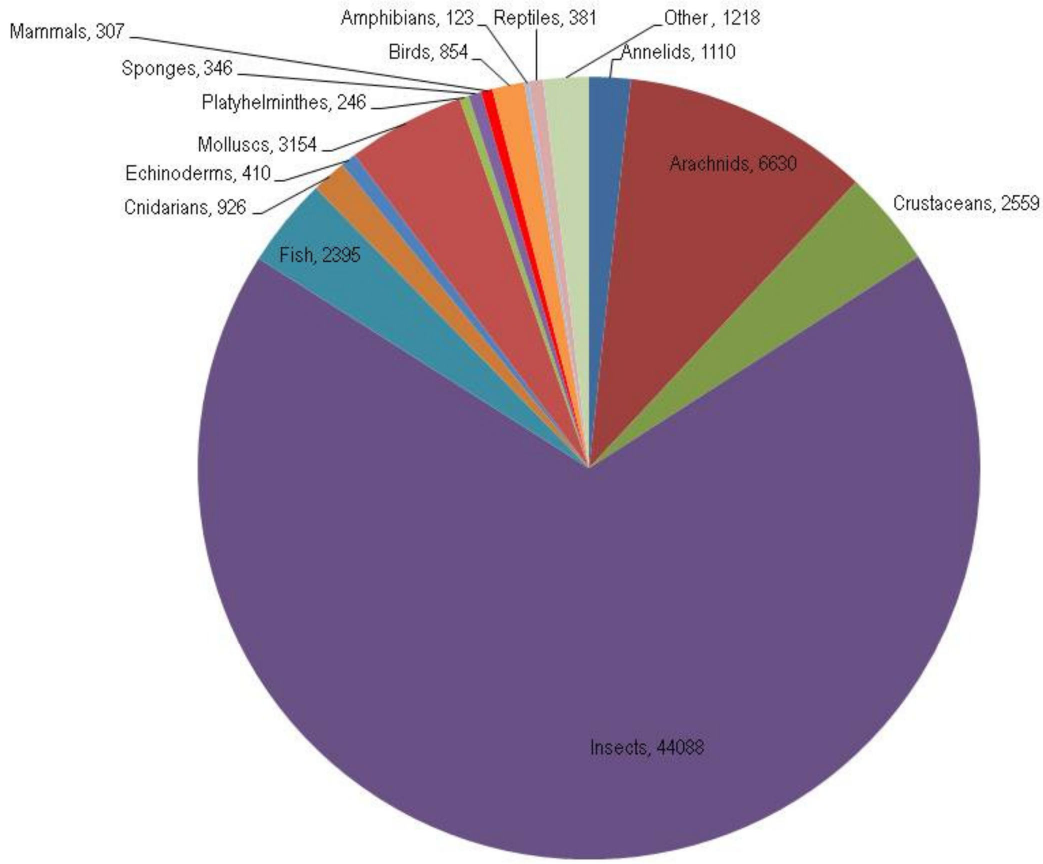

Figure 1. Numbers of known animal species in South Africa per taxonomic group. Many more species have yet to be discovered and described, especially among insects. Further details of diversity are presented in Appendix 1.

B. Trends in new species descriptions

Trends in the description of new animal species from South Africa over the last 30 years indicate that the fauna is far from completely known, with a large number of new species described (Fig. 2), and that the rate of descriptions was highest in the last decade (2000-2009) (2,566 species), up from 1,400 in the 1990s (1990-1999) and 1,462 species in the 1980s (1980-1989) (Fig. 3).

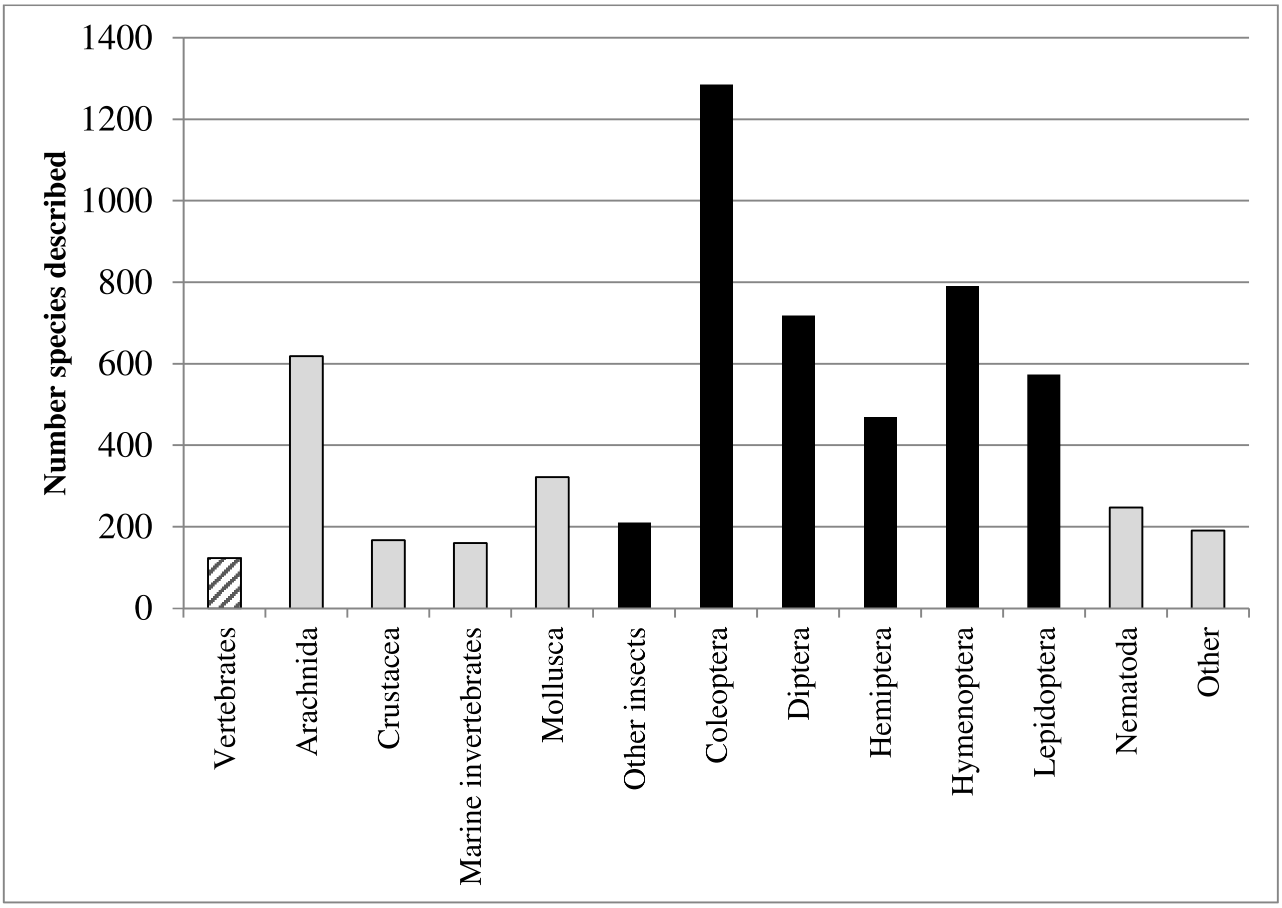

Figure 2. Number of new species described in major taxa / groupings of taxa between 1978 and 2011. Black=insects, light grey=invertebrates, hatched =vertebrates. Other = all other animal taxa. Source of data: Zoological Record, July 2012.

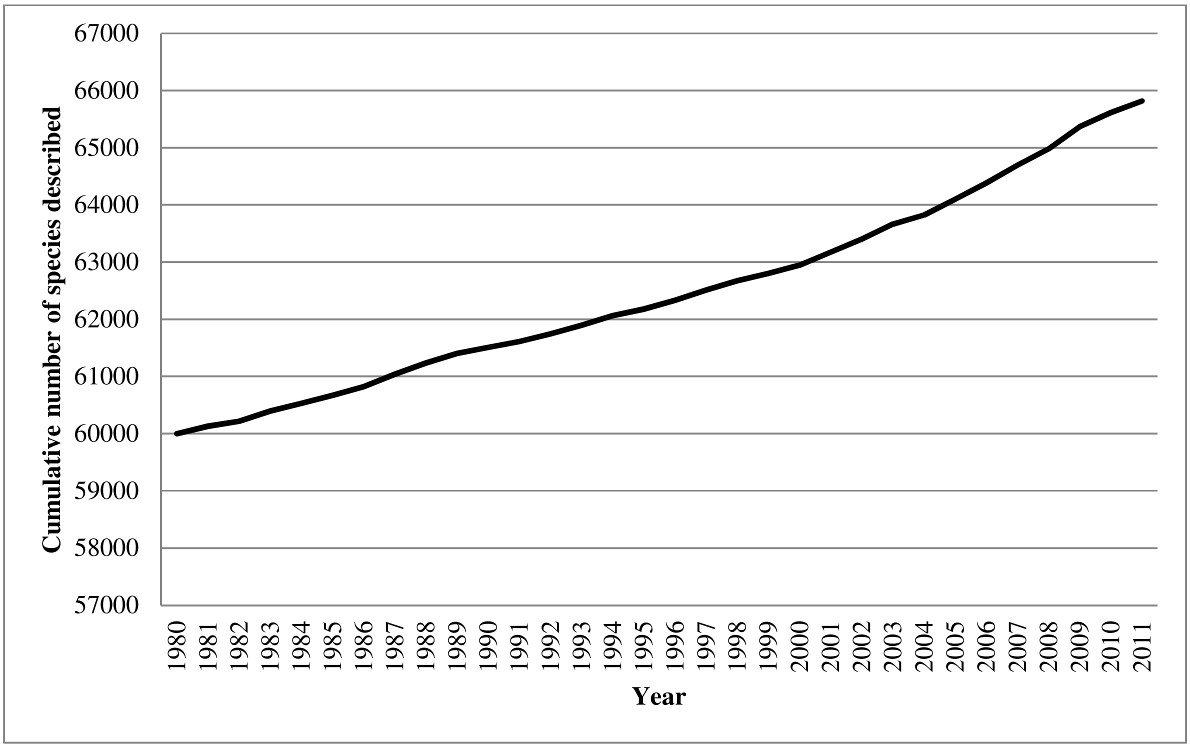

Figure 3. Rate of species description for South African animals between 1980 and 2011. Source of data: Zoological Record, July 2012.

Summary box

- >65,000 animal species known from South Africa
- 44,088 insect species known.
- Estimated 80,000 undiscovered / undescribed animal species in South Africa.
- Rate of species description per decade: 1980s = 1,462; 1990s=1,400; 2000s=2,566

C. Review of existing human capacity in zoological taxonomy

i. Number of taxonomists

In South Africa, a total of 92 professionals do taxonomic research involving animals, although not all of them work solely in this discipline, most of them include animals from outside South Africa in their research, and some of them rarely publish. In addition, 14 retired taxonomists still contribute to research, and while citizen scientists have not been counted, there are at least three individuals who are qualified in entomological taxonomy and who do publish but are not employed in the field, and several more non-professionals who publish mostly on marine molluscs and butterflies.

While it is difficult to categorise taxonomists, 68 were considered to be focused on taxonomic research only, while 35 have diverse interests but do publish in taxonomy.

The animal taxonomists are employed at 27 different institutions, including:

- 12 Universities (43 taxonomists),
- Parastatals / research institutions or facilities such as SANBI, Agricultural Research Council (ARC), Oceans & Coasts (part of DEA) and South African Institute for Aquatic Biodiversity (SAIAB) (26 taxonomists)
- 12 natural science museums (23 taxonomists).

Comparable data are not available for previous decades, but there has certainly been a decrease in the number of animal taxonomists employed at museums, which is the traditional place of work for such professionals. The report produced by Herbert *et al*. (2001)[5] indicated that in 1991 there were 62 taxonomists employed at museums, and that this decreased to 41 in 2001. In 2011 the count stood at 23 animal taxonomists, which suggests that if the past trends continue, within 20 years there will be no taxonomists employed at museums.

ii. Taxonomic focus and bias

Globally effort is very unequally distributed amongst different taxonomic groups, with a large percentage of taxonomists engaged in studying groups that are among the best documented. For example, in Australia it is estimated that there are 17 species of higher vertebrate for each taxonomist concerned with this group, but 840 insects and spiders for each taxonomist concerned with these groups. The figures for South Africa are far more extreme, with 28 individuals working on vertebrates (mammals, birds, reptiles, fish and amphibians) (Fig. 4), which have less than 4,000 species in South Africa, and a similar number of taxonomists working on insects, with more than 44,000 species. This translates into a ratio of one taxonomist for every 28 species of mammals, and Lepidoptera (butterflies and moths) with one taxonomist for 7,000 species (Fig. 5).

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5 Herbert D.G. 2001. Museum natural science and the NRF: crisis times for practitioners of fundamental biodiversity science. S. Afr. J. Sci. 97, 168–172.

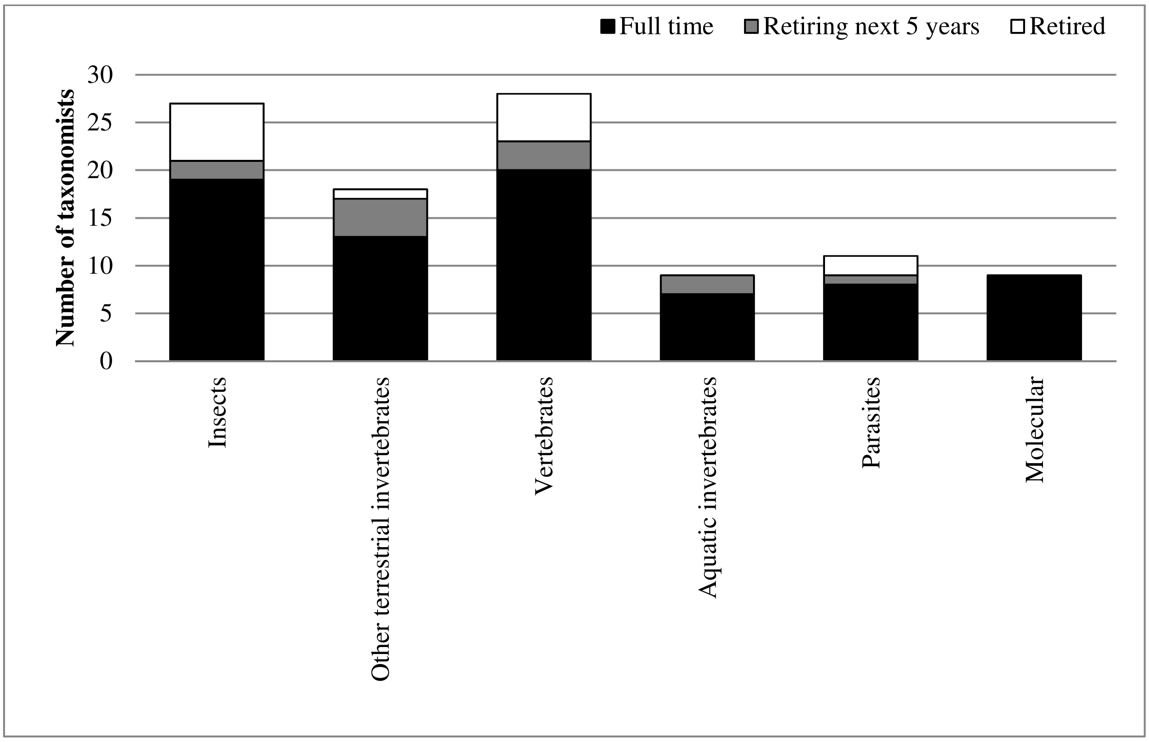

Figure 4. Number of taxonomists based in South Africa according to expertise or focus, with an indication of the number who have retired and who will be retiring in the next five years. The molecular biologists usually work on several different groups and so they have been counted separately. Aquatic invertebrates includes both marine and freshwater groups.

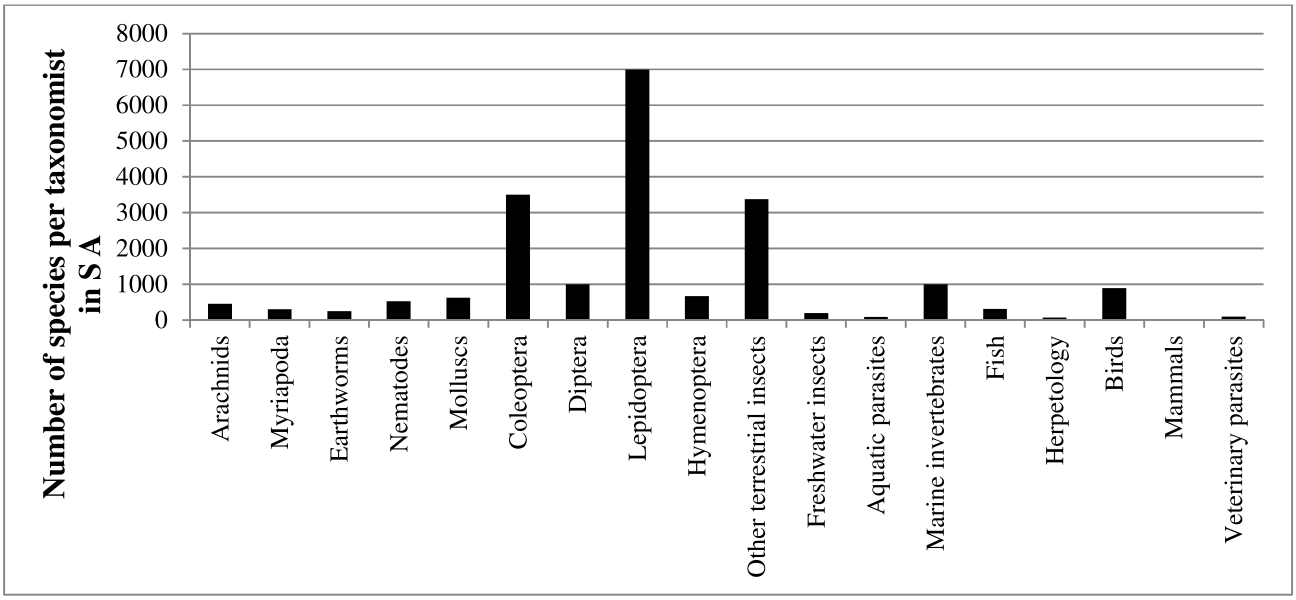

Figure 5. Ratio of species: taxonomists for different groups / taxa in South Africa.

iii. Age distribution

The age distribution of animal taxonomists in South Africa is acceptable, with half being under 50 years of age, and 15 retiring within the next five years (Fig. 6). What this indicates is that there will be a decrease in capacity unless trained taxonomists are employed to replace those that retire. An important and beneficial trend is that taxonomists often continue their research after retirement and this can even be their most productive period.

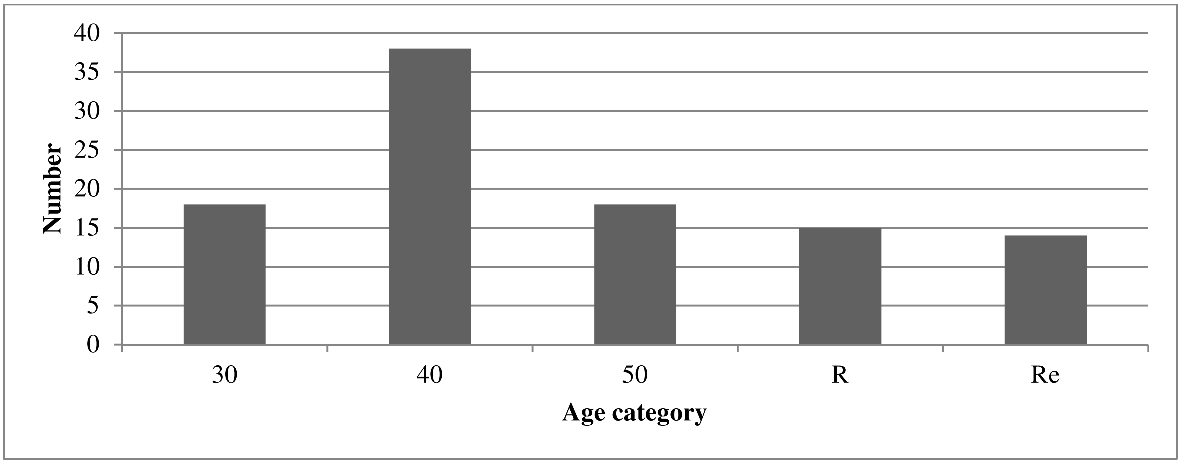

Figure 6. Age distribution of professional animal taxonomists in South Africa as in 2012. 30=under the age of 40; 40=40-49; 50=50-60; R=retiring in the next 5 years; Re=retired but still practicing.

iv. Qualifications and NRF rating

In terms of qualifications of South African animal taxonomists, 99% have at least a MSc and 89 (81%) have a PhD which means that the workforce is well qualified. All the university taxonomists have PhD degrees.

National Research Foundation (NRF) ratings provide an indication of the outputs and impact of the researcher. Fifty-three of the taxonomists are rated, including six who are retired. Of those still employed, 51% are rated, with one A-rated, 8 B-rated, 33 C-rated and five Y-rated. There are two main issues to note in these figures: i. there are no Y-rated (ie. promising young researchers) at museums, and only five across all institutions (Fig. 7) which is a concern for the future of animal taxonomy in South Africa, and ii. 65% of museum researchers do not have a rating (Fig. 8) which suggests a weak research culture at these institutions. Also of interest is that six of the B-rated researchers do descriptive taxonomy and have published taxonomic revisions which highlights the fact that doing this type of work does not necessarily result in lower NRF rating, which is a common perception amongst the taxonomy community.

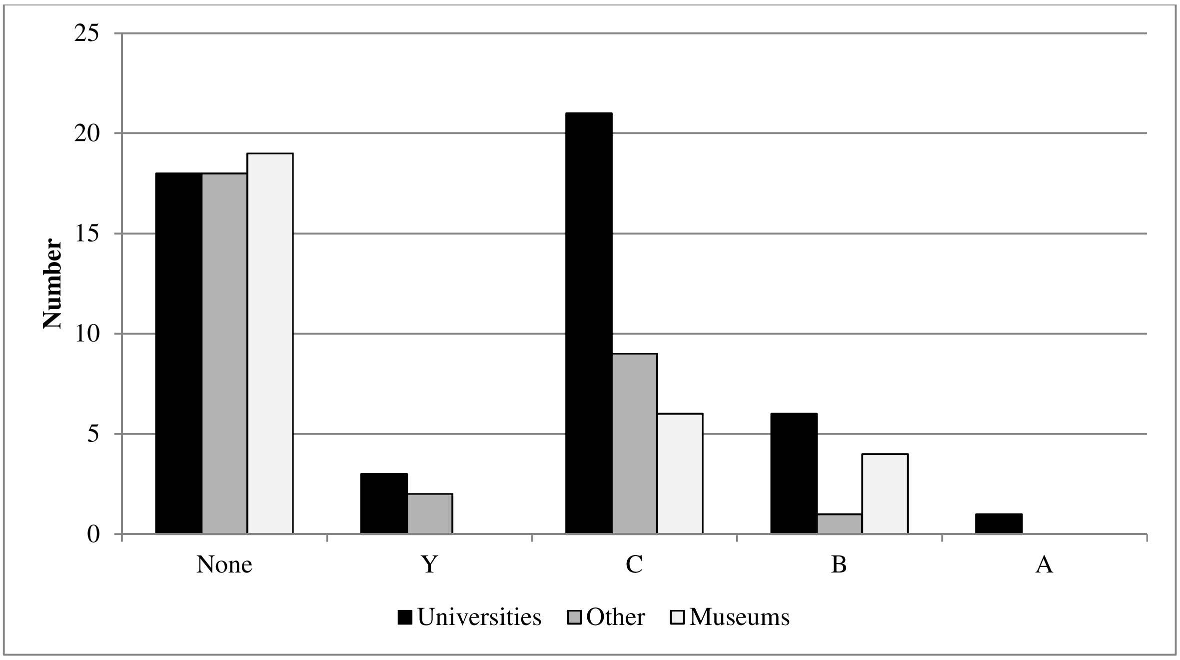

Figure 7. Number of NRF-rated researchers and ratings across museums, universities and other organisations. None=no rating.

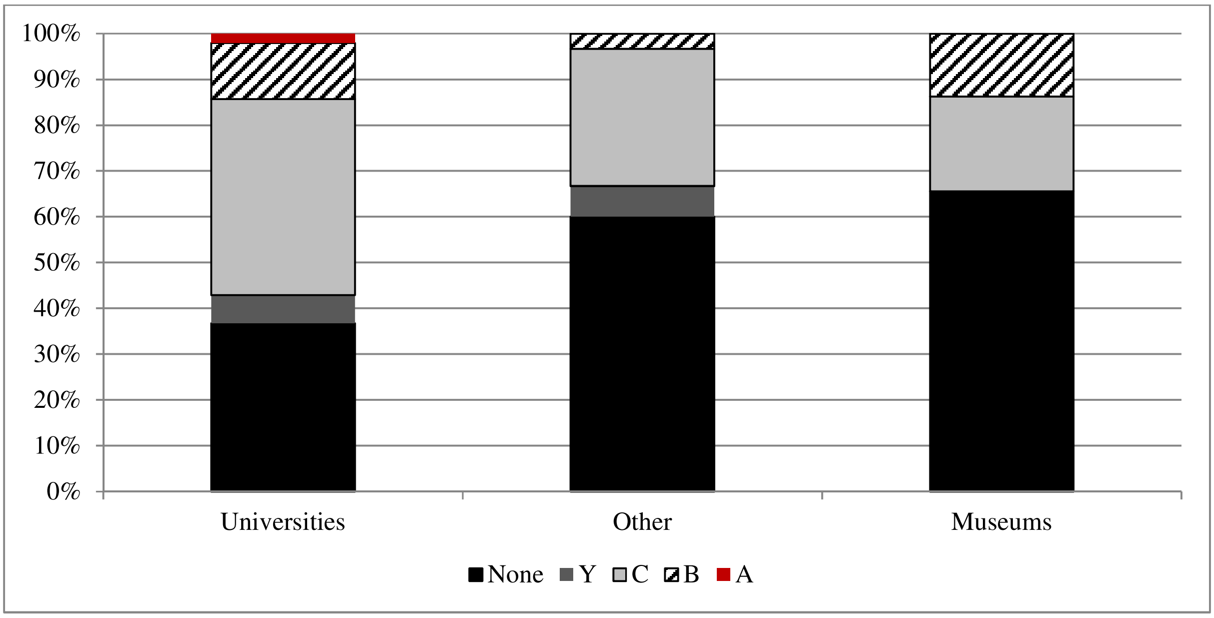

Figure 8. Percentage of researchers with different NRF ratings at universities, museums and other institutions.

iv. Demographics

The zoological taxonomy community in South Africa is largely untransformed in terms of racial representation, with 7% black, 7% coloured, and the remaining 86% white. Gender representation is better, with 37% of the workforce female (Fig. 9). An unpublished report on capacity in systematics[6] indicated that 52 black MSc or PhD students graduated in biosystematics between 1994 and 2004, which is about 33% of the total number of graduates. This indicates that even though black students do study taxonomy at a postgraduate level, few become professionals in animal taxonomy.

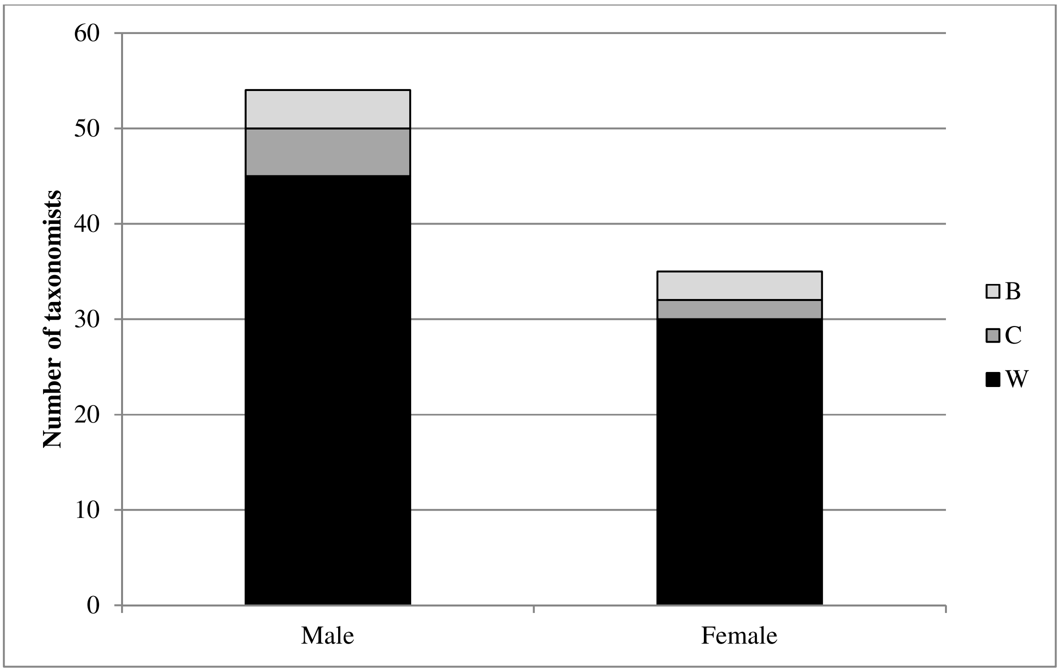

Figure 9. Demographics of the zoological taxonomist community in South Africa. Only permanent employees considered. B=Black, C=Coloured, W=White.

v. Capacity development:

A major concern is that while there is a solid academic base of 43 animal taxonomists at universities, 21 work on either vertebrates or molecular biology, which means that there is limited capacity for training in those taxa which have the largest knowledge gaps, and the existing trends in skewed focus are likely to be perpetuated as academics supervise students in their specialty. Indications are that the greatest capacity needs are in marine invertebrates and insects. While there are 23 full time insect taxonomists, only three of these are based at universities and one of these will be retiring in the next five years. This

6 Makwarela,A.M. 2005. The State of the Nature of South African Biosystematics. Education, training and research perspectives. Unpublished report of the NRF.

will leave two entomologists who can train postgraduate students, but one of them focusses mostly on non-taxonomic subjects, and the other also divides his time across various topics. The situation is less severe for marine invertebrates with five professionals based at various universities, but the only one who is currently training postgraduates in a variety of marine taxa will be retiring within two years, potentially leaving a major gap unless this is filled by the other academics in the field.

It is frequently stated that it is difficult to attract postgraduate students in taxonomy because there are no posts for graduates. A study in 2005 by the South African Biosystematics Initiative (SABI)[7] showed that this is not the case, and that the majority of postgraduates who had done taxonomic / systematic projects were employed, with 65% either in academia or research. The other 35% included foreign students who studied in South Africa, and only 3 out of 111 graduates were not working.

vi. Attraction and retention of taxonomists

Challenges relating to attracting and retaining taxonomists in museums have been identified as the poor salaries and the lack of career path options. The latter is certainly a constraint for retaining staff, who could be confined to the same position for their entire career because of the absence of promotion opportunities.

Summary box

- 106 animal taxonomists, with 92 employed in permanent positions
- 28 vertebrate taxonomists, 23 insect taxonomists
- Ratio of taxonomists : known species number: Vertebrates: 1:28; Lepidoptera: 1:7,000
- 23 taxonomists at museums, down from 62 in 1991
- 56 taxonomists younger than 50
- 81% of animal taxonomists have a PhD
- 54 taxonomists with NRF rating, including 1 A, 12 Bs, 36 Cs and 5 Ys.
- Potentially only 1 entomologist at a university to train postgraduates in insect taxonomy
- 86% white, 7% black, 38% female workforce

C. Review of national research infrastructure:

i. Zoological collections

Natural science or natural history collections are an essential component of taxonomy. The zoological specimens in South Africa's collections are largely irreplaceable, and cover most of South Africa, as well as other parts of the continent, and have been collected over a 170-year period.

7 Makwarela,A.M. 2005. The State of the Nature of South African Biosystematics. Education, training and research perspectives. Unpublished report of the NRF.

Traditionally collections of preserved animals or related materials are stored in museums and a few small collections are held by universities. The collections comprise a range of different materials including skins, skulls, skeletons, whole specimens stored in preservative fluid such as ethanol or formalin, internal organs also wet stored, birds eggs and nests, shells of molluscs, pinned insects and tissue or DNA samples often deep frozen or stored in absolute ethanol. These collections act as a reference for identification of samples, as a source of material for taxonomic study and as a repository where material collected and studied by researchers can be housed and maintained for use by other scientists in the future. Without the specimens, the data generated from and associated with them cannot be verified.

An assessment of the biodiversity research collections in South Africa was commissioned in 2009 by the NRF and the resulting report has recently been released[8] and a summarised version focussing on the zoological collections has been published[9]. The information presented in this Strategy is taken from these documents.

In total, 23 institutions in South Africa hold about 75 different collections of zoological specimens. Information on the collections assessed including details about their size, governance and staffing is provided in Table 1. The total holdings of the zoological collections were counted as 10,088,921 samples but the actual number of individual specimens is likely to be closer to 15–18 million because some samples contain many specimens.

At the time of the assessment, a total of 66 scientists or curators and 53 technicians or collections managers were employed in zoological collections in South Africa (Table 1). Four of the researchers or curators were retired and worked on an honorary basis, and the university collections did not have full-time curators. In total then, the permanent staff complement was 115, of whom 81 were at museums (excluding ARC, Onderstepoort Veterinary Institute (OVI), and SAIAB). Fifteen collections had no scientist or curator associated with them, and 10 collections had no technical or collection management support.

The assessment showed that 17 institutions had collections categorised as Vulnerable or Highest Risk based on a suite of criteria including environmental conditions under which they are stored, staffing, use and extent of digitisation. These institutions spanned the range of governance structures from universities to national museums.

Overall, while there are some well-managed, resourced and used zoological collections in South Africa, this is not the general situation. The problems identified were distributed across virtually all institutions. In addition, the collections environment could not generally be considered to be particularly dynamic especially in terms of the management and dissemination of information associated with the collections

8 Gerard et al. 2011. Collecting now to preserve the future. NRF audit report of South Africa's natural science collections.

9 Hamer M. 2012. An assessment of zoological research collections in South Africa. S Afr J Sci.108(11/12), Art. #1090, 11 pages. http://dx.doi.org/10.4102/sajs.v108i11/12.1090

and the use of the collections for in-house research. These problems could result in the collections never being effectively or innovatively utilised.

The assessment identified three main challenges that need to be addressed if the situation at museums with zoological collections is to be addressed: i. A need to broaden the scope of use of collections and associated data beyond a small group of taxonomists so that their relevance and value is increased, ii. A need to develop a dynamic research culture with a critical mass of researchers at any one institution, and iii. Probably the most critical issue at this stage, to address the fragmentation of governance, and the inappropriate placement of the natural science collections under departments of arts and culture (both nationally and provincially).

Table 1. Institutions with zoological collections: their governance structure, extent of zoological collections and permanent staff associated with the collections (technical and scientific). Those museums where both human and natural science collections are housed within the same institution are indicated by HS (human science collections) + NS (natural science collections). (from Hamer, 2012).

GOVERNANCE	INSTITUTION	NUMBER OF SPECIMENS	NUMBER OF COLLECTION STAFF
Department of Arts & Culture (national) (DAC)	Northern Flagship Institute, Ditsong Museum, Pretoria (ex Transvaal Museum)	2,835,286	19
	Southern Flagship Institute, Iziko Museum, Cape Town (South African Museum)	3,620,854	12
	KZN Museum, Pietermaritzburg (HS+NS)	706,826	8
	National Museum, Bloemfontein (HS+NS)	281,316	14
Department of Agriculture, Forestry & Fisheries (DAFF), Agricultural Research Council (ARC)	Biosystematics Division, National Collections, Pretoria	1,357,886	22
Department of Agriculture, Forestry & Fisheries (DAFF), Onderstepoort Veterinary Institute (OVI)	Gertrude Theiller Tick Collection	2,723	1
Department of Agriculture, Forestry & Fisheries (DAFF), Plant Protection Research Institute (PPRI)	Biocontrol Unit, Cedara, Hilton (reference collection)	1,900	0
National Department of Health (NDH) (parastatal, 30% of funding provided)	National Health Laboratory Services (NHLS), Vector Control Unit, Medically Important Arthropod Collection	60,000	0
Department of Water & Environmental Affairs (DWEA), SANParks	Skukuza Reference Collection	13,000	2
Department of Science & Technology (DST), National Research Foundation (NRF) National Facility	South African Institute for Aquatic Biodiversity (SAIAB), Grahamstown, National Fish Collection	86,000	5
Eastern Cape Department of Art, Sport, Recreation & Culture (DASRC)	Albany Museum, Grahamstown (HS+NS)	650,560	6
	Amatole Museum, King Williams Town (HS+NS)	34,196	3

	East London Museum (HS+NS)	38,805	3
	Port Elizabeth Museum (HS+NS)	52,998	9
Northern Cape Department of Arts, Sport, Culture & Recreation (DASCR)	McGregor Museum, Kimberley (HS+NS)	31,100	2
eTekwini Municipality	Durban Natural Science Museum	159,048	5
Oceanographic Research Institute (ORI)	Coral Collection	500	0
Rhodes University	Entomology collection (mostly education collections)	31,500	1
Stellenbosch University	Entomology collection (includes education collections)	12,000	0
University of Free State	Aquatic Parasite collection	24,000	0
University of Pretoria	Scarabaeidae beetle collection	30,000	1
Witwatersrand University	Various zoological collections (includes education collections)	60,732	2
TOTAL ZOOLOGICAL COLLECTION HOLDINGS & STAFFING		10,091,230	115

ii. Specimen databases

Primary specimen data (specimen identity, collection locality and date of collection) captured into spreadsheets or relational databases are a crucial output from taxonomic research and collections and are used by researchers, by land and marine spatial planners and for species threat assessments (Red Listing). Without these products, the value of both taxonomy and collections is substantially reduced.

Of the 67 collections assessed as part of the NRF report, in terms of the degree to which specimen information was captured on a database, 24 (36%) were completely captured, an improvement since a previous assessment done in 1999[10], and just lower than the Federal collections in the USA (40%). A total of 6,478,426 specimens were yet to be captured on databases, although this number will have decreased since the assessment. Information from the large insect collections remained largely uncaptured in databases.

Old catalogue books, field notes and other historical documents associated with the collections often provide invaluable information about the specimens and their collection, including habitat, weather, exact location and the collectors. Storage of these documents was generally haphazard, and no institutions had scanned or duplicated these documents. With the exception of the SAIAB collection, there was also no standardised storage system for data sheets associated with the material.

The South African Biodiversity Information Facility (SABIF) serves as a repository for primary biodiversity data, and also disseminates this both through the SABIF website and through the Global Biodiversity Information Facility (GBIF). Data from 15 of the collections had been provided to SABIF at the time of the assessment but this number will have increased slightly. This is a surprisingly low number considering that funding has been provided for the last five years to enable data capture. The majority (94%) of animal records currently disseminated by SABIF are from the South African Bird

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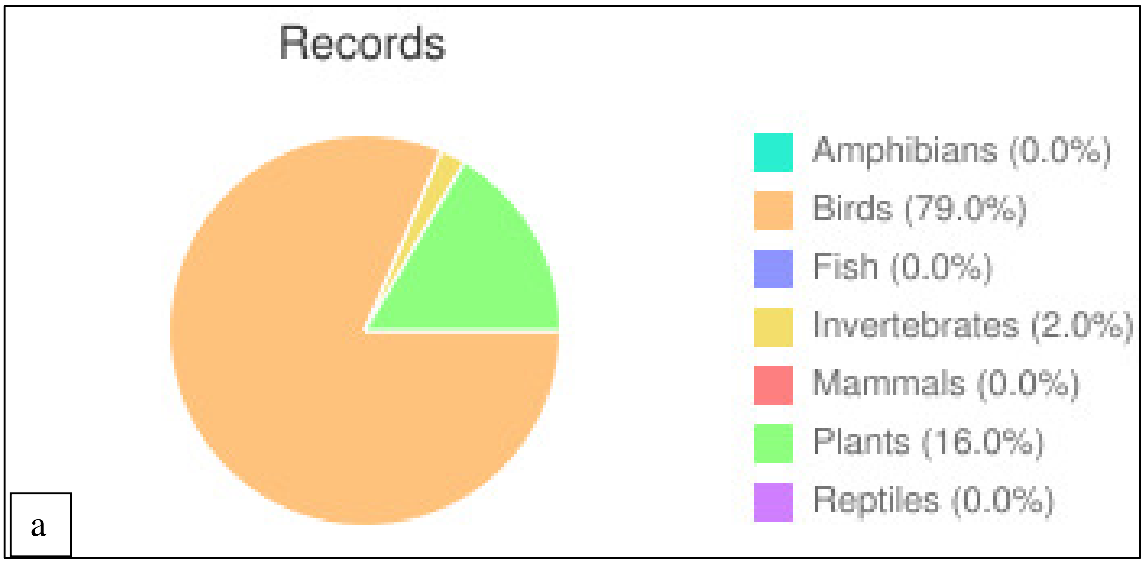
1. 10 Taylor, P.J. & Hamer, M. 1998. A report on the South African zoological collections audit . SAMA Bull. 2001;25(2):5–19.

Atlas and bird ringing data and from the SANBI plant database, with animal data from collections making a negligible contribution, with less than 600,000 records (Fig. 10a, Tables 2, 3). If the large plant and bird databases are removed, the composition of the holdings is more in proportion to the diversity and holdings of collections (Fig. 10b).



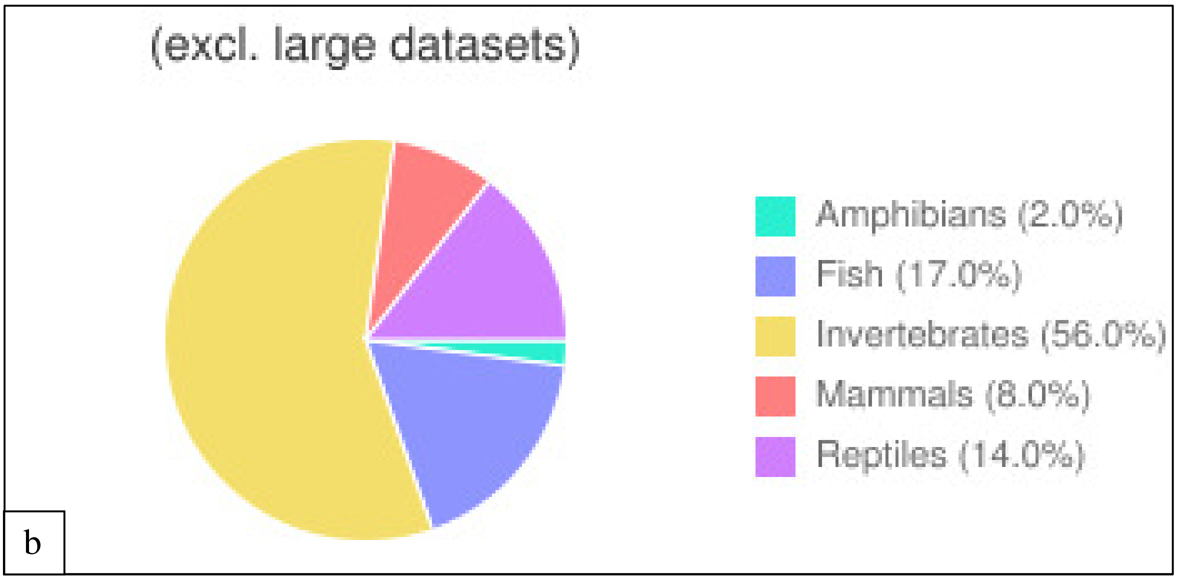


Figure 10. Composition of records held by SABIF. a. Total data holdings. (from http://www.sabif.ac.za/index.php?option=com_content&view=article&id=52&Itemid=29, accessed 24 July 2012). b. Data holdings with large datasets removed. http://www.sabif.ac.za/index.php?option=com_content&view=article&id=52&Itemid=29. Accessed 24 July 2012.

Table 2. Details of species occurrence records provided to SABIF. (http://sibis.sanbi.org/faces/Statistics.jsp?1=1, accessed 24 September 2012)

Group:	Species names:	Records:	Georeferenced records (QDS or better):
Amphibians	284	12 245	7 455 (60%)
Birds	1 334	9 294 709	9 225 390 (99%)
Fish	6 796	85 786	76 448 (89%)
Invertebrates	29 344	285 980	217 158 (75%)
Mammals	692	44 232	4 (00%)
Plants	118 325	1 868 311	1 562 011 (83%)
Reptiles	1 373	74 675	52 843 (70%)
Total	158 148	11 665 938	11 141 309 (95%)

Table 3. Details of species occurrence data for animals provided by South African institutions to SABIF (modified from http://sibis.sanbi.org/faces/Statistics.jsp?1=1, accessed 24 September 2012).

Data source:	Publisher:	Updated:	Content:	Species names:	Records:	Georeferenced (at least QDS):
Albany Museum	SABIF	2009	Invertebrate specimens	3 502	74 253	71 542 (96%)
ARC Bees	SABIF	2010	Bee specimens	1 067	15 132	7 587 (50%)
ARC Spiders	SABIF	2010	Spider specimens	100	2 753	2 745 (99%)

Iziko SA Museum	SABIF	2010	Invertebrate specimens	25 445	107 482	49 235 (45%)
SABAP-1	SABIF	2010	Bird observations	934	7 084 092	7 084 092 (100%)
SABCA	SABIF	2010	Butterfly observation records	806	86 659	86 340 (99%)
SAFRING	SABIF	2010	Bird ringing observation records	1 228	2 160 121	2 141 298 (99%)
SAIAB	SABIF	2010	Fish specimens	6 753	85 681	76 345 (89%)
SARCA	SABIF	2010	Reptile observation records	328	15 771	15 693 (99%)
Transvaal Museum	SABIF	2010	Bird, Mammal, Reptile and Amphibian museum specimens	2 658	161 470	41 025 (25%)
SABIF Totals				48 107	9 827 936	9 606 420 (97%)

There is no indication for these data whether the identification or the classifications and nomenclature of the records has been verified or updated, and it is possible that there are a large number of inaccuracies and outdated names, especially, but not exclusively, in the invertebrate records.

Of major concern in terms of databases is the loss of data by many taxonomists and postgraduate students who do not share or deposit data or material into any legacy repository such as SABIF or a collection institution which means that the primary data generated is lost. The amount of lost data over the past few decades cannot be estimated, and unless there is a decisive action about long-term data and specimen management, this trend will continue.

A search of the GBIF data for all animal taxa from South Africa, including for specimens and observations from other institutions outside South Africa showed that there is good spatial coverage of the entire country, with no grid square lacking any data (Fig. 11). However, this is probably largely a result of the South African Bird Atlas Data (SABAP), which comprises the largest proportion of the SABIF data.

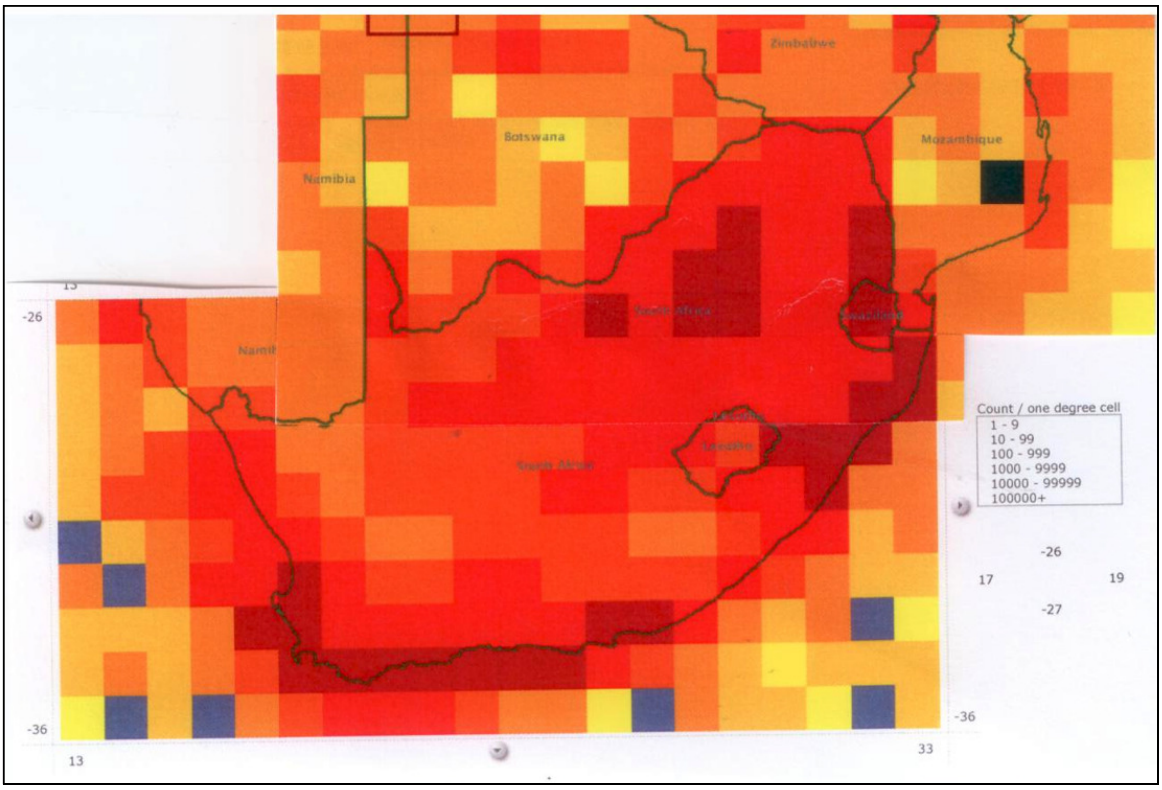


Figure 11. Density of records of animal specimens / observations per degree grid cell held by GBIF. Darkest red = highest number of records, yellow=fewest records. Downloaded from GBIF data portal 23 October 2012.

The Animal Demography Unit of the University of Cape Town has managed several large national atlas projects covering birds, reptiles, and butterflies, and was also a partner in the frog atlas project. The unit holds and manages large datasets from these projects, and metadata details are provided on the ADU website[11]. The actual datasets are not accessible, but most of these have been provided to SANBI and are accessible through SABIF.

iii. Genetic databases

Most journals require that DNA sequence data be lodged and made accessible through GenBank[12], a genetic sequence database, and annotated collection of all publicly available DNA sequences. Sequences for an estimated 467 South African species are included in the database, but it is not simple to identify which of these are animals, and which ones are indigenous to South Africa.

DNA barcoding is a technique which uses a short genetic sequence from a standard part of the genome to identify species. Barcoding helps taxonomists with hard-to-identify specimens, and is an innovative

11 http://adu.org.za/

12 http://www.ncbi.nlm.nih.gov/genbank/

way for non-experts to identify biological material. While there has been some criticism of barcoding and it does not work for all taxa, it has been adopted by many countries and researchers, and its use has been proven in a range of applications. Barcode sequences are lodged and made accessible through the Barcode of Life Database, or BOLD[13]. Several researchers both resident in South Africa and from foreign countries have submitted animal samples from South Africa. In July 2012 there were 8,499 records of South African animal samples in the database covering Annelida, Mollusca, Arthropoda and Chordata. South African institutions and individuals have contributed the bulk of these samples (5,068). Unfortunately, only 834 of these samples were identified to species level, with an additional 515 samples identified only to family level, and the remainder to order level only (Fig. 12). A total of 391 species (identified), have been barcoded and barcodes made accessible in BOLD to date. This limits the usefulness of the barcode data for species identification since without the identity being associated with a barcode, the only information that can be provided is whether the barcode sequence matches one already in the database or not. The low number of vertebrates excluding fish is also notable but it is possible that some of the more recently submitted specimens are not yet accessible in the database.

The African Center for DNA Barcoding (ACDB) of the University of Johannesburg is currently running several projects aimed at barcoding animal taxa, including fishes, molluscs, spiders, scale insects, amphipods and alien invasive animals[14].

iv. Molecular laboratories and infrastructure

Most of the universities where taxonomists are based have access to molecular laboratory facilities and some also have access to sequencers. SAIAB and the ARC also have molecular laboratories, but none of the museums have even basic facilities. Museum researchers who are involved in molecular systematics usually collaborate with university researchers either locally or internationally to carry out DNA analyses. Many researchers send samples overseas for sequencing because this is often more cost and time efficient than having samples processed locally. Access to DNA laboratories does not appear to be a major constraint in systematic and taxonomic research, although funding for chemicals and equipment are likely to be greater limitations in this type of research.

13 http://www.boldsystems.org/

14 http://acdb.co.za/index.php/projects.html

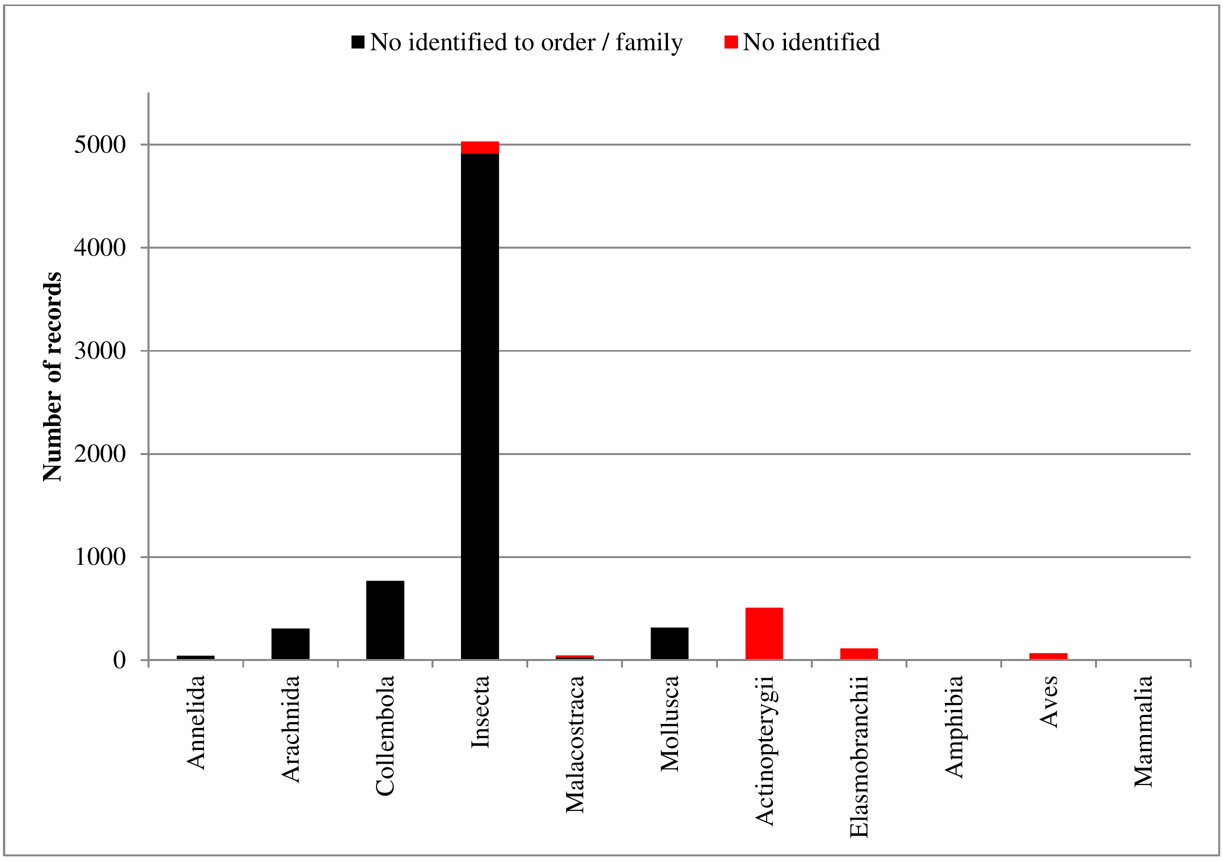


Figure 12. Number of specimens from South Africa that have been barcoded and that are accessible in the BOLD database. It is not possible to estimate the number of species because so few of the specimens are identified beyond order level.

D. Funding for taxonomy

Funds available for research collection curation activities excluding staffing and infrastructure maintenance were non-existent to small in 2009/10. The range recorded was from zero to R300,000 per collection, with an average of R21,000 per collection and 10 cents per specimen. The total national allocation of funds for curation consumables was approximately R1.08 million for 2009/10, and this amount has declined rather than increased over the last two years. This limits the potential for expansion and upgrading of the collections because few new cabinets, containers and consumables can be purchased.

The South African Biosystematics Initiative (SABI) was established by the Department of Science & Technology (DST) and the NRF in response to a motivation from the taxonomic community highlighting the decline in research funding for taxonomy allocated to museums, as well as declining capacity in these institutions. It was also believed that the funding system of the NRF discriminated against descriptive taxonomy which was suggested to be fundamental to all other fields in the biological sciences. SABI was created to address the following objectives:

- Address dwindling national **capacity** in systematics.
- Provide **leadership and co-ordination** to promote innovative research in the field of systematics.
- Empower South African systematists to employ and develop modern scientific technologies and approaches with regard to **the documentation and use of biological resources**.
- Enhance the ability of South African systematists to contribute to the National System of Innovation and **the information society**, and thus to **respond to national priorities in agriculture, health, sustainable development and conservation**.
- To assist the broader scientific community and government in the fulfilment of national and global **biodiversity-related commitments**.
- To promote **awareness of the importance of systematic research** in the broader community through education and outreach projects.

SABI is currently under review by the NRF and so an assessment of the extent to which it has achieved its objectives will not be carried out here. It is important to note that the emphasis of these objectives is on delivering products that are associated with health, agriculture, sustainable development, biodiversity-related commitments, and documenting biodiversity.

SABI provided research grants, as well as free-standing bursaries at a higher level than the standard NRF bursaries, postdoctoral grants for museums, travel grants for postgraduates and funding for workshops. In addition a SABI Forum was held annually or at 18 month intervals. An estimated average of R12 million per annum was provided by SABI from 2005 to 2012, which means a total investment of about R96 million for systematics in South Africa. SABIF has allocated R1 million per annum for data capture for the last four years, which means that at least R100 million in grants and for activities relating directly to taxonomy has been dispersed over the last seven years. This is not limited to animal taxonomy.

Most institutions provide some funding for research, and they provide access to equipment, vehicles, literature resources, internet and laboratory facilities including DNA sequencing and electron microscopy. There have been other programmes within the NRF that have also provided funding for taxonomy. This makes it difficult to provide an estimate of actual investment in systematics, especially zoological systematics, but the amount is likely to be over R20 million per annum.

Summary box

- 15 million specimens in 23 institutions and 75 collections in South Africa
- 17 institutions with collections rated as Vulnerable or at High Risk of deterioration / neglect
- >6 million specimens in collections yet to be captured on databases
- 9,927,936 animal records held by SABIF, but 94% of these are bird observations
- 8499 records of animals from South Africa in BOLD database, 834 of these identified to species level
- Estimated R100 million allocated through SABI and SABIF over last 7 years

E. Trends in research outputs in zoological taxonomy

There is currently no co-ordinated list of literature covering the taxonomy of South Africa's animals, nor a list of South African animals with the date of description or change in classification or status. This makes it very difficult and time consuming to provide an accurate assessment of publications and discoveries over time.

For the information presented here the Zoological Record database was used. This only provides references for publications dating back to 1978.

i. Number of papers published

South African taxonomists published a median of 1.6 papers each per annum over the last 11 years. Thirteen of the 106 researchers have been in a professional post for less than five years and so these individuals do have a lower output than those employed for the full 11 year period. One point of concern is that of the 16 museum taxonomists who have not retired or who have been employed for more than five years, only two had published more than the median number of papers.

ii. Species description

Taxonomy is often described as being of fundamental importance to other fields of biology and to biodiversity conservation because it documents, describes and names taxa. Without a formal name it is not possible to access information about a species or specimen. The large number of undiscovered and undescribed species and the importance of addressing these knowledge gaps is widely given as the motivation to increase capacity in taxonomy and funding for the discipline. An examination of the number of new species described by South African taxonomists over the last 11 years however, showed that 36 taxonomists (35%) have not described any new species, and 54% in total have described less than five species in this period (Fig. 13).

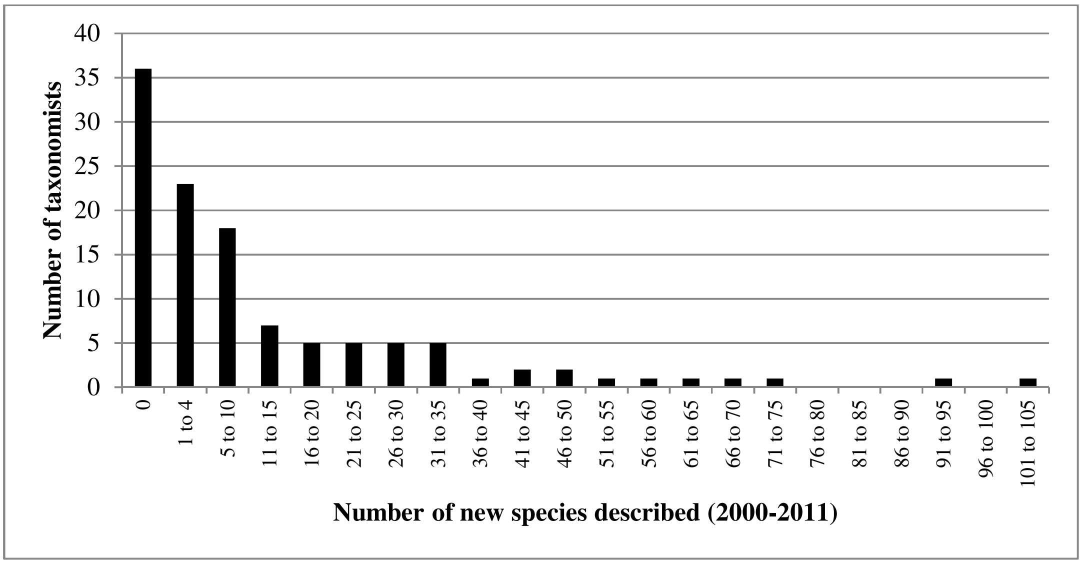


Figure 13. Frequency distribution of new species described by taxonomists permanently employed in South Africa over an 11-year period.

Museums are often considered to be where descriptive taxonomy is done, but even if the 16 taxonomists based at museums, and not retired or appointed in the last five years are considered, they have described 225 animal species in the last 11 years, and average of 0.9 species per taxonomist per year. The global trend is somewhat similar and Costello *et al.* (2012)[15] showed that the number of species described per taxonomist globally has decreased, although the number of species in total has not, and neither has the number of taxonomists.

In terms of temporal trends, since 1980 there have been 10 individual years where more than 200 South African species have been described, and nine of these have been post 2000, which suggests a general increase (Fig. 14). For taxonomists based in South Africa, the years with the highest number of species described were 2002 and 2009 (Fig. 14). However, the contribution of South African taxonomists to species descriptions has declined: the average annual contribution in the 1980s was 41.5%, in the 1990s this decreased to 38.7%, and in the 2000s to 29.9%.

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15 Costello MJ, Wilson S, Houlding B. (2012) Predicting total global species richness using rates of species description and estimates of taxonomic effort. Syst Biol. Oct;61(5):871-83. doi: 10.1093/sysbio/syr080. Epub 2011 Aug 18

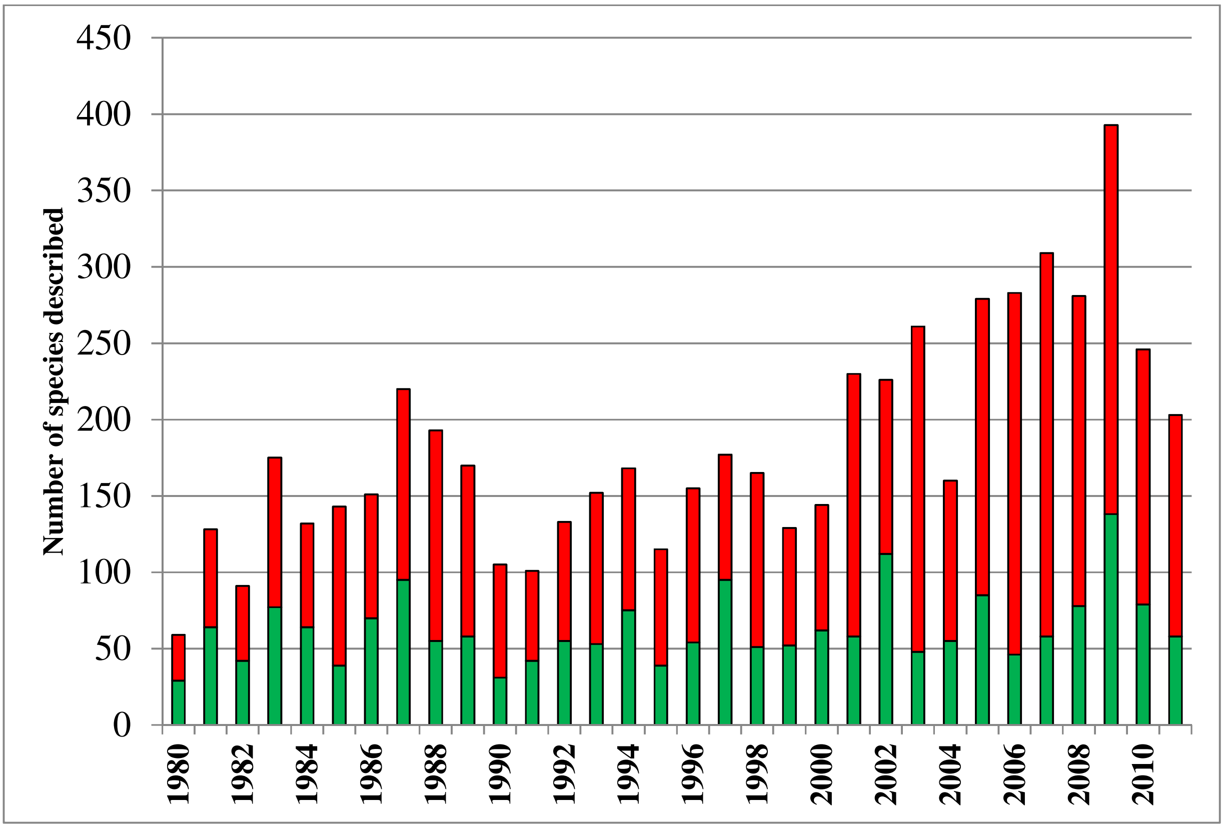

Figure 14. Number of new animal species from South Africa described per year. Green=taxonomists based in South African institutions; red=taxonomists based outside of South Africa.

The following points highlight a number of important trends:

- Total = 6000 SA species described in 31 years
- Average of 193 species described / year (compared to 770 / year for Europe (Fontaine *et al.*, 2012))
- 1.1% of number of animal species described globally / year are from South Africa (about 17,000 in total per year are described globally)
- <10% of the fauna has been described in the last 30 years
- Rate of descriptions: South African taxonomists = 2500 species described in 31 years = 80 species / year
- 100 taxonomists working / year = 0.8 SA species described / year / per person
- 66% of new South African species were described by foreign taxonomists in last 31 years
- The estimated 80,000 undescribed animal specieswill take 355 years to described at the current rate of description

iii. Other systematic outputs

It will be argued that taxonomy is about more than new species descriptions and the breakdown of other types of outputs is presented in figure 15. The number of taxonomic revisions that cover more than three species, and that include redescriptions, and additional data is low (approximately 16 per year for all taxonomists over the last 11 years), and the number of checklists (22 in 11 years), and publications that include distribution data, including new locality records are also relatively low (257 in 11 years). About 260 papers have been published that are focused on molecular phylogenies or phylogeography and it appears that this component of taxonomy and systematics is a current strength in South Africa. These studies provide unique information including DNA sequences for taxa, insight into true diversity and evolutionary processes that contribute to diversity, and possible relationships between taxa.

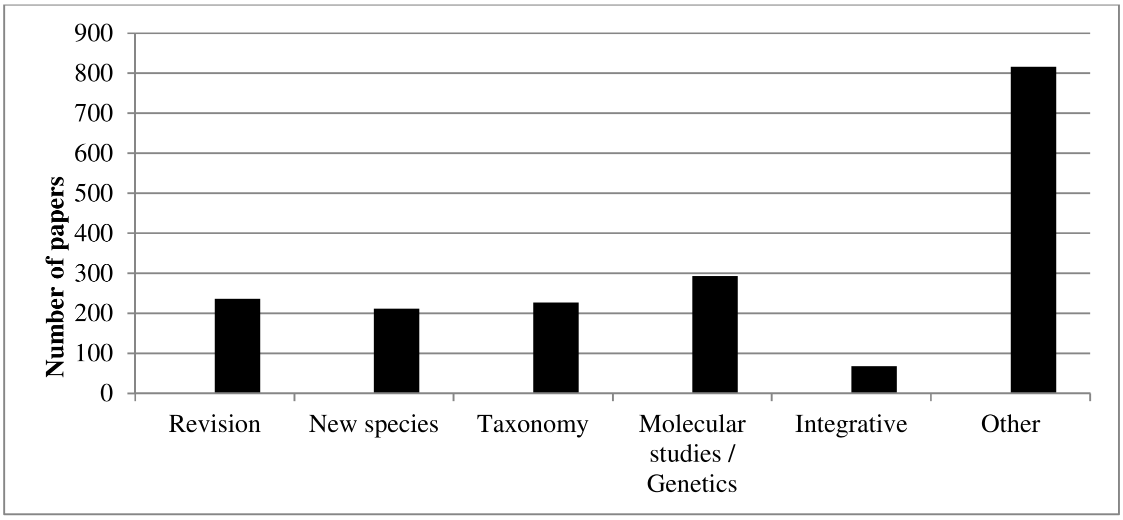

Figure 15. Number of papers per category published by taxonomists in South Africa between 2001 and 2011. Revision = papers where more than 3 species are dealt with, New species = 1 / 2 new species descriptions, Taxonomy = checklists, keys, redescriptions of < 3 species, field guides, nomenclature, diagnostic characters and variation in characters; Molecular studies / Genetics = hybridization, gene expression, phylogeography, phylogenetics, population genetics, chromosomal studies, cytogenetics, Integrative = studies using both morphology and molecular approaches, Other = all other publications not falling within previous categories.

iv. Publically accessible taxonomic outputs

In order to increase the appreciation for the work done by taxonomists, outputs from research should be accessible to a wide audience. There have been excellent field guides published for all the vertebrate groups, for butterflies, terrestrial molluscs of the eastern part of South Africa, fruit chafers, scorpions and dragonflies, and various other guides that allow identification to higher taxonomic levels for insects, spiders, marine invertebrates and dung beetles. These are all invaluable contributions which have been mostly poduced by taxonomists. Species level information for South African animals on the web is limited, and information that does exist is fragmented across hundreds of different websites.

Part 3: Implications of the current trends: what needs to be addressed in a strategy?

A. Documenting, describing and identifying biodiversity

Overall, South African zoological taxonomists have published over 1,500 papers in the last 11 years and this can be considered a substantial contribution to knowledge about animal diversity. A deeper examination of the trends indicates a move away from descriptive and revisionary taxonomy and a move towards phylogenetic analyses that may identify genetic divergence but do not formalise this in terms of the description of new taxa. While many publications in the latter field are of exceptional quality, have been published in high impact international journals, and have contributed to understanding evolutionary processes, they have limited use for addressing the GTI priorities. In other words, they do not directly address the taxonomic impediment. There is a disjoint between what is needed from taxonomists and what research is done by taxonomists. This leads to decreased value for the discipline and makes it difficult to promote as being really fundamental or foundational to other disciplines and to biodiversity conservation and management. This in turn makes it impossible to attract ring-fenced funding from government or funding agencies with a conservation and sustainable use focus.

To some extent the trends are global; there is a general move away from morphological, descriptive taxonomy and developing expertise on a particular taxon to working on a number of taxa using molecular techniques but not developing the knowledge that allows identification of material to species level or the formal description and naming of new taxa identified. The rate of animal species description in Europe is, however, currently higher than it was 100 years ago, and for many taxa continues to increase, with an average of 644 species described per year between 1998 and 2007[16]. The total number of species described per year globally has also not shown a decline between 2000 and 2009[17]. In South Africa there is a general increase in the number of species described in the last decade compared to the two previous decades, but the contribution of local taxonomists to this has declined.

A workshop was run at the recent Southern African Society for Systematic Biology (SASSB) conference (July 2012) to discuss the need for revisionary and monographic taxonomic publications and the reasons

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16 Fontaine B, van Achterberg K, Alonso-Zarazaga MA, Araujo R, Asche M, et al. (2012) New Species in the Old World: Europe as a Frontier in Biodiversity Exploration, a Test Bed for 21st Century Taxonomy. PLoS ONE 7(5): e36881. doi:10.1371/journal.pone.0036881

17 http://timgostony.com/iisetemp/RetroSOS__FINAL.pdf

for the decline in this type of work. The workshop involved taxonomists working on all taxa and not only animals. Taxonomists based at universities, which is the largest component of the community gave the following reasons:

- They receive incentive funding from their institution based on the number of publications in ISI or SAPSE listed journals. Large monographs are time consuming and will therefore result in a reduction in the amount of funding received.
- Promotions criteria include the impact factor of the journals published in and the citation record for papers published. Monographic and descriptive taxonomy are not publishable in high impact journals and are not well cited, even if they are well used.
- Promotions criteria also include NRF rating and taxonomists who only publish descriptive work will not be able to get a high NRF rating and this will negatively impact on both promotions and NRF funding.

There are some misperceptions in the reasons given: of the 92 animal taxonomists practicing in South Africa, 47 are rated. Not all of the unrated researchers are those who do not publish molecular phylogenies, and not all of the rated researchers only publish this type of research. In addition, at least half of the B-rated researchers do descriptive taxonomy, including the description of new species, although some of their work may include molecular analyses. In terms of output, only 22 of the taxonomists assessed have published an average of more than two papers per annum, which suggests that output is also not currently a major driver either. The decrease in capacity at museums, the relative speed at which molecular expertise can be developed, and the perception that molecular research is of higher quality than morphological investigation may be stronger influences. Whatever the causes of the trends, mechanisms of ensuring that biodiversity is documented and described in such a way that the research outputs translate directly into useful data for conservation and management of biodiversity are critical. This may mean exploring non-traditional ways of describing species.

B. Capacity constraints

The skewed capacity relative to species diversity needs to be addressed. Critical gaps are in entomology, and in relation to this, lack of insect taxonomists at universities to train postgraduates is a major concern.

The loss of posts, and appointments made at low levels or grades at museums were identified through the SASSB workshop and during the collections assessment. This is a major concern because museums should be the “heart” of animal taxonomy. The low salaries and potential for promotion, low morale, low productivity and loss of research culture at museums are also a concern.

C. Accessibility and dissemination of knowledge

Unless taxonomic information is accessible for use beyond narrow specialists, the discipline will always be undervalued by society at large. There are several trends in publication and data management that do not enable access to information:

- Publication of research outputs is predominantly in highly specialised scientific journals which are not accessed by the majority of scientific community or users of taxonomic data.
- The language and terminology used in publications is highly technical and often inconsistent within a taxon which means that the information is only accessible to a very small group of narrow specialists.
- Many publications are only readily accessible to those who can afford to pay for a subscription.
- The information generated is scattered across thousands of journal articles, and is not consolidated or co-ordinated in any way, which means that accessing it is almost impossible for anyone outside a narrow group of specialists.
- Many data sets, including character matrices, primary data, notes and datasheets are lost because they are not published or made accessible or managed in the long term. This is hugely inefficient and wasteful of resources expended in collecting the data.

A national strategy is required to address the challenges in addressing the needs of users of taxonomic information, of developing capacity for priority taxa and for making taxonomic data accessible.

D. Strategy vs academic freedom

It is recognised and accepted that taxonomists have the freedom to research whatever topics and taxa they choose, and that this type of freedom results in new discoveries; it is frequently stated that exploratory and theoretical research is where the cutting edge discoveries are made and where innovation happens, and that this is the nature of science and research. A strategy for "blue-sky" systematics research would be counter to the nature of this type of research. Funding for such research, where science excellence is the primary aim, has been provided through SABI, even when the research did not directly align with the stated objectives and this has boosted systematics research nationally, but it has not resulted in a major contribution to addressing the taxonomic impediment. In the UK funding for taxonomy is targeted at the production of specified products, rather than funding any taxonomic research purely on the basis of scientific excellence. This is likely to be the approach required in South Africa to ensure that specified products that address the taxonomic impediment are delivered.

There is often conflict between what users need and what taxonomists themselves see as priorities, and between delivering on the basic needs of the users of taxonomic information and producing research which is publishable in high impact journals. There has been a strong resistance amongst the taxonomic community to serving the needs of users of data and other researchers, with a strong push towards developing taxonomy as a stand-alone discipline rather than one that simply services the needs of others. However, if taxonomists focus only on academic research and do not provide the knowledge and information that is so fundamental to other areas of biodiversity research and decision-making, then the discipline will be seen as purely academic and it will not be considered as a high priority amongst funding agencies or decision-makers. Local needs will have to be filled through foreign collaborations, or ways of working without the taxonomic data and information will be found. Ensuring that the needs of users of taxonomic information can be met, without constraining original academic research is a challenge that is not going to be easily addressed in the short-term.

E. Leadership and co-ordination for taxonomy

The following excerpt is from the document by Herbert *et al*. (2001)[18] which was submitted via the NRF to the (then) Department of Arts, Culture, Science & Technology to motivate for ring-fenced funding for taxonomy: "*A message which comes through strongly and repeatedly in the literature relating to fundamental biodiversity research in South Africa is the need for some form of national co-ordinating body or centralised agency to provide focus and leadership. This body should have the power, will, human resources and funding to identify research priorities in the fundamental biodiversity sector, and to support and co-ordinate appropriate research*". The report indicated that the National Botanical Institute had played this role for plants to some extent, but motivated for a broader body to play the role across different taxa. The report resulted in the establishment of SABI, but this was more of a funding mechanism, rather than a permanent co-ordinating body. SANBI has been mandated to play this role since 2004 through the Biodiversity Act, but the extent to which this has been achieved, and how it can fulfill this mandate and possibly co-ordinate and drive the implementation of the National Biosystematics Strategy requires intense discussion, action and investment. The absence of co-ordinated and accessible taxonomic products for animals is an indication that SANBI has not played this role in the last eight years.

Part 4. A five-year strategy for taxonomy in South Africa

A. Approach to identifying priorities

A needs assessment for Africa was carried out in 2001[19] but of course the biodiversity environment has changed in the last 10 years, with increasing emphasis on climate change impact and adaptation and increasing focus on ecosystem services rather than species conservation. Technologies relating to

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18 Herbert D.G., Smith G.F., Hamer M.L. and Scholtz C.H. (2001). Taxonomy and systematics research in South Africa: vital research facing a crisis in capacity and resources. Unpublished. report to the National Research Foundation and the Department of Arts, Culture, Science and Technology, Pretoria.

19 Klopper R.R., Smith G.F. and Chikuni A.C. (2002). The Global Taxonomy Initiative in Africa. Taxon 51, 159–165.

publishing, molecular biology and the management, manipulation and dissemination of large biodiversity data sets have also rapidly and radically improved in this time period.

Whether another assessment of needs is required at this stage is debatable. Priority research themes are global and have been identified by many different countries, funding organisations and research institutions. At a national level, there has been a marine biodiversity research strategy workshop where priorities were identified, and a brain-storming session was held in October 2012 for users of foundational biodiversity information, including taxonomic products, to identify priorities. The National Biodiversity Assessment of 2011[20] also provides useful themes where information relating to taxonomy is needed. It may be more effective, and cost and time efficient to use global priorities, in combination with outcomes of the workshops and the National Biodiversity Assessment, to identify specific priorities for South Africa, rather than carrying out another extensive (and expensive) survey.

A DST programme on "foundational biodiversity knowledge and information" is currently being implemented. This includes taxonomic research, as well as the management and dissemination of the information generated. The strategy presented here needs to align with the approach and principles of that programme, which will provide funds for taxonomy.

Within a seven-year period a limited number of outputs and outcomes are achievable. Past strategies and needs assessments have been vast wish lists which have resulted in a lack of implementation and little real advancement in terms of reducing the taxonomic impediment. In addition, they have focused on inputs (resource needs and what will be done/ activities) rather than what will be produced (outputs) and the consequences of the outputs (outcomes). The main outputs in the past have been considered to be research publications, and while these are essential for formalising the knowledge, and for ensuring quality, they seldom directly address knowledge and information needs. This means that resourcing the implementation of strategies is often unappealing to funders in the long term.

The needs identified in the UK assessment[21], as well as in the GeoBon implementation plan[22] for biodiversity monitoring, the Aichi targets of the CBD[23] and the Millennium Development Goals[24], the GBIF Forwards Look document[25], and the report on an e-conference on Strategies in Taxonomy:

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20 http://bgis.sanbi.org/nba/project.asp

21 Boxshall, GI & Self, D. 2011. UK Taxonomy & Systematics Review – 2010. Results of survey undertaken by the Review Team at the Natural History Museum serving as contractors to the Natural Environment Research Council (NERC) http://www.nerc.ac.uk/research/programmes/taxonomy/documents/uk-review.pdf

22 http://www.earthobservations.org/documents/cop/bi_geobon/geobon_detailed_imp_plan.pdf

23 http://www.cbd.int/sp/targets/

24 https://www.cbd.int/doc/books/2009/B-03186.pdf

25 Peterson, TA, Canhos, D., Gärdenfors, U., Scholes, R.J., Shirayama, Y. 2010. GBIF Forward Look Report. GBIF Secretariat. http://www.gbif.org/orc/?doc_id=3032

[25] Grant, F., de Jong, Y., Kirschner, J., Petřík, P., Segers, H., Sharman, M., Tillier, S., Watt, A., Young, J. (Eds.). 2009. Strategies in Taxonomy: Research in a Changing World. Report of an e-conference.

Research in a Changing World[26] were used to identify priority outputs from taxonomy. These needs are global and are relevant to the South African context as well.

In most needs assessments the following are seen as the main requirements by users of taxonomic data:

1. Identification of material / specimens (either as a service, or enabling this through the provision of user-friendly identification keys / resources) (What is it?)

2. Accurate species occurrence and abundance data sets (Where does it occur and how many are there and how is this changing / has this changed over time?)

3. Co-ordinated information about species, including classification, nomenclature and information including functional role, threat status, importance to humans (What is it called and what does it do?).

These needs (ouputs) are, in broad terms, to enable countries / regions / organisations to be able to manage and conserve biodiversity, which in turn will enable people to have sustainable livelihoods (outcome), and so they must be seen as priorities, especially in a country such as South Africa, where levels of poverty and rates of loss of natural habitat and biodiversity are high.

Appropriate human capacity and the maintenance of collections are essential to the delivery of the three main needs and for future research. Access to collecting permits has been identified in the past as an obstacle to taxonomic research and this also needs attention.

Given the diversity of animals in South Africa, and the financial and capacity constraints, it is impossible to deliver on the three needs for all animal species and so prioritization is critical. The approach to identifying priority taxa is to consider:

- Feasibility, including expertise available (there should be either local or international capacity to contribute to research or capacity development), the current state of knowledge relative to the diversity (there should be some knowledge base existing and there should be a possibility of making substantial progress in terms of enabling identification of species and the development of data sets), and
- Rationale for taxonomic study: ie. is the taxon of major importance in ecosystem functioning, a keystone taxon, high proportion of endemic species, or of economic value?

B. Aim of the South African Zoological Taxonomy Research Strategy

The aim of the strategy is to ensure that zoological taxonomy in South Africa is co-ordinated, and that the outputs meet the needs of the user community and contribute to research that promotes sustainable livelihoods.

Over the next seven years the focus will be on consolidation, co-ordination and dissemination of comprehensive taxonomic information, for use by a wide range of stakeholders. Research where taxonomy is integrated into and enhances larger research projects is also prioritized because such activities will illustrate the value of taxonomy to the broader community, and will contribute to the development of priority data sets in a relevant context.

This focus is critical to illustrate the importance of taxonomy because it delivers what is required by a range of users, it also allows the identification of gaps, and allows an incremental approach to research. While it might be considered as "basic", it will form a crucial foundation for future work.

C. Strategic Objectives for 2013-2018

SO 1. To develop and make accessible accurate and comprehensive primary data sets for specimens of selected taxa for use in land and marine spatial planning, species threat assessments, biodiversity monitoring and research relating to global change impacts on biodiversity.

SO 2. To carry out zoological taxonomic research which is aligned with the needs of major initiatives and that is integrated into broader research programmes to ensure that taxonomy delivers useful and used knowledge.

SO 3. To develop identification tools for taxa of major concern for conservation, sustainable use and the management of invasive, disease vectors and pest species. This includes the development of a DNA barcode reference library for the priority species.

SO 4. To develop capacity to enable taxonomists to contribute to the broad dissemination of their outputs, and to develop new capacity in line with identified priorities.

Four additional objectives deal with outputs which may not be considered as being the primary work of taxonomists, but the contributions and participation in the activities by taxonomists are essential, and the outputs from these objectives are critical for supporting or enabling taxonomy research, or for promoting its value.

SO5. To provide a complete and regularly updated checklist of animals in South Africa, including classification, synonyms and local names which is publically accessible through the internet.

SO6. Co-ordination and dissemination of existing foundational information for priority species.

SO 7. To initiate discussions on the recommendations made in the NRF report on the status of biodiversity collections in South Africa.

SO 8. To explore mechanisms for enabling access to collecting permits so that this is not a major impediment to the exploration of animal diversity in South Africa.

D. Activities required to achieve Strategic Objectives:

SO1. To develop and make accessible accurate and comprehensive primary data sets for specimens of selected taxa for use in spatial planning, species threat assessments, biodiversity monitoring and research relating to global change impacts on biodiversity.

SABIF has provided funding for the digitisation of specimen data, and co-ordinates the data sets developed through this and other programmes. The actual data sets are not readily accessible, mostly because of restrictions by data providers who must be contacted to obtain written permission to use the data. This severely limits the use and application of the data, which in turn limits the promotion of collections and the justification for the collection of primary biodiversity data. In addition, there has been little vetting of specimen identification or updating the names and classifications or standardisation of these in the datasets provided to SABIF. Many of the datasets are incomplete in that individual institutions have submitted their data for a particular taxon, but not other institutions. There has also been no effort to review the existing data for taxa to determine the coverage, either taxonomic or spatial.

Surveys of neglected areas to develop primary data sets is the work of taxonomists who generally have the knowledge required to identify target species or taxa in the field, and to find them in their natural habitats. While surveys are critical, some understanding of the extent and quality of existing data is required before investing resources in new surveys. This requires digitization and consolidation of records from specimens, mostly in collections.

The following are considered as priority activities for the next five year period:

1.1. Vertebrates

- Review of the data for *mammals, reptiles, amphibians and fish* to identify the extent of digitistation and identify major gaps in terms of collections that have not been databased. Birds are not included here because of the comprehensive Bird Atlas project.
- Review of the quality of the data with a focus on taxonomic accuracy in terms of identification and updating of names and classifications and on geographic gaps.

1.2. Terrestrial invertebrates

1.2.1. The *butterfly* data have all been consolidated and accuracy reviewed, and maps have been produced to identify collecting / data gaps. There are activities and plans by the ADU and LepSoc to continue to generate data and this is strongly encouraged to provide a product similar to that of the Bird Atlas which will allow monitoring of changes in distribution and populations over time.

1.2.2. *Other terrestrial invertebrate taxa*: An assessment is required to determine which taxa have:

i. sufficient material in collections that is identified to an appropriate level,

ii. sufficient expertise to validate the identifications, and a critical mass of researchers who can contribute to addressing gaps in data.

These are criteria that should be used to determine which taxa to invest resources in improving the quality and expanding existing datasets in the next five years.

Potential taxa include the following, but there may be others:

- *Spiders, Scorpions, Solifugids, Opilionids*. The South African National Survey of Arachnida (SANSA) was co-ordinated by the ARC in the last five years and although that project has been completed, there is still a need for considerable additional data. There is a critical mass of experts who are well networked, including with international experts, and who have shown commitment to atlasing and identification of material and so this project should be continued.
- *Dragonflies*. The ADU is co-ordinating a mapping project on dragonflies in collaboration with Stellenbosch University. The gathering of data is mostly through a virtual museum and the participation of citizen scientists but given that the group is well known and readily identifiable this is feasible. In addition, there is already substantial existing data and several interested people to continue the work and the group has been suggested as an important indicator for water quality and rehabilitation of alien infested waterways.
- *Bees.* The ARC has collected bee data and has some expertise to identify these, but also has an established international network of experts. A substantial data set has been complied and the quality of this is perceived to be good. In addition, bees are ecologically important as pollinators, and so this dataset should continue to be developed.
- *Dung beetles*. There is currently a project underway to database the dung beetles in South Africa's collections. Specimens are being identified / re-identified by experts and georeferencing is being done using a systematic approach. There is a risk that the expertise required to continue the project in the future may not be available, and efforts to address this risk need to be made.

3.3. *Freshwater invertebrates*

Data sets for freshwater invertebrates were identified as a priority need by the National Biodiversity Assessment of 2011. It is uncertain which freshwater taxa are relatively well surveyed (apart from dragonflies). Over the next five years priority taxa for different freshwater habitats should be identified, and the extent of data and data gaps and required expertise should be reviewed.

3.4 *Marine invertebrates*

The strategy for marine biodiversity states that: "South Africa lacks basic national marine biodiversity databases and lists that are available for public dissemination. Such lists as well as lists of endemic and range restricted species are a key requirement to support conservation assessment, planning and management". Priority taxa should be those that could be considered to play an important role in ecosystem processes and in creating habitats, but again, expertise must be accessible and willing to contribute. Priorities include the following taxa:

- *Corals and coral reefs*: an atlas is being developed and this taxon provides an ideal opportunity for the participation of citizen scientists, and various organisations. The taxonomy is sufficiently resolved to allow the accurate identification of species, but distribution and abundance data are incomplete and inaccessible.
- *Polycheate worms*: there is a solid foundation of work on which to base future research, and there are two polychaete taxonomists based in South Africa. The collections do require databasing and checking of identifications, and it may be necessary over the next five years to limit the database to selected families for which knowledge is more complete, and for which additional survey data can be collected by a network of citizen scientists and organisations.
- *Echinoderms*. There has been some effort to revise the taxonomy and work on collections for Asteroidea (star fish), and there has been ongoing work on Holothoroidea (sea cucumbers). A student project on the Echinoidea is being initiated at UCT.
- *Marine molluscs*. There has been substantial taxonomic and survey work carried out mostly by the KZN and Iziko Museums over many years. Vast amounts of data have been compiled but the data are not openly accessible.
- *Barnacles*: a student project at UCT has revised the South African species and examined the collections and this will provide a useful starting point to continue to develop the data set further by surveys.

SO 2. To carry out taxonomic research which is aligned with the needs of major initiatives and that is integrated into broader research programmes to ensure that taxonomy delivers useful and used knowledge.

Revisionary taxonomic work, especially that which uses different approaches has been highlighted as a major need in other strategies[27]

The DST programme for foundational biodiversity information and knowledge suggests two approaches for ensuring that taxonomic research and outputs address the needs of users that that they are taken up and applied in decision-making:

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[27]Grant, F., de Jong, Y., Kirschner, J., Petřík, P., Segers, H., Sharman, M., Tillier, S., Watt, A., Young, J. (Eds.). 2009. Strategies in Taxonomy: Research in a Changing World. Report of an e-conference.

- Identifying what are the main needs for foundational biodiversity information from users, including other researchers, and then developing projects to address these needs, and
- Developing projects that will involve researchers and practitioners all along the biodiversity information value chain to ensure that the knowledge generated is taken up and applied (Fig. 16).

The principles for research projects are that they must be collaborative so that resources are efficiently used in data collection and so that a more comprehensive data set is generated, that any surveys / sampling is quantified so that abundance estimates are produced which is critical to ensure broad application of the data, and that all knowledge generated becomes publically accessible within a reasonable time frame.

This approach does not specify which taxa must be worked on, or whether morphological or molecular approaches must be used or whether surveys should cover one or many sites or areas, or which geographic areas are a priority. Instead, the research must be part of the integrated project, and / or must provide data that has been identified as being important for achieving higher level objectives. The work of almost any taxonomist willing to directly contribute to a broader objective and to work as part of a team can be accommodated. What is required is a change in *how* taxonomists work and think rather than *what* they actually do. This approach will allow taxonomists to publish high impact work and through collaborations to increase research outputs.

There is currently a large emphasis on ecosystems as opposed to species in conservation biology but several publications have highlighted the importance of the identity and functional role of the individual species in the ecosystems[28], [29] and it is in this field that taxonomists could play a critical role. Surveys of what species / higher taxa occur in an ecosystem, using modern technologies to identify and compare diversity in ecological samples, and applying phylogenies to identify functional role or traits are the kinds of research activities that would contribute to understanding ecosystem functioning.

The integrated projects could also focus on a particular location / biome / habitat / region which is thought to be of high value in terms of diversity and endemism or for providing ecosystem services or for providing natural resources, but which is poorly explored, and where taxonomic outputs are required for land and marine spatial planning and management of biodiversity. Phylogeographic or phylogenetic approaches could be integrated with morphological studies to explore, document and / or describe diversity within or across taxa, and large teams could potentially generate valuable and comprehensive taxonomic, spatial and quantified population data sets that would serve a several different stakeholders.

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28 Díaz, S., Tilman D., Fargione, J. et al. 2005. Biodiversity regulation of ecosystem services. In: Hassan R, Scholes R, Ash N, editors. Ecosystems and human well-being Current state and trends - Findings of the Condition and Trends Working Group of the Millennium Ecosystem Assessment. Washington, DC: Island Press. pp. 297-329

29 Hooper, D.U., Chapin, F.S., Ewel, J.J., Hector, A., Inchausti, P., Lavorel, S., Lawton, J.H., Lodge, D.M., Loreau, M., Naeem, S., Schmid, B., Seta, H., Symstad, A.J., Vandermeer, J., & Wardle, D.A. 2005. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. Ecological Monographs, 75(1): 3–35.

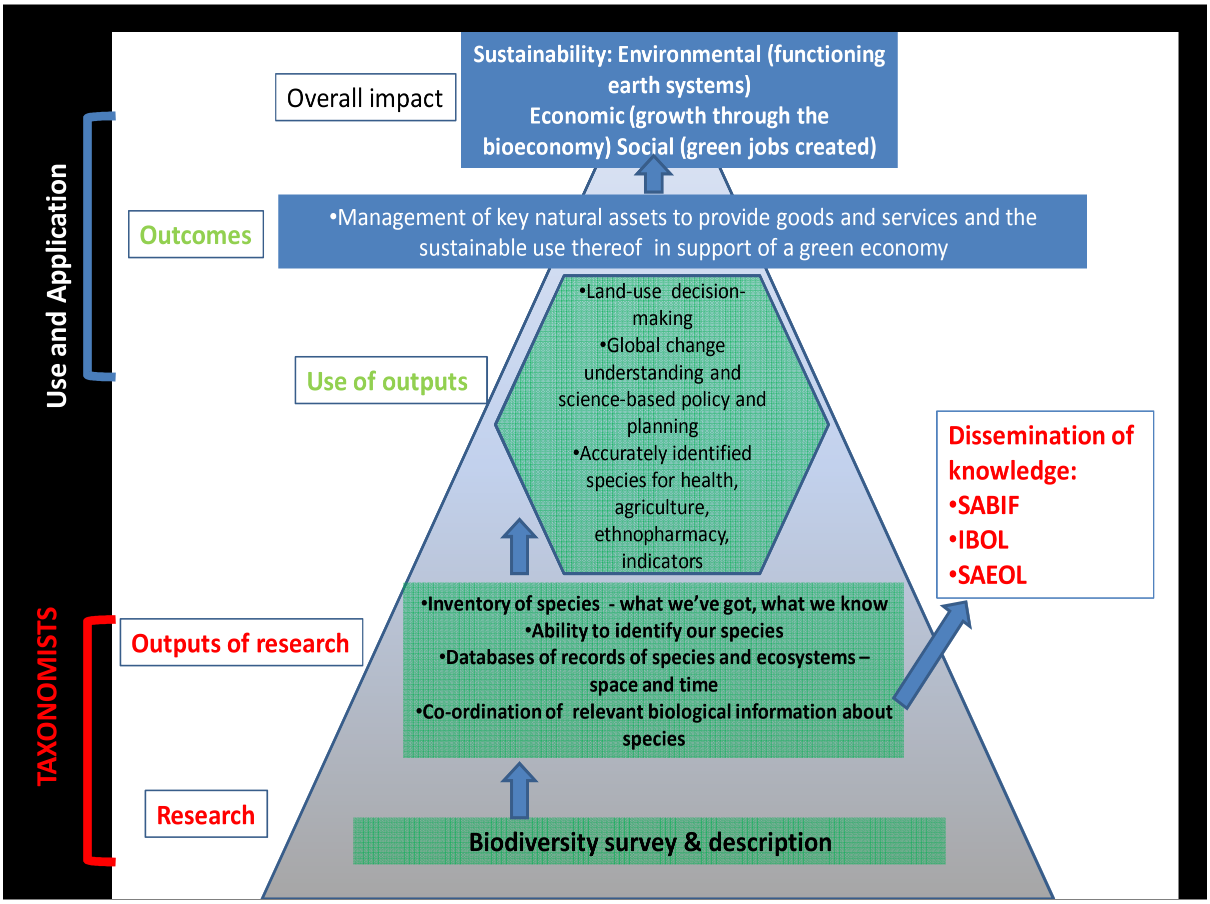

Figure 16. Schematic diagram of the value-chain of biodiversity information, from knowledge generation to the ultimate aim of environmental sustainability and economic growth. (From the submission to the DST for a Foundational Biodiversity Information programme).

Activities:

2.1. Develop and implement projects that illustrate the importance of taxonomic research for research in the fields of global change, ecosystem functioning and the bioeconomy.

2.2. Use these projects as models and for promotion of taxonomy to funders and decision-makers to illustrate the value of taxonomy.

SO 3. To develop identification tools for taxa of major concern for conservation, sustainable use, and the management of invasive, disease vectors and pest species. This includes the development of a DNA barcode reference library for the priority species, as well as online keys.

Activities**:**

3.1. Determine existing projects and resources for the identification of priority taxa and categories of animals, identify gaps and develop a plan for addressing these and for providing access to those that are already developed.

3.2. Provide an open access internet platform for the submission of identification keys for the animals of South Africa, and ensure that these are arranged and accessible in a logical and user-friendly way.

3.3. Provide a list of all species and localities for which material has been barcoded, and a list of those species that are a priority for getting material barcoded.

3.4. Initiate project/s for sampling and submitting specimens from priority taxa and categories for barcoding to expand the barcode reference library.

3.5. Explore innovative mechanisms for the documentation, description and identification of species.

SO 4. To develop capacity to enable taxonomists to contribute to the broad dissemination of their outputs, and to develop new capacity in line with identified priorities.

The analysis of existing capacity in the first section of this document clearly indicates three major challenges that need to be addressed: i. the urgent need for taxonomists in entomology and marine invertebrate taxonomy; ii. the lack of expertise at universities for the training of entomology postgraduates; and iii. the lack of attractive posts at museums which should be the heart of animal taxonomy. None of these challenges are simple, cheap or quick to address since they are controlled by government departments and universities which have agendas other than biodiversity conservation and management. Some effort at least should be directed to raising awareness of the capacity constraints and needs amongst relevant institutions and departments.

Activities:

4.1. So-called up-skilling of taxonomists to enable them to submit material for barcoding, to use the BOLD database, and to use other new technologies or approaches associated with generation and dissemination of taxonomic data.

4.2. Explore the feasibility of a coursework masters for systematics / taxonomy. Funding, levels of interest from prospective students, curriculum, capacity and institutional arrangements all require investigation.

4.3. Develop capacity for priority taxa through training of MSc and PhD students. Where appropriate expertise is not available in South Africa, it may be necessary to send students overseas to work with experts on South Africa's fauna, or to bring internationally-based experts to South Africa where they could then also contribute more broadly to projects. Funds to enable this must also be sourced, but such activities could be built into the new DST programme. These opportunities should be used to attempt to address the equity / transformation of the existing demographics of the animal taxonomy community in South Africa.

4.4. The role of “citizen scientists” in exploring and documenting South Africa’s biodiversity needs to be considered. Citizen scientists have made major contributions to surveys, taxonomy and data collection especially for birds, frogs, reptiles, fish and butterflies. While there are constraints for taxa that are more difficult to identify, there is still enormous potential for productive involvement of citizen scientists.

4.5. Establish links with international taxonomists who can contribute to documenting South Africa’s biodiversity, and to capacity development where expertise does not exist locally. Encourage participation of global experts in projects that address other objectives in the strategy, especially for priority taxa where expertise is lacking nationally.

Supporting Objectives:

SO5. To provide a complete and regularly updated checklist of animals in South Africa, including classification, synonyms and local names which is publically accessible through the internet.

This is the most basic and important product of taxonomic research. While there have been lists published for certain taxa these are not publically accessible, and are not updated. Details of which taxa still require checklists are included in Appendix 1.

To date lists including about 22,000 animal species in South Africa have been compiled and provided to SANBI, either by taxonomists or by contract staff based at SANBI, and lists for another 15,000 species are currently being developed. Checklists for at least 27,000 species still remain to be compiled and at this stage there are no experts in South Africa available to assist with this activity.

The lists compiled to date include some basic information where this is readily available, including broad distribution of the species, threat status, and whether introduced or indigenous. The compiler of the list and the source of the information for each species is also included. The principle of acknowledgement of the author of the list is promoted and citations of information from the checklist should include the author of a particular list so that credit is received for input. The national list should not be seen as a copyrighted product, and should be open access, with credited references when the data are used elsewhere.

One institution must take responsibility for ensuring that the lists are made publically accessible, for ensuring that updates are made, either in-house by carrying out literature scans, or by taxonomists who are willing to commit to regularly updating the list and providing this to the co-ordinating institution, and for highlighting the gaps in the list and identifying mechanisms for addressing these. Given the legal mandate of SANBI to “promote and co-ordinate taxonomy” in South Africa, this institution must take responsibility for ensuring that the list is at least 80% complete within seven years. The participation of animal taxonomists in South Africa and internationally in order to achieve this objective is critical.

Activities:

5.1. Website for dissemination of lists to be established and populated. There have been many discussions around the format of the lists, but it seems that allowing users access to full data sets, and allowing them to down load these so that they can be searched, ordered and manipulated will be the most useful approach.

5.2. Checklist compilation for outstanding taxa: Over the next seven years, at least 25,000 species to be added to the national list, using the literature.

5.3. Updates to existing lists to be done at least twice per annum, either through input by taxonomists who take responsibility for a particular taxon, or through SANBI staff member using electronic version of Zoological Record and other web-based resources.

5.4. Checklists to be provided to the Catalogue of Life, The Encyclopedia of Life and GBIF at least on an annual basis.

SO 6. Co-ordination and dissemination of existing fundamental biodiversity information for priority taxa

Globally a major complaint by users of fundamental information is the lack of access to existing basic knowledge. While there is a large amount of information available on the internet, this is scattered across hundreds of different websites that use different formats and access models, and which are not easy to find. Ideally all animal species should have a web page as per the EoL species pages, where information, including relevant reference and literature (through the Biodiversity Heritage Library) is co-ordinated, links are provided to relevant websites, and information is continuously added as new knowledge is generated. This is not only important from a user perspective, but also ensures that knowledge generation is incremental, rather than each new researcher having to find all the existing knowledge in scattered publications, which is not an efficient approach and which does lead to duplication of effort. This is also a useful mechanism for collecting and disseminating indigenous knowledge about animal species. Given the large number of animal species, prioritisation of species to develop pages for is required.

Categories of species for which information is most commonly required, based on the Encyclopedia of Life hotlist, on the GTI and on GEOBON are as follows:

- **Threatened and endangered species**. The official IUCN Red List, as well as species included on the revised South African Threatened and Protected Species (TOPS) list (this overlaps to some extent with the list in 2).

- **Harvested species**, including fish, wildlife, marine invertebrates.
- **Alien invasive species**.
- **Insect pest species of crops**.
- **Insect vectors of human and livestock diseases**.
- **Biocontrol species**.
- **Animals commonly encountered in gardens and households**.
- **Venomous species**.

Obviously species pages for any other animals that can be contributed should be included, but the list above serves as a target for the next seven years.

As revisions or taxonomic research are carried out in South Africa basic species information for each species revised or described should be contributed. Where species pages exist already (eg. in EoL), and new knowledge is generated, this should be co-ordinated on one species page.

Activities:

6.1. Establish a standard format and data headings for species pages, and identify mechanism for co-ordination and dissemination of these, either through a South African website, or through EoL, but with the ability to extract species of relevance for South Africa. An MoU between SANBI and EoL has already been signed and the relationship needs to be developed further. A strategy for the SA EoL has been developed and provided to EoL, and is currently being implemented.

6.2. Present a workshop for taxonomists and citizen scientists on the use of the format / software to enable the contribution of a wide range of the community.

6.3. Compile lists of species for which pages are required as a priority and make these accessible on the website.

6.4. Initiate compilation of pages, and disseminate these as soon as they have been compiled through a website.

6.5. Develop a process for submission of additional information, and for review and comments to continually improve the quality of information disseminated.

SO 7. To initiate discussions on the recommendations made in the NRF report on the status of biodiversity collections in South Africa.

The decline in funding, capacity, a research culture and morale at South African natural science museums and collections was noted in the NRF report. The GTI objectives include the recognition of collections and support for these by governments because collections are essential infrastructure for taxonomic and other research. Ideally this strategy should make recommendations to address the problems highlighted in the report, but the challenges are complex and not quickly or easily addressed.

The main objective for the collections should be to bring them into the national system of science and innovation and to fully unlock their potential to address questions of relevance to society. If this is not done, then the collections will continue to be perceived as curiosities of little value beyond a small and decreasing number of taxonomists. Government is only likely to invest in the collections and research on them if there is a fundamental change in this perception.

Actions that need to be carried out are:

7.1. To hold multilateral discussions between relevant government departments to initiate a solution to the existing governance challenge. The report recognised that the current governance system, where the natural science collections in museums fall under the national or provincial departments responsible for arts and culture means that they are not a priority or even in the mandate of their governing structures.

The Biodiversity Act[22] states that SANBI may '*establish, manage, control and maintain … collections of dead animals that may exist*' but the feasibility of SANBI undertaking this task has not been discussed in depth. NEMBA will be reviewed in the next few years and there needs to be a strong recommendation put forward for what is required to achieve the mandate and to improve the situation at the museums.

7.2. The second critical action required to improve and fully engage with the collections relates to the use of these for addressing questions of relevance to society. If the collections are seen to be useful only to taxonomists then it is unlikely that government will be willing to invest in them to the required extent. Collections do have the potential to be used in answering a wide range of questions relating to climate change, sustainable use of resources and human health and well-being. The research strategy and approach to research proposed here and in the DST programme as well as the co-ordination and dissemination of information and data will require the use of specimens in collections and the participation of researchers in the institutions and this will be a mechanism for promoting the value of the collections. The collection institutions do have to ensure that they have an open access policy for providing data to other users. If accessing data is a bureaucratic process or impossible, the value of the collections and institutions is diminished. Monitoring the use of data, and requests for acknowledgement of the institution by users are valuable mechanisms for motivating for the investment in these resources.

Museums / collection institutions should also be playing a major role in the vouchering of barcoded specimens, and in providing material for barcoding.

7.3. In addition to these major recommendations, and in the light of declining resources, museum staff and managers need to ensure that, as a priority, the loss of collections is minimized. Strong plans that prioritise activities that are essential to securing the collections, that allocate staff to these activities with targets and deadlines linked to individual workplans, and an assessment of workloads across the institution, and reallocation of responsibilities to ensure a fair spread to achieve the main targets are critical at this point but do seem to be lacking at several institutions.

SO 8. To explore mechanisms for enabling access to collecting permits so that this is not a major impediment to the exploration of animal diversity in South Africa.

The regulating environment for the collection of biodiversity in South Africa is highly fragmented and extremely complex. A workshop funded by SABI and facilitated by SANBI was held in 2008 where problems and possible solutions from both permitting authorities and researchers were discussed. A smaller follow up workshop in 2009 identified potential mechanisms for facilitating permitting for *bona fide* researchers.

SANBI has employed a Permitting Officer although the bulk of her work at this stage is focused on SANBI permit applications. The following activities have been initiated, and need further action over the next seven years:

8.1. Establishment of a list of *bona fide* researchers which is accessible on the internet, and the promotion of this amongst conservation authorities to assist with decision-making regarding the issuing of permits. SANBI has convened a panel which will vet the applications from researchers to be included on the list, and some applications have been received. The taxonomic community can support this initiative by submitting applications to be included on the list, and by adhering to regulations and restrictions of conservation authorities, as well as by submitting reports and data as requested by the authorities when permits have been issued. The frustrations of accessing permits are well known, but the permitting authorities have valid complaints about researchers who break the law and who never submit reports, and this leads to a negative perception of researchers by the authorities.

8.2. Promotion of the need to streamline the permitting process to enable the exploration of South Africa's biodiversity, amongst conservation authorities and the Department of Environmental Affairs. SANBI has made contact with most of the permitting authorities and the national department and interacts with them on a fairly regular basis. This relationship needs to be taken further to identify any mechanisms that could be used to address the very complex and time-consuming requirements for obtaining a permit.

D. Way forward: Implementation of the strategy

i. Once finalised the strategy will need to be translated into an **implementation plan** that assigns responsibility and identifies resource requirements as well as targets for the different activities.

ii. Once implementation has been initiated, progress against the targets will need to be **monitored and remedial action initiated where necessary**.

iii. The strategy will need to be **reviewed and revised** at the end of the seven year period (2020).

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Appendix 1. Diversity of animals in South Africa (from various sources). Those rows in red indicate taxa for which no checklist has been compiled, those in green where the list, or part of the list is currently being compiled, and black is where the list has been completed. Data taken from Griffiths et al. (2010)[30] for marine taxa, from the Water Research Commission series on freshwater invertebrates for freshwater organisms, and from a range of sources including data compiled by Adie (2004) for the SABI State of the Nature study, Scholtz & Holm (1985)[31] and completed checklists.

PHYLUM	CLASS	SUBCLASS	ORDER	COMMON NAME	Global number of species	SA number	Main habitat/s
ACANTHOCEPHALA				Spiny-headed worms	1150	17	marine
ANNELIDA	Clitellata	Hirudinea		Leeches	800	50	freshwater
ANNELIDA	Clitellata	Oligochaeta	Haplotaxida	Earthworms, freshwater worms	7,684	300	terrestrial, freshwater
ANNELIDA	Polychaeta			fanworms, bristleworms	8,432	760	marine; 6 species freshwater
ARTHROPODA	Arachnida	Acari	Astigmata, Mesostigmata, Prostigmata, Oribatida	Mites	48,000	3075	terrestrial, freshwater
ARTHROPODA	Arachnida	Acari	Ixodida	Ticks	900	860	terrestrial, parasitic

[30] Griffiths , C.L., Robinson, T.B., Lange, L. & Meade, A. 2010. Marine Biodiversity in South Africa: An Evaluation of Current States of Knowledge. PLoS ONE 5(8): e12008. doi:10.1371/journal.pone.0012008
[31] Scholtz, C. & Holm, E. 1985. *Insects of southern Africa*. Butterworths, 502pp.

ARTHROPODA	Arachnida		Amblypygi	Tailess whipscoprions	136	3	terrestrial
ARTHROPODA	Arachnida		Araneae	Spiders	40,700	2088	terrestrial
ARTHROPODA	Arachnida		Opiliones	Harvestmen	6,400	179	terrestrial
ARTHROPODA	Arachnida		Palpigradi		80	1	terrestrial
ARTHROPODA	Arachnida		Pseudoscorpiones	False scorpions	3,300	135	terrestrial
ARTHROPODA	Arachnida		Schizomida	Short-tailed whipscorpion	230	1	terrestrial
ARTHROPODA	Arachnida		Scorpiones	Scorpions	1,764	145	terrestrial
ARTHROPODA	Arachnida		Solifugae	Sun spiders	1,095	143	terrestrial
ARTHROPODA	Branchiopoda		Anostraca	Fairy shrimp	300	50	freshwater
ARTHROPODA	Branchiopoda		Conchostraca	Clam shrimp	224	12	freshwater
ARTHROPODA	Branchiopoda		Cladocera	Water fleas	620	55	50 freshwater, 5 marine
ARTHROPODA	Branchiopoda		Notostraca	Tadpole shrimp	11	3	freshwater
ARTHROPODA	Chilopoda			Centipedes	3,149	141	terrestrial
ARTHROPODA	Diplopoda			Millipedes	12,000	462	terrestrial
ARTHROPODA	Entognatha		Collembola	Spring tails	7,500	160	terrestrial
ARTHROPODA	Entognatha		Diplura		800	35	terrestrial
ARTHROPODA	Insecta		Arachaeognatha	Hump-backed bristletails	470	18	terrestrial
ARTHROPODA	Insecta		Blattodea	Cockroaches	3,68-4,000	108	terrestrial
ARTHROPODA	Insecta		Coleoptera	Beetles	360,000 - 400,000	17,427	terrestrial/freshwater
ARTHROPODA	Insecta		Dermaptera	Earwigs	1,816	58	terrestrial
ARTHROPODA	Insecta		Diptera	Flies	152,956	5,883	terrestrial/freshwater
ARTHROPODA	Insecta		Embioptera	Web spinners	200-300	15	terrestrial
ARTHROPODA	Insecta		Ephemeroptera	May flies	2,500-3,000	99	terrestrial / freshwater
ARTHROPODA	Insecta		Notoptera	rockcrawlers, heelwalkers	37	5	terrestrial

ARTHROPODA	Insecta		Hemiptera	Bugs	80,000-88,000	4,829	terrestrial/freshwater
ARTHROPODA	Insecta		Hymenoptera	Bees, wasps, ants	115,000	5,273	terrestrial
ARTHROPODA	Insecta		Isoptera	Termites	2,600-2,800	122	terrestrial
ARTHROPODA	Insecta		Lepidoptera	Butterflies and moths	174,250	6,783	terrestrial
ARTHROPODA	Insecta		Mantodea	Mantids	2,200	131	terrestrial
ARTHROPODA	Insecta		Mecoptera	Hanging flies	481	21	terrestrial
ARTHROPODA	Insecta		Megaloptera	Alderflies	250-300	7	terrestrial
ARTHROPODA	Insecta		Neuroptera	Lacewings	5,000	350	terrestrial
ARTHROPODA	Insecta		Odonata	Damselflies and dragonflies	6,500	207	terrestrial / freshwater
ARTHROPODA	Insecta		Orthoptera	Grasshoppers	24,380	765	terrestrial
ARTHROPODA	Insecta		Phasmida	Stick insects	2,500-3,300	32	terrestrial
ARTHROPODA	Insecta		Phthiraptera	Lice	3,000-3,200	1,044	terrestrial parasites
ARTHROPODA	Insecta		Plecoptera	Stone flies	2,274	39	terrestrial / freshwater
ARTHROPODA	Insecta		Psocoptera	Book lice	3,200-3,500	79	terrestrial
ARTHROPODA	Insecta		Siphonaptera	Fleas	2,525	89	terrestrial parasites
ARTHROPODA	Insecta		Strepsiptera	Twisted-winged parasites	596	11	terrestrial parasites
ARTHROPODA	Insecta		Thysanoptera	Thrips	6,000	228	terrestrial
ARTHROPODA	Insecta		Tricoptera	Caddisflies	12,627	222	terrestrial / freshwater
ARTHROPODA	Insecta		Zygentoma (Thysanura)	Silverfish	370	48	terrestrial
ARTHROPODA	Malacostraca		Amphipoda		7,000	454	terrestrial, freshwater, marine
ARTHROPODA	Malacostraca		Bathynellacea		150	5	terrestrial, freshwater, marine

ARTHROPODA	Malacostraca		Cumacea		1,593	98	marine
ARTHROPODA	Malacostraca		Decapoda		18,000	750	freshwater, marine
ARTHROPODA	Malacostraca		Euphausiacea		90	49	marine
ARTHROPODA	Malacostraca		Isopoda		9,000-11,000	290	13 freshwater, 277 marine species
ARTHROPODA	Malacostraca		Leptostraca		41	4	marine
ARTHROPODA	Malacostraca		Mysida		1,106	58	marine
ARTHROPODA	Malacostraca		Speleogriphacea		3	1	freshwater
ARTHROPODA	Malacostraca		Stomatopoda	Mantis shrimp	859	35	marine
ARTHROPODA	Malacostraca		Tanaidacea		1,098	19	marine, freshwater, estuarine
ARTHROPODA	Maxillopoda	Branchiura	Arguloida	Fish lice	173	4	marine
ARTHROPODA	Maxillopoda	Copepoda		Copepods	2,000	429	freshwater, marine
ARTHROPODA	Maxillopoda	Mystacocarida			12	3	marine
ARTHROPODA	Maxillopoda	Pentastomida			130	6	aquatic parasites
ARTHROPODA	Maxillopoda	Thecostraca		Barnacles	38	69	marine
ARTHROPODA	Ostracoda			Seed shrimp	13,000	165	45 marine, 120 freshwater
ARTHROPODA	Pauropoda				715	2	terrestrial
ARTHROPODA	Pycnogonida			Sea spiders	1,340	101	marine
ARTHROPODA	Symphyla				208	2	terrestrial
BRACHIOPODA				Lamp shells	550	31	marine
BRYOZOA				Moss animals	5,700	270	marine
CEPHALORHNCHA	Priapulida			Penis worms	20	1	marine
CHAETOGNATHA				Arrow worms	121	28	marine
CHORDATA	Actinopterygii			Ray-finned fishes	30,383	2,200	freshwater, marine
CHORDATA	Amphibia			Frogs	6,515	123	freshwater
CHORDATA	Appendicularia / Thaliacea			Larvaceans and thaliaceans	81	80	marine

CHORDATA	Ascideacea			Sea squirts	2,300	176	marine
CHORDATA	Aves			Birds	9990	854	terrestrial
CHORDATA	Cephaloochorda ta			Lancets / amphioxus	33	1	marine
CHORDATA	Chondrichthyes			Sharks, skates, rays, chimaeras	1176	188	marine
CHORDATA	Mammalia			Mammals	5487	307	marine, terrestrial
CHORDATA	Myxini		Myxiniformes	Hagfish	77	4	marine
CHORDATA	Reptilia			Reptiles	8734	381	marine, terrestrial, freshwater
CHORDATA	Sarcopterigii			Lobe-finned fishes	8	3	marine, freshwater
CNIDARIA	Anthozoa			Corals, anemones	7,500	457	marine
CNIDARIA	Cubozoa			Box jelly fish	36	2	marine
CNIDARIA	Hydrozoa			Hyrdrozoans	3500	457	marine
CNIDARIA	Scyphozoa			Jelly fish	175	10	marine, freshwater
CTENOPHORA				Comb jellies	166	11	marine
ECHINODERMATA	Asteroidea			Star fish	1,859	91	marine
ECHINODERMATA	Crinoidea			Sea lilies	635	19	marine
ECHINODERMATA	Echinoidea			Sea urchins, pansy shells	940	59	marine
ECHINODERMATA	Holothuroidea			Sea cucumbers	1,430	122	marine
ECHINODERMATA	Ophiuroidea			Brittle stars	2,139	119	marine
ECHIURA				Spoon worms	176	21	marine
ENTOPROCTA				Kamptozoans	170	6	marine
GASTROTRICHA				Gastrotrichs	400	3	freshwater, marine, estuarine
HEMICHORDATA				Acorn worms and graptolites	108	11	marine
MOLLUSCA	Aplacophora				400	2	marine
MOLLUSCA	Bivalvia			Bivalves	9,200	650	freshwater,

							marine
MOLLUSCA	Cephalopoda			Octopus, squid, cuttlefish	800	195	marine
MOLLUSCA	Gastropoda			Gastropods	60,000	2262	2262 marine, 53 freshwater, 450 terrestrial
MOLLUSCA	Polyplacophora			Chitons	650	29	marine
MOLLUSCA	Scaphopoda			Tusk shells	350	16	marine
MYXOZOA					1300	6	freshwater, marine parasites
NEMATODA				Round worms	>28,000	1055	freshwater, marine, terrestrial, parasitic
NENATOMORPHA				Horsehair worms	331	unknow n	freshwater, parasitic
NEMERTEA				Ribbon worms	1,200	17	
ONYCHOPHORA				Velvet worms	165	10	terrestrial
PHORONIDA				Phoronorids	10	2	marine
PLATYHELMINTHES	Cestoda			Tape worms	5,000	83	parasites
PLATYHELMINTHES	Monogenea				2000	49	
PLATYHELMINTHES	Trematoda			Flukes	9,000	72	parasites
PLATYHELMINTHES	Turbellaria			Flat worms	4,500	42	marine, freshwwate r, terrestrial
PORIFERA				Sponges	6,000	346	freshwater, marine
ROTIFERA				Rotifers / wheel animals	2,180	34	34 freshwater, 0 marine
SIPUNCULA				Peanut Worms	144	47	marine
TARDIGRADA				Water bears	1,045	38	freshwater

Total=65,571 species