South African National Survey of Arachnida (SANSA): review of current knowledge, constraints and future needs for documenting spider diversity (Arachnida: Araneae)

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Biodiversity is one of the most important concepts in contemporary biology, with a broad range of applications. In November 1995, South Africa ratified the Convention on Biological Diversity (CBD). Signatories are obligated to develop a strategic plan for the conservation and sustainable use of biodiversity. To meet the requirements of the CBD, the South African National Survey of Arachnida (SANSA) was initiated in 1997. This national project has several aims: to document and describe the arachnid fauna of South Africa; to consolidate all the available data on South African arachnids into one relational database and to make this biodiversity information available to science; and to address issues concerning their conservation and sustainable use. Extensive sampling took place and the SANSA database contains a wealth of biodiversity data that are used to provide answers to ecological questions. Presently 71 spider families, 471 genera and 2170 species are known from South Africa, representing approximately 4.8% of the world fauna. This paper presents the current state of spider biodiversity information and how it is managed. It demonstrates the importance of running a national inventory; emphasises the significance of using a good database application; and the importance of capacity development to improve the quality and integration of biodiversity information. Further, it shows the role SANSA has played in unifying and strengthening arachnid research, with the major thrust to discover the spider diversity in South Africa. We discuss the present status of knowledge, constraints to improving this, and the future directions for research. SANSA has provided the foundations for a more integrative approach to spider diversity research. Future research should build on this legacy by linking taxonomic diversity with that of functional diversity, predicting the response of this diversity to global change drivers. Functional approaches will link these studies to ecosystem processes. Global collaborative studies at several sites following standardised sampling protocols and focused research questions would add value to the SANSA collection and the importance of spiders for the health of ecosystems.

Keywords: **agro-ecosystems; biodiversity informatics; biomes; national lists; protected areas; provinces; urban areas; virtual museum**

INTRODUCTION

At a global scale, the signatories to the Convention on Biological Diversity (CBD) had failed to significantly reduce biodiversity loss by 2010 (Convention on Biological Diversity, 2006; Butchart *et al.*, 2010). The 20 Aichi Biodiversity Targets represent a new set of goals for the year 2020 (http://www.cbd.int/sp/) (Adenle, 2012). The majority of the goals refer to diversity that has not yet been inventoried or described. South Africa ratified the CBD and in meeting these goals the country will have to: (1) discover, describe and inventory species; (2) analyse and synthesise information into predictive classification systems; and (3) organise this information into an efficiently retrievable form that best meets the needs of science, conservation and society.

Natural history collections with their primary data provide extremely valuable biodiversity information to science and society (Smith *et al.*, 2003; Robertson *et al.*, 2010; Scoble, 2010), and the vast majority of information about South African biodiversity originates from the country's natural history collections (Drinkrow *et al.*, 1994; Hamer, 2012). Specimens in natural history collections play a vital role in the CBD goals, i.e. to discover and make an inventory of a group, and to database the primary data to be able to manage the information and make it available in an efficiently retrievable form. To help document and have access to these primary data, the Global Biodiversity Information Facility (GBIF) was established by governments in 2001 to encourage free and open access to biodiversity data via the Internet; the South African node of GBIF is referred to as SABIF (South African Biodiversity Information Facility). Through a global network of 57 countries and 47 organisations, GBIF promotes and facilitates the mobilisation, access, discovery and use of information about the occurrence of organisms over time and across the planet. In January 2011, the digital records of approximately 26% of vouchered specimens in South African zoological collections could be queried through the SABIF Data Portal or the GBIF Data Portal (Coetzer *et al.*, 2012). The scientific community needs the biodiversity information held by South Africa's natural history collections for important national and provincial biodiversity projects, such as the National Spatial Biodiversity Assessment (Reyers & McGeoch, 2007) or provincial State of Biodiversity reports (Turner, 2012).

Invertebrates constitute more than 80% of all animal diversity, yet they are under-represented in studies of southern African diversity (McGeoch *et al.*, 2011). Determining invertebrate diversity is particularly challenging because: (1) a large proportion of species are small and can only be identified under a microscope; (2) there is a high proportion of undescribed species; (3) the determination of species names is time consuming and, in taxa whose taxonomy is poorly known, it may not be possible; (4) species determinations are costly as they can only be done by specialists; (5) many species distributions are still poorly known; (6) professional taxonomists are few; (7) sampling methods and protocols are not standardised; and (8) knowledge of responses to environmental change is generalised and limited.

To document and conserve the biodiversity of a group, correct identification and species distribution data are of central importance (Bengtsson *et al.*, 1997). The newly emerged field of conservation biogeography is concerned with the distributional dynamics of species and how they relate to the conservation of biodiversity (Robertson *et al.*, 2010). With any invertebrate group, e.g. spiders, a species list arranged according to an accepted classification system provides an essential framework for this research.

For nearly two decades, the arachnologists of South Africa have cooperated on a national level following the initiation of the South African National Survey of Arachnida (SANSA). In this paper, we discuss the important role this national survey has played in unifying and strengthening arachnid research in South Africa. We discuss the taxonomic impediment, one of the biggest constraining issues for SANSA, as accurate species determinations are central to the documentation of arachnid diversity. SANSA's proposed mechanisms to deal with the unresolved taxonomy of many of the larger spider families in Africa are discussed. Biodiversity inventorying and monitoring involves scientists, their students and the public (Podjed & Muršič, 2008) in a process of collection data management, data consolidation into a relational database, and the development of taxonomic aids through biodiversity informatics, capacity building and infrastructure.

One of the aims of such a national survey is to manage the data so that it provides biodiversity information that best meets the needs of science and society. We review the present status and constraints of biodiversity and ecological knowledge of spiders in South Africa. The last decade has seen an exponential growth in the knowledge of the group in South Africa, and a summary of the patterns observed, mechanisms identified, constraints and potential directions for future research is provided.

SOUTH AFRICAN NATIONAL SURVEY OF ARACHNIDA (SANSA)

The South African National Survey of Arachnida (SANSA) was launched in 1997 in accordance with the country's obligations to the CBD (Dippenaar-Schoeman & Haddad, 2006; Foord *et al.*, 2011a). SANSA is an umbrella project implemented at a national level in collaboration with researchers and institutions countrywide, dedicated to document and unify information on arachnids in South Africa. SANSA's aims are to: (1) discover, describe and make an inventory of the arachnid fauna of South Africa; (2) organise all available information in a relational database and to make the data available to science and society; (3) use this information to address sustainable use of arachnids and to undertake conservation planning; (4) develop products that meet the needs of the community; (5) create awareness through education, training and online bio-informatics; and (6) build capacity and infrastructure to unify and strengthen biodiversity research on spiders and other South African arachnids.

SANSA is managed by the Arachnida Unit at the National Collection of Arachnida (NCA) at the Plant Protection Research Institute (PPRI), Agricultural Research Council (ARC) in Pretoria (Figure 1), with support from the University of the Free State. The activities of SANSA have run over three periods:

***SANSA I (1997–2005)*:** the national project was established and several participants from the universities of the Free State, Limpopo, Pretoria and Venda were included, as well as several museums and nature conservation agencies. A relational database was developed at the ARC to capture all the primary data available at that stage in the NCA (Dippenaar-Schoeman & Craemer, 2000). During this period, all available published literature on South African spiders was gathered and species information was added to the database, to aid identification of specimens and generate distributional data for described species.

***SANSA II (2006–2010)*:** the South African National Biodiversity Institute (SANBI) joined the project through their Threatened Species Programme in 2006. SANSA II saw the integration of a series of *ad hoc* projects into targeted surveys in degree squares throughout South Africa (Dippenaar-Schoeman, 2011; Foord *et al.*, 2011a). All the data were collated into the database, including all published records on species housed in collections both locally and abroad (including both taxonomic and ecological data), to determine the spatial coverage of the species, and to determine where the "gaps" in these data lie for planning future surveys. A rarity index was calculated for each species based on their currently known occurrence (level of endemicity) and an estimate of population size (Foord *et al.*, 2011b). This data formed the basis of the First Atlas of the Spiders of South Africa, hereafter referred to as FASSA (Dippenaar-Schoeman *et al.*, 2010).

***SANSA III (2011–present)*:** the biodiversity data generated in FASSA was analysed to determine where more sampling is needed in the country. Ongoing surveys, continued accessioning at the NCA, as well as specimen identifications have contributed to a constant increase of species records in FASSA (Dippenaar-Schoeman *et al.*, 2010). With the wealth of data at hand, review papers are now available on spiders in caves

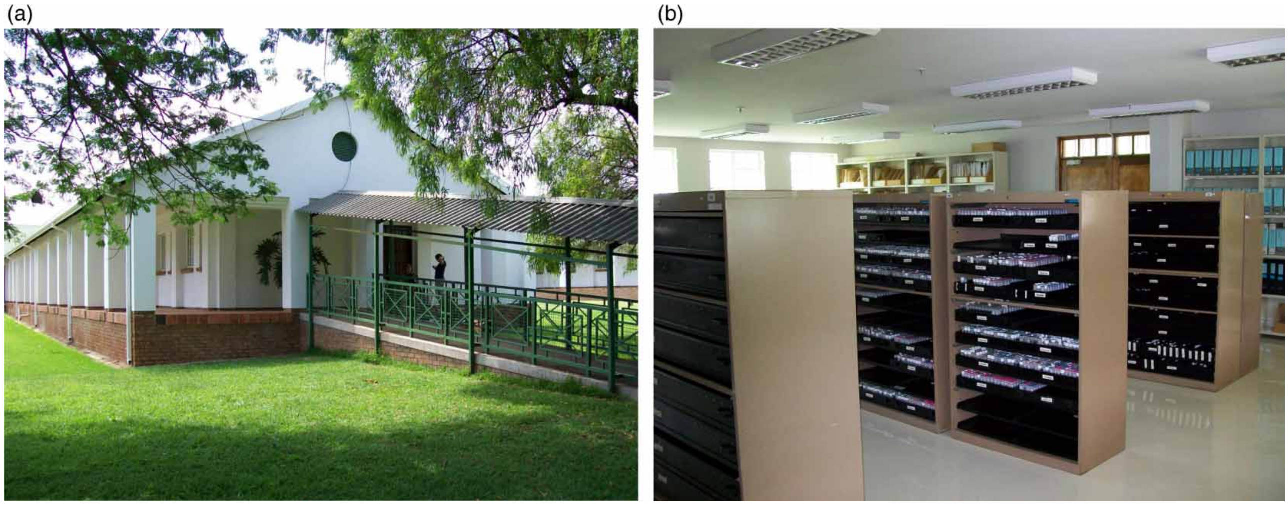

Figure 1. The National Collection of Arachnida: (a) the Biosystematics building at the Agricultural Research Council Roodeplaat campus; (b) the cabinets housing the specimens in the National Collection of Arachnida.

(Dippenaar-Schoeman & Myburgh, 2009), agro-ecosystems (Dippenaar-Schoeman *et al.*, 2013a), the Savanna Biome (Foord *et al.*, 2011b) and the Grassland Biome (Haddad *et al.*, 2013).

DATA CONSOLIDATION

In addition to valuable voucher specimens, natural history collections contain historical records of the diversity and distribution of species, providing a basis for identifying species in danger of extinction and monitoring temporal changes in distribution (Wheeler *et al.*, 2012). However, contemporary collections house less than 15% of the organisms estimated to be on earth (Scheffers *et al.*, 2012), and within a rapidly changing world, surveying and addition of new specimens remains a priority. Collections should not only be preserved, but the information associated with the specimens must be managed to provide accurate and current biodiversity information in a useable format (Coetzer *et al.*, 2012). The primary data associated with the specimens contains valuable information on their distribution and general habitat. The first red listing of spiders in South Africa is presently underway. The SANSA relational database provides the framework for the first IUCN red listing exercise. The CBD and GBIF have demonstrated the importance of good biodiversity data, and have contributed to a renewed interest in specimen databases of natural history collections (Yesson *et al.*, 2007; Faith *et al.*, 2013).

The digitisation of arachnid specimen data in the NCA began in 1991. A relational database was developed at the ARC for the collected specimens (NCAD) and includes fields for species names, specimen information and literature references. In 2000, the data was migrated to a Microsoft Access relational database. The second phase of SANSA, which started in 2006, saw the consolidation of all other existing arachnid data into a MySQL relational database with a browser front-end, enabling multiple users to gain access to the database simultaneously. It was standardised according to the standards required by the Darwin Core for sharing information on biodiversity (Wieczorek *et al.*, 2012). The spider taxonomic classification system follows the online World Spider Catalog (2014), and taxonomic updates are regularly implemented. This data migration exercise provided an opportunity for extensive data cleaning, geo-referencing, and to develop procedures and support for data validation. It is a complex database scheme especially developed for the NCA, and two of the modules can be browsed online (Dippenaar-Schoeman *et al.*, 2012). Forms and reports were customised to meet all the requirements for arachnid research, such as user-friendly drop-down boxes to select family, genus and species, and the opportunity to add morphological data as well as photographs, maps and other images. The database presently used for SANSA data consists of the following modules:

***African Arachnida Database (AFRAD)*:** This is a taxon-based database module that includes information on all the species of spiders recorded from the Afrotropical Region (>6000 spp.), including data on their morphology, behaviour and distribution, images of morphological characters (e.g. genitalia), and distribution maps and identification keys. This information can be continually updated for each family, genus and species as resources are made available. Resources for many families and species are available online and can be printed as fact sheets from http://www.arc.agric.za/arc-ppri/Pages/AFRAD/AFRAD-Homepage.aspx (Dippenaar-Schoeman *et al.*, 2012). This data was extensively used in a book chapter on spider diversity in Africa (Jocqué *et al.*, 2013).

***National Collection of Arachnida Database (NCAD)*:** This module captures the primary data associated with collected specimens that have been deposited in the NCA. Currently more than 200 000 specimens from 61 000 accessions are included in the database. An annual growth of between 5000 and 6000 new accessions has been maintained over the last six years. During the period 2006–2010, SABIF provided funding for databasing, which enabled all the data from the NCAD to be made available through the SABIF website. Recently, new entry fields have been added to incorporate information on DNA sampling, including CO1 and other sequence data. A checklist of the types housed in the NCA is now available online at the ARC Website (Marais *et al.*, 2013). Since the initiation of SANSA in 1997, >160 holotypes have been added to the NCA type collection.

***South African National Survey Database (SANSAD)*:** In 2006, a module was created that was linked to AFRAD. It integrates published data on South African spiders gathered from the taxonomic and ecological literature, including records housed in more than 17 institutions worldwide. As most of the natural history collections in South Africa do not have professional arachnologists as curators, it was decided to include only records extracted from published data, as the certainty or accuracy of identifications could not be reliably assessed for unpublished data. The SANSAD dataset presently contains 17 651 records representing 2170 spider species.

***Virtual Museum (VM)*:** A virtual museum was developed as part of the SANSA awareness project in 2006 to house the large number of photographs received from the public and scientists requesting identifications. Submitted photographs are made accessible through a VM database linked to the SANSA taxon database. It can be viewed at http://www.arc.agric.za:8080/. Presently it contains 3086 entries represented by >8000 photographs from 478 localities throughout South Africa. Many of the photographs submitted for the VM cannot be identified from a photo alone. Photographers are therefore requested to provide us with the collected specimen, where possible. This has increased the proportion of species-level identifications, and presently we have records of >700 species in the VM. The VM serves as an important source for new distribution records, behavioural observations (e.g. Dippenaar-Schoeman & Haddad, 2011; Kelly & Dippenaar-Schoeman, 2014), and information on the colour of live specimens for taxonomic descriptions (e.g. Van Niekerk & Dippenaar-Schoeman, 2013). Photo submissions have also been used extensively to illustrate several recently published books (Dippenaar-Schoeman & Van den Berg, 2010; Holm & Dippenaar-Schoeman, 2010; Dippenaar-Schoeman *et al.*, 2013b; Dippenaar-Schoeman, 2014a; Dippenaar-Schoeman & Haddad, 2014), fact sheets, newsletters and the SANSA website. These images also play an important role in training, as they are used in the AFRAD online database from which fact sheets on the families, genera and species can be printed (Dippenaar-Schoeman *et al.*, 2012).

SANSA FIELD SURVEYS

Biodiversity inventories are essential to identify key areas for conservation and to monitor the effects of threats, and are considered good investments by conservationists (Balmford & Gaston, 1999). Data in the SANSA database was used to undertake a GIS-based gap analysis in 2007. The focused SANSA field surveys employed a standardised protocol using seven different methods (Dippenaar-Schoeman & Haddad, 2008; Haddad & Dippenaar-Schoeman, 2015) that was used to collect poorly sampled degree-square grids. Limited manpower and subsequent identification of material restricted the number of degree-square grids that could be sampled. More than 40 degree squares were sampled, mainly in the Savanna and Grassland Biomes, although isolated grids were also sampled in the other biomes. This effort has provided valuable material, improving our knowledge of the distribution of species and providing a wealth of specimens for taxonomic studies.

A large number of specimens were received from other surveys. Standard collecting methods were followed, and the methods used depend on the ecological questions asked and habitat sampled (Eardley & Dippenaar, 1996). With a few exceptions, pittraps is often the default sampling method for spiders in research projects. A large proportion of the ground-dwellers were collected by pitfall trapping, leaf litter sifting, or active searching at the base of grass tussocks and under rocks. Plant-dwelling species were collected by beating, sweeping, canopy fogging (occasionally), or actively searching on vegetation, bark and flowers (Figure 2). By-catch samples received from students and other researchers included specimens collected by canopy fogging, D-Vac, pitfalls, Malaise, reptile and blue tsetse fly traps, and yellow, blue and white pan traps. Additional data was also obtained from the Spider Club of Southern Africa (SCSA) and public participation. In several protected areas, reserve managers made important contributions by collecting specimens, e.g. Swartberg Nature Reserve (Dippenaar-Schoeman *et al.*, 2005b).

Voucher specimens from these surveys are deposited in the NCA, National Museum in Bloemfontein (NMBA), Ditsong National Museum of Natural History in Pretoria (TMSA) and the KwaZulu-Natal Museum (NMSA). Despite the extensive sampling, large areas in South Africa are still underrepresented in the database, particularly the more arid western parts of the country. This can largely be attributed to logistical challenges and the restricted distribution of human resources and time necessary to sample these areas properly.

SPECIMEN IDENTIFICATION

One of the biggest constraints for SANSA is the lack of good taxonomic revisions for many of the larger spider families in Africa, with particular reference to the Agelenidae, Araneidae, Linyphiidae, Lycosidae and Theridiidae. The taxonomic descriptions of South African spiders reached a peak during the late 1800s and early 1900s, when more than 730 species were described. Unfortunately, most of these descriptions are inadequate, lacking any drawings, and most type specimens are housed in overseas museums.

Most taxonomic research in South Africa was undertaken during the period from 1820 to 1960, focusing largely on the fauna of the coastal provinces, as most of the practising arachnologists were stationed in cities there. From 1960 to 1980 there was a considerable decline in the description of new species. However, during the last three decades there has been a resurgence; more than 500 species have been described since 1980, mainly due to modern taxonomic revisions, the development of several South African taxonomists and the efforts of overseas taxonomists.

In part, the increase in taxonomic study of the fauna since 1997 can be attributed to SANSA. This project has attracted large numbers of students and amateur collectors that have complimented the sampling efforts of professional arachnologists, providing material from many poorly sampled parts of the country. International networking and collaboration has also drawn attention to the poor state of knowledge of African spiders (Dippenaar-Schoeman & Jocqué, 1997), resulting in a renewed interest in discovering and describing the spiders of South Africa. Since the start of SANSA, 371 new species have been described and >300 species known from other parts of Africa have been newly reported from South Africa. A considerable number of taxonomic and biodiversity-related outputs came from the ARC, museums and universities in South Africa. Training of new taxonomists has resulted in the completion of eight MSc and three PhD studies since 1997. Two universities presently employ full-time arachnologists involved in ecological and taxonomic research, and student training in these fields. Globally, collaborative taxonomic research that aims to address relevant ecological, biogeographical and evolutionary questions might also pave the

Figure 2. SANSA collecting activities: (a) Robin Lyle organising the pittraps to sample soil arachnids at Ezemvelo Nature Reserve; (b) fogging trees at Lajuma to sample arachnids in the tree canopy; (c) Reginald Christiaan, a BIOTA intern, sampling plant-dwellers at Soebatsfontein; (d) SANBI para-ecologists sampling at the Makana Botanical Gardens, Grahamstown.

way for systematic reviews of spider families, for which limited expertise exists.

Aside from taxonomic literature, several resources are now available to facilitate the identification of South African spiders, including several textbooks (Dippenaar-Schoeman & Jocqué, 1997; Dippenaar-Schoeman, 2002b; Holm & Dippenaar-Schoeman, 2010), field guides (Dippenaar-Schoeman & Van den Berg, 2010; Dippenaar-Schoeman *et al*., 2013b; Dippenaar-Schoeman, 2014a; Dippenaar-Schoeman & Haddad, 2014), the *First Atlas of South African Spiders* (Dippenaar-Schoeman *et al*., 2010) and websites such as the SANSA Virtual Museum (www.arc.agric.za:8080) and the African Arachnid Database (www.arc.agric.za:8081). Workshops and training are also provided to para-taxonomists and the public.

SPIDER DIVERSITY DATA

Spider Atlas and spider diversity

The first version of FASSA was published in 2010 and the electronic version is available online from the ARC website at http://www.arc.agric.za/arc-ppri/Pages/Biosystematics/SANSA.aspx (Dippenaar-Schoeman *et al*., 2010). A total of 2003 species from 70 families were listed in FASSA. After the phylogenetic study by Ramirez (2014) the number of families now totals 73, and 167 species have been added to the fauna since FASSA, bringing the present total to 2170 species, representing 4.8% of the global fauna. Based on current knowledge, 1286 of these species are endemic (59.3%), 333 species are known throughout southern Africa, while 477 are widely distributed throughout Africa; 74 species have a cosmopolitan distribution. The high percentage of endemics will probably change as sampling in neighbouring countries increases. The most species rich families are Salticidae (343 spp.), followed by the Gnaphosidae (171 spp.) and Thomisidae (141 spp.). Two families, Chummidae and Penestomidae, are endemic to South Africa (including the enclave of Lesotho). During the last 14 years (2001–2014), 264 species have been added to the national list.

The data in FASSA included the following information for each species: georeferenced distribution data for each record from South Africa, arranged alphabetically by province and locality, indicating type locality; occurrence in each floral biome; number of records from protected areas and agro-ecosystems; known distribution in Africa, or beyond (cosmopolitan or introduced); conservation status, including an endemicity index and abundance index; and an indication of the species' taxonomic status. The georeferenced data was used to create a distribution map for each species. All the new data will be included in the second version of FASSA, which is now in preparation, with updated maps and images. Eventually we would be able to provide information on each species that can also feed into the Encyclopedia of Life.

National species list

Any biodiversity management project in a country is dependent on correct and regularly updated national species lists. At a symposium on the status of the diversity of the fauna in South Africa (Dippenaar-Schoeman, 2002a), the first counts for all the arachnid orders were made. Collation of all the known species data from published papers and national collections into the SANSA database enabled us to publish the first species lists for the Pseudoscorpiones (Dippenaar-Schoeman & Harvey, 2000), Solifugae (Dippenaar-Schoeman *et al.*, 2006; Dippenaar-Schoeman & González Reyes, 2006) and Opiliones (Lotz, 2009). A recent revision of the Phyrnychidae (Amblypygi) indicates that only three species of this order occur in South Africa (Prendini *et al.*, 2005). However, no comprehensive review papers have been published on any of these orders dealing with biological, biogeographical and ecological data yet, with the exception of Prendini (2005), who discussed patterns of scorpion diversity and distribution in southern Africa. For the first time ever, spider data were available for inclusion in the National Spatial Biodiversity Assessment (NSBA) in 2010. This assessment uses a range of species data (for threatened and endemic taxa) to identify species richness areas within South Africa.

SANBI co-ordinates the compilation of checklists of South African animals for dissemination through the Biodiversity Advisor. The lists, once compiled, will be regularly updated according to the taxonomic literature. These checklists are being incorporated into the SABIF and GBIF infrastructure/portals, as well as provided to the Encyclopedia of Life. National lists of all the arachnids were provided to SANBI on request for their database in 2013 (Dippenaar-Schoeman, 2013).

A new updated National spider species list is in preparation for publication (Dippenaar-Schoeman *et al.*, in prep.), which will include the guild, RI values and common name of each species. The common names provided will update the first list of common names published by Dippenaar-Schoeman & Van den Berg (1988).

Table 1. Endemicity index values calculated for each of the spider species.

Endemicity index	Distribution
6	endemic – known only from type locality/one locality only
5	known from one province only, wider than only the type locality
4	known from two adjoining provinces only
3	South Africa >two provinces or not adjoining
2	Southern Africa (south of Zambezi and Kunene Rivers)
1	Afrotropical region
0	Cosmopolitan

Conservation assessment

Protected species are organisms that are of such high conservation value or national importance that they require national protection. Species listed in this category will include, among others, species listed in terms of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Presently, all of the species of the baboon spider genera *Ceratogyrus*, *Harpactira* and *Pterinochilus* (Theraphosidae) are listed on the SANBI website (http://www.speciesstatus.sanbi.org) as protected species, as identified by the National Environmental Management: Biodiversity Act 10 of 2004 (NEMBA).

All the spiders of South Africa are presently being assessed for their conservation status using the World Conservation Union (IUCN) criteria for red-listing of species. This is done with the support of the SANBI Threatened Species Programme. Two workshops took place at the 11th African Arachnological Society colloquium in the Free State (January 2014) and at the National Botanical Gardens in Pretoria (13 July 2014).

Red Data assessments

As part of FASSA, data gathered for each species provided the basis for Red Data assessments. The conservation status of each species was based on a rarity index (RI), which is a combined metric based on an endemicity index (EI) and total population nationally. The EI (i.e. distribution of a species) included seven categories, ranging from known only from type locality (score of 6), to cosmopolitan or with a distribution beyond the borders of the Afrotropical Region (score of 0) (Table 1). This data was compiled based on currently known distribution data available from the literature, Spider World Catalogue, and information from the SANSA database and Virtual Museum. The total population nationally is an estimate of population size based on the number of collecting records, i.e. number of populations from point localities, known for each species in the SANSA database. It was divided into three categories: 1 – abundant, known from >10 localities; 2 – rare, known from between 4–10 localities, and 3 – very rare, only known from 3 or fewer localities. Although these latter categories are essentially crude estimates of population sizes, they do provide a relative estimate from which to work. Information on the taxonomic status for each species was also provided (1–3), indicating whether the species was revised since 1960 or the description had good illustrations (3), revised prior to 1960 (2), or known only from a poorly detailed original description prior to 1960 (1).

The RI was calculated based on the sum of the EI and AI values. Future sampling will inevitably lead to the discovery of additional populations of most of the South African species and result in a decrease in the RI values for many species. All the species with values of 0–3 will be considered "least concern", based on the wide distribution of these species throughout Africa, or beyond. A high percentage of species fall into this category. Species with an EI value of 6 might be listed as "data deficient" and will warrant additional collecting. As part of the FASSA, information is also available on, for example, whether the species has been sampled from protected areas or agroecosystems, providing additional data on their conservation status.

FOCUSED SAMPLING THRUSTS

Although spiders are sampled throughout the country, some SANSA sampling focused on specific areas as they concentrated on particular end users: (1) agro-ecosystems, to identify species that are important predators and potential biological control agents; (2) protected areas, to identify species that already receive some protection in South Africa; (3) floral biomes, to determine spider associations with specific habitats; (4) urban and suburban areas, to quantify the effects of urbanisation on spiders, to identify spiders that still occur in these disturbed areas, and to identify introduced (and possibly) invasive species, and (5) provincial diversity.

Agro-ecosystem diversity

As agro-ecosystems cover large parts of some provinces, the diversity of fauna found in these disturbed areas contributes towards our knowledge of the country's biodiversity. Agro-ecosystems are regarded by some researchers as an additional "biome" and provide interesting insights into the assembly of novel ecosystems in the Anthropocene. The diversity of spiders in crop systems and the role they play as predators have been the subject of several post-graduate studies (Coates, 1972; Dippenaar-Schoeman, 1976; Gaigher, 2008; Van den Berg, 1989; Haddad, 2003; Mellet, 2005; Midega, 2005).

A checklist of spiders found in agro-ecosystems, including plantations, was recently published based on data extracted from the NCA database (Dippenaar-Schoeman *et al*., 2013a). It provided information on species distribution patterns, but also the adaptability of species to the possible threat of agricultural disturbances when being evaluated for red listing. Thus far, 51 families represented by 238 genera and 413 species have been recorded from more than 30 crops in South Africa. Results show that certain spider species are more regularly sampled in crops and could be considered agrobionts. Several species frequently sampled in crops are introduced, such as the agrobiont linyphiid *Ostearius melanopygius* (O. P.-Cambridge).

The impact of crops on spider diversity varies, and comparative surveys show either no impact on species richness (Van der Merwe *et al*., 1996) through to a significant reduction. These reductions can be a consequence of tilling, orchard establishment and pesticide application in the case of orchards (Haddad *et al.*, 2008) or frequent mechanical disturbances in the case of annual crops (Botha *et al.*, 2014).

Cotton

Extensive sampling of spiders in conventionally cultivated cotton fields in North-West, Limpopo and Mpumalanga took place (Van den Berg, 1989, Van den Berg *et al*., 1990; Van den Berg & Dippenaar-Schoeman, 1991a; Dippenaar-Schoeman *et al*., 1999a), as well as genetically modified Bt-cotton (Mellet *et al.*, 2006). Thirty-one families, represented by 92 genera and 127 species were sampled.

Maize

Maize is a very important crop in South Africa, with an average of 2.5 million hectares being planted annually. Surveys in maize were undertaken to determine the diversity of species and also to investigate the effects of intercropping in maize agro-ecosystems (Midega *et al*., 2008), as well as effects of Bt maize on arthropods (Truter *et al.*, 2014). Unpublished surveys were also undertaken in Bt maize in Mpumalanga (Marais *et al*., 2008). Surveys undertaken from 2011–2013 investigated the plant and arthropod species composition and diversity patterns along maize fields and field margins in two different biomes across South Africa (Botha *et al.*, 2014). Although maize crops cover a large area the spider diversity is low, with only 79 spider species sampled so far (Dippenaar-Schoeman *et al*., 2013a).

Orchards

A number of surveys in orchards in the Mpumalanga Lowveld resulted in several papers on spider diversity in citrus (Van den Berg *et al*., 1987, 1992; Dippenaar-Schoeman, 1998, 2001), macadamia (Dippenaar-Schoeman *et al*., 2001a,b) and avocado (Dippenaar-Schoeman *et al*., 2005a), while further surveys were conducted on spider diversity in pistachio orchards in the arid Northern Cape (Haddad *et al*., 2004a,b, 2005, 2008; Haddad & Dippenaar-Schoeman, 2006a; Haddad & Louw, 2006). Spider species composition of orchards is strongly influenced by the surrounding matrix of native vegetation. The arboreal spider diversity in these orchards increases from macadamia (80 spp.), pistachio (87 spp.), avocado (90 spp.) to citrus (116 spp.).

Pine plantations

In many areas of Africa, the planting of exotic pine trees has superseded the area covered by indigenous forests. Three spider surveys resulted in records for a total of 136 species (Van den Berg & Dippenaar-Schoeman, 1988; Van der Merwe *et al*., 1996; Uys, 2012).

Proteas (Commercial)

Arthropods associated with commercial Proteaceae in the Western Cape Province were examined by Sasa (2011). Twenty-four species of spiders were recorded in his study.

Strawberries

The spider diversity in strawberries is lower than the other crops, with 31 species recorded mainly from Gauteng and North West (Coates, 1972, 1974; Dippenaar-Schoeman, 1976, 1977, 1979; Smith Meyer, 1996).

Termites

In South Africa, the first diversity studies on arachnids to determine their abundance and their role as natural enemies in farming systems was undertaken from 1965 to 1970 in three provinces, focusing on the role of spiders as predators of termites, an important pest of grazing. These surveys indicated that the distribution of some spider species is usually associated with the distribution of termites.

Tomatoes

Several surveys have been undertaken in the tomato producing areas of South Africa in search of biological control agents of tomato pests. During these surveys, 356 spiders were sampled in total, representing 16 families and 62 species (Krüger & Dippenaar-Schoeman, 2000).

Vineyards

Several surveys have been undertaken in vineyards of South Africa and 52 species have been recorded so far (Mansell & Dippenaar-Schoeman, 2007; Halleen & Dippenaar-Schoeman, 2013). Some surveys were conducted in the Cape Floristic Region of South Africa, where wine grape production and diversity conservation are of major importance, and innovative management of the landscape is necessary (Gaigher & Samways, 2010). A total of 13 spider families represented by 36 species were sampled from vineyards in this study, while 43 species from 16 families were sampled from natural fynbos habitat (Gaigher, 2008; Gaigher & Samways, 2010, 2014). Although spiders may be of benefit as predators in vineyards, they may also pose problems as possible invasive species when they land in containers of table grapes and are inadvertently exported from South Africa (Craemer, 2006; Mansell & Dippenaar-Schoeman, 2007; Kobelt & Nentwig, 2008; Bosselaers, 2013).

Protected areas (PAs)

Inventorying and monitoring diversity of invertebrates in protected areas forms an integral component of assessing their performance and providing the information necessary for conservation management. Invertebrates constitute the largest proportion of terrestrial and freshwater diversity and serve a series of critical ecosystem functions, and as a consequence must necessarily be considered in protected areas (McGeoch *et al*., 2011). However, inventorying invertebrates is associated with a series of regularly cited and well-recognised challenges, including their enormous richness and diversity of habits and habitats, inadequate systematic and biological knowledge, and the shortage of expertise and capacity.

One of the objectives of SANSA is to determine the number of arachnid species presently protected in PAs in South Africa. Being a team effort, SANSA has overcome some of the problems associated with invertebrate inventorying. At present, >192 PAs have been surveyed in South Africa, ranging from biosphere reserves, national parks, reserves, state forests, RAMSAR sites, botanical gardens to conservancies. However, this is still a small fraction of the protected areas sampled and an effort needs to be made to survey more of them.

As many of the surveys run over 12 months or longer periods, these data are extremely valuable, as they provide substantial insight into annual and long-term trends in the diversity, abundance and distribution of the species concerned. These surveys have also made material available to taxonomists, resulting in several faunistic papers and the description of many new species (e.g. Wesołowska & Haddad, 2009, 2013; Haddad & Wesołowska, 2011, 2013).

PAs have proven to be particularly valuable sites to SANSA, both from the perspective of encountering pristine habitat and high diversity, as well as for the safety of survey teams (Dippenaar-Schoeman *et al*., 1999b, 2005b). To determine the species present in a PA is essential for the development of a red data list for the arachnids of South Africa and to assist with decisions on how to successfully conserve the arachnid diversity. Species inventories are critical for effective PA management and are generally considered to be important by PA managers (Engelbrecht, 2010), specialist taxon scientists and ecologists. Most of the provincial conservation agencies need this type of diversity data for planning.

Eastern Cape Province

From the Eastern Cape 23 PAs have been sampled, mainly reserves, but also two national parks and state forest areas (Table 2). In 13 of these areas >50 specimens have been sampled. The Mountain Zebra National Park was the first national park for which a species list was published (Dippenaar-Schoeman, 1988), with a subsequent update (Dippenaar-Schoeman, 2006). Behavioural studies of the subsocial eresid *Stegodyphus tentoriicola* Purcell were undertaken in the Mountain Zebra National Park (Ruch *et al*., 2009a, 2012).

The second national park presently being surveyed in the province is the Addo Elephant National Park (Wiese & Dippenaar-Schoeman, 2014). Results of the Mkambathi Nature Reserve (Dippenaar-Schoeman *et al*., 2011) and Silaka Nature Reserve (Forbanka & Niba, 2013) have been published, while surveys in the Asante Sana Nature Reserve formed part of a PhD study (Midgley, 2012), looking at the structure of epigaeic invertebrate communities along an altitudinal gradient.

Free State Province

A total of 14 PAs have been sampled in the Free State, with 12 reserves represented by >50 records in the NCA (Table 2). The PAs include nature reserves, a national park and a botanical garden. Published records include surveys in the Free State National Botanical Gardens (Butler & Haddad 2011; Neethling & Haddad, 2013) and the Erfenis Dam Nature Reserve (Fourie *et al*., 2013), while surveys are presently underway in the Kalkfontein Dam Nature Reserve (Josling & Lotz, 2014), Amanzi Private Game Reserve (Butler & Haddad, 2014) and Amohela-ho-Spitskop Conservancy (Dippenaar-Schoeman *et al*., 2008).

Gauteng Province

A total of 24 PAs have been sampled in Gauteng, with 12 containing >50 records (Table 2). The PAs mainly include reserves and botanical gardens. The only published data is from the Roodeplaatdam Nature Reserve (Dippenaar-Schoeman *et al*., 1989; Engelbrecht, 2013). A species list of the spiders of the Suikerbosrand Nature Reserve is in preparation, while surveys in the following nature reserves are still underway: Klipriviersberg (Faiola *et al*., 2014), Serene Valley (Kelly *et al*., 2014), Ezemvelo (Lyle & Dippenaar-Schoeman, 2014), Tswaing Crater (Dippenaar-Schoeman, 2014b) and Groenkloof (Dippenaar-Schoeman & Lyle, 2014), as well as the Pretoria National Botanical Gardens (Kassimatis, 2008).

KwaZulu-Natal Province

KwaZulu-Natal is the best sampled province in South Africa with regards to arachnids. A total of 38 PAs have been sampled, with 24 represented by >50 samples (Table 2). Species lists and diversity data of several reserves have been published: Ndumo Game Reserve (Haddad *et al*., 2006; Wesołowska & Haddad, 2009), Tembe Elephant Park (Haddad *et al*., 2010), the Mkhuze Game Reserve and Phinda Private Game Reserve (Lovell *et al*., 2007), Hluhluwe/iMfolozi Park (Mgobozi *et al*., 2008; Ngome State Forest (Van der Merwe, 1994; Van der Merwe *et al*., 1996; Dippenaar-Schoeman *et al*., 2006b), and the iSimangaliso Wetland Park (Combrink, 2007; Combrink & Kyle, 2006).

Limpopo Province

Data from 41 PAs are available, with 13 areas represented by >50 records (Table 2). Surveys in the Vhembe Biosphere Reserves are presently undertaken as part of a PhD study (Schoeman, 2014). Published papers from nature reserves in the province include Nylsvley (Heidger, 1988; Leroy & Leroy, 2005; Dippenaar-Schoeman *et al*., 2009), Polokwane (Dippenaar *et al*., 2008; Foord *et al*., 2013), Makelali (Whitmore *et al*., 2001, 2002a), Mashovela Nature Reserve (Foord *et al*., 2013), Sovenga Hill (Modiba *et al*., 2005), Blouberg (Muelelwa *et al*.,

Table 2. Spider surveys in Protected Areas (PAs) of South Africa.

Provinces	PAs sampled	PAs>50 records	No. of publications	PA published papers
Eastern Cape	23	13	2	Asante Sana NR; Mountain Zebra NP; Mkambathi NR; Silaka NR
Free State	14	12	3	Erfenisdam NR; Free State BG
Gauteng	24	12	1	Roodeplaatdam NR
KwaZulu-Natal	38	24	8	Hluhluwe NR; Ndumo GR; Phinda GR; Spioenkop NR; Tembe EP; Ngome SF
Limpopo	41	14	11?	Blouberg NR; Nylsvley NR; Polokwane NR; Kruger NP; Makelali NR; Mashovela NR; Sovenga Hill; Soutpansberg C
Mpumalanga	10	2	3	Kruger NP (in part); Verloren Valley NR; Bergvliet SF
North West	8	4	0	
Northern Cape	8	2	0	
Western Cape	26	15	8	De Hoop NR; Karoo NP; Swartberg NR; Robben Island (in part); Table Mountain NP (in part)

BG, Botanical Garden; C, Conservancy; EP, Elephant Park; GR, Game Reserve; NR, Nature Reserve; NP, National Park; SF, State Forest.

2010; Foord *et al.*, 2013), and the Western Soutpansberg Conservancy (Foord *et al.*, 2002, 2013; Foord & Dippenaar-Schoeman, 2003; Muelelwa *et al.*, 2010).

Mpumalanga Province

Except for sampling in the Kruger National Park (Dippenaar-Schoeman & Leroy, 2003; Robertson *et al.*, 2011; Reynolds, 2014) and Verloren Vallei Nature Reserve (Jansen *et al.*, 2013), only 10 PAs have been sampled, but only four are represented by >50 samples (Table 2). This includes studies looking at the effect of invasive weeds and fire on spiders (Robertson *et al.*, 2011; Reynolds, 2014), spider diversity in pine plantations at the Bergvliet State Forest, Sabie (Van den Berg & Dippenaar-Schoeman, 1988) and surveys in the Lowveld Botanical Gardens (Leroy, 2008) and Witbank Nature Reserve undertaken by the SCSA.

Northern Cape Province

A total of eight PAs have been sampled in the Northern Cape, with four represented by >50 records (Table 2). Three of these surveys were undertaken at Benfontein, Rooipoort and Tswalu, which form part of the Diamond Route reserves (Lyle & Dippenaar-Schoeman, 2013). Material is still being sorted from a large survey that was undertaken on the Oryx Game Farm. Results of the Augrabies National Park and the Tswalu Nature Reserve will be published soon (Dippenaar-Schoeman *et al.*, in prep.).

North-West Province

The North West province is still under-sampled. Only eight surveys have been sampled in the province with only four having >50 records (Table 2). The only long- term survey, a 4-year study in the Kgaswane Mountain Reserve, will be published soon.

Western Cape Province

From the Western Cape 26 PAs have been sampled, including the three National Parks (Table 2). About 15 PAs have >50 records, including several reserves, state forest areas, heritage sites, wilderness areas, as well as the Kogelberg BR. Published results include the Table Mountain National Park (Picker & Samways, 1996; Pryke & Samways, 2008; Rebelo *et al.*, 2011), Karoo National Park (Dippenaar-Schoeman *et al.*, 1999b), Swartberg Nature Reserve (Dippenaar-Schoeman *et al.*, 2005b), De Hoop Nature Reserve (Haddad & Dippenaar-Schoeman, 2009) and Robben Island (Mukherjee *et al.*, 2010; Roets & Pryke, 2013; Steenkamp, 2014).

SANSA is also participating in the iImbovane outreach project, which involves pupils and teachers in biodiversity science at 25 secondary schools in the Western Cape. This project is one of four long-term surveys managed by the DST-NRF Centre of Invasion Biology (CIB) (Marais, 2013). Also, as part of the CIB, the first results of a six-year survey in the Cederberg Wilderness area are ready for publication (Foord & Dippenaar-Schoeman, 2014).

Floral biomes

Since spiders provide an essential ecosystem service as predators, it is important to determine their diversity in all of the different ecosystems in South Africa. All seven floral biomes recognised in South Africa (Low & Rebelo, 1996; Mucina & Rutherford, 2006) were sampled as part of SANSA. A summary of spider species richness found in each of the biomes suggests that the Savanna Biome is the most diverse (1230 spp.), but sampling is very uneven and biased towards this particular biome, with 23 739 records from 1260 sites (Table 3). It is followed by the Fynbos with 1014 spp., Grassland Biome with 792 spp. and the Thicket Biome with 641 spp.

In developing an understanding of sample completeness in the different biomes generic richness was used as a surrogate of species richness (Foord *et al.*, 2013). A coverage-based comparison (Chao & Jost, 2012) of samples based on generic richness from the different biomes suggests that coverage is very high in the Grassland and Savanna Biomes (0.97–0.99), acceptable in the Fynbos and Nama Karoo (>0.9), low in the Forest and Thicket (<0.85) and very low in the Succulent Karoo (0.34) (Figure 3a). There is a linear increase in coverage (Figure 3b) and generic richness (Figure 3c) with the log of area except for Succulent Karoo, which represents a significant outlier. Succulent Karoo in particular would therefore need to be prioritised in any future surveys.

Forest Biome

South African forests only cover approximately 0.3% of South Africa's land surface (Mucina & Rutherford, 2006). To

Table 3. Spider diversity in the different Floral Biomes of South Africa.

Biome	No. of records	No. of localities	Families	Species	Reference
Savanna	23739	1260	62	1230	Foord *et al.*, 2011b; Dippenaar-Schoeman *et al.*, 2013
Fynbos	10170	148	67	1014	SANSA database
Grassland	11470	900	58	792	Haddad *et al.*, 2013; Dippenaar-Schoeman & Haddad, 2014
Forest	3969	87	61	646	SANSA database
Thicket	2607	54	66	641	SANSA database
Nama Karoo	2705	82	54	632	SANSA database
Succulent Karoo	680	32	51	332	SANSA database

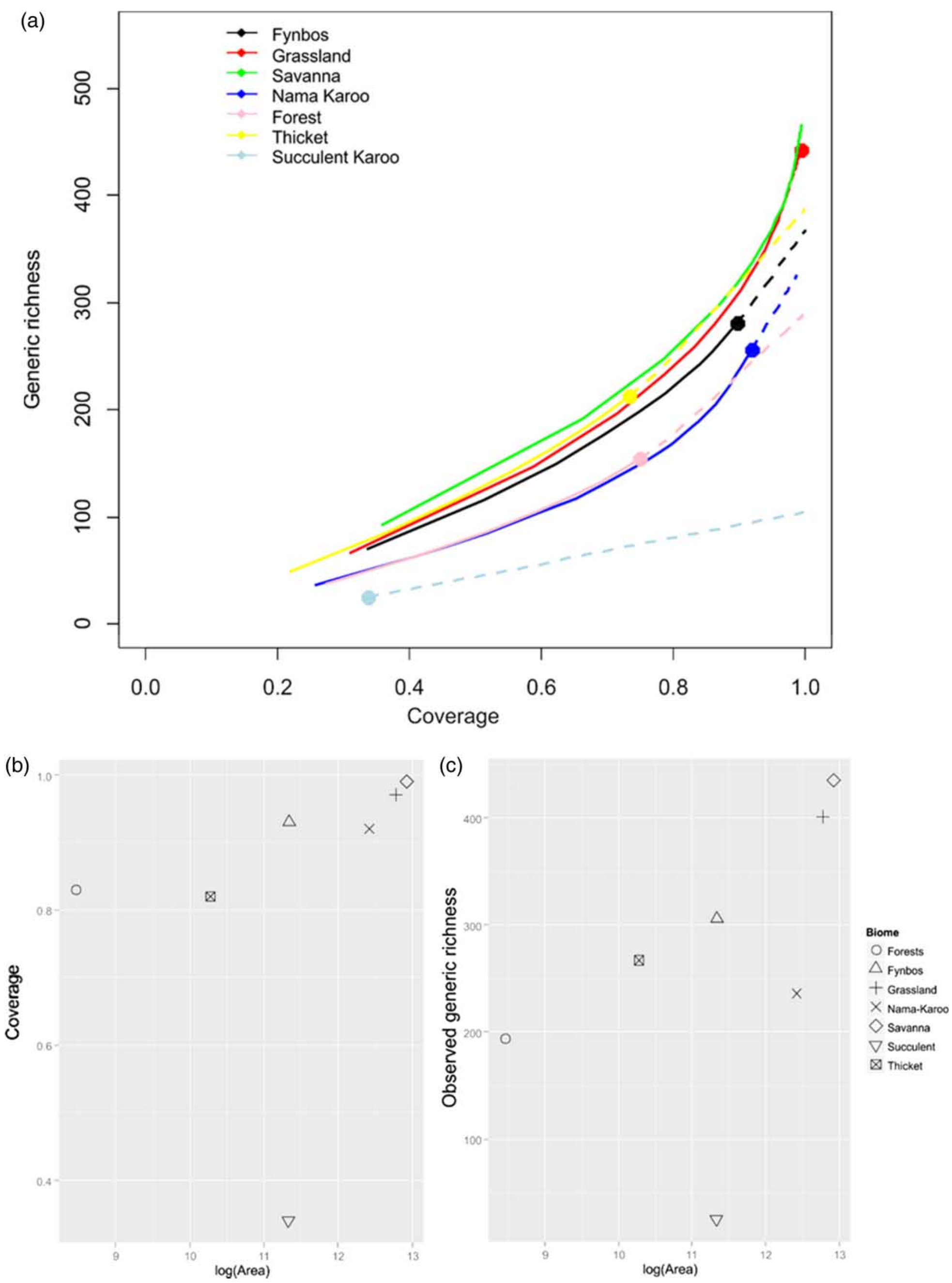

Figure 3. (a) Coverage (Chao & Jost 2012) of generic diversity in each of the seven biomes. Foord *et al.* (2013) showed that generic diversity is an efficient surrogate of spider diversity. Only sites with more than 10 records were included; (b) coverage and (c) observed number of genera as a function of log area covered by biome.

date 60 spider families represented by 551 species have been recorded from forests. The Forest Biome has been fairly extensively sampled, with 4018 records from 165 localities (Table 3). Forests have several endemic species, especially from the families Archaeidae, Microstigmatidae, Phyxelididae and Migidae, species that require focused conservation effort.

Only a few quantitative published studies exist that are focused on the spider fauna of South African forests (Van der Merwe *et al.*, 1996; Dippenaar-Schoeman & Wassenaar, 2002, 2006; Haddad *et al.*, 2010), although spiders have been included in several other ecological studies in forests (e.g. Lawrence, 1953; Moran & Southwood, 1982; Nicolai, 1989; Kotze & Samways, 1999, 2001; Horn, 2004; Lawes *et al.*, 2005).

Fynbos Biome (Cape Floristic Kingdom)

Despite the relatively small extent of coverage of about 6.7% in South Africa, the Fynbos Biome is regarded as a priority hotspot for conservation (Myers *et al.*, 2000). A total of 466 localities have been sampled in this biome, with 10 575 records recorded in the SANSA database (Table 3). Presently, 67 spider families represented by 1014 spp. are known from the biome. To date, only eight studies have been published that focus on fynbos spider diversity (Tucker, 1920a; Coetzee *et al.*, 1990; Visser *et al.*, 1999; Dippenaar-Schoeman *et al.*, 2005b; Haddad & Dippenaar-Schoeman, 2009; Gaigher & Samways, 2010, 2014; Mukherjee *et al.*, 2010). Picker & Samways (1996) showed that most of the endemic invertebrate species recorded on the Cape Peninsula were from Table Mountain, including various arachnids (Sharatt *et al.*, 2000; Pryke & Samways, 2008, 2009, 2010, 2012a; Roets & Pryke, 2013). A long-term survey was undertaken in the Cederberg Mountains, where arachnids and certain insects have been sampled at an elevational gradient over a period of 10 years using 680 pit traps at 17 altitudinal sites. To date, more than 10 000 spider specimens have been identified from these samples and they are all housed in the NCA (Botes *et al.*, 2006a; Seshothela & Dippenaar-Schoeman, 2011; Foord & Dippenaar-Schoeman, 2015, in review).

Grassland Biome

A total of 58 families represented by 792 species have so far been recorded from this biome (Table 3); 58 spp. are endemic to the biome (Haddad *et al.*, 2013). An illustrated guide to the spiders of the Grassland Biome is also available (Dippenaar-Schoeman & Haddad, 2014). Grassland survey results have focused on the Free State (Lotz *et al.*, 1991; Haddad & Dippenaar-Schoeman, 2002, 2006b, 2007; Haddad, 2005; Butler & Haddad, 2011; Fourie *et al.*, 2013; Neethling & Haddad, 2013), Gauteng (Van den Berg & Dippenaar-Schoeman, 1991b), Mpumalanga (Jansen *et al.*, 2013), Eastern Cape (Dippenaar-Schoeman *et al.*, 2011) and KwaZulu-Natal provinces (Van der Merwe *et al.*, 1996). Spiders have also featured in studies using functional feeding groups as indicators of habitat quality (Kaiser *et al.*, 2009) and taxonomic surrogates (Buschke & Seaman, 2011), and burning effects on invertebrates (Uys *et al.*, 2006; Little *et al.*, 2013).

Nama Karoo Biome

This is South Africa's second-largest biome and is mainly found in the western half of the country. Presently 2705 records of spiders are housed in the NCA from 379 localities, and represent 618 spp. from 54 families (Table 3). Most sampling in this biome was done on an *ad hoc* basis between 1890 and 1930 by arachnologists stationed at the Iziko South African Museum, resulting in a considerable number of species being described (e.g. Tucker, 1917, 1920b, 1923). Published results are mainly from collecting undertaken in the Mountain Zebra National Park (Dippenaar-Schoeman, 1988, 2006), Karoo National Park (Dippenaar-Schoeman *et al.*, 1999b), and Nama Karoo grassland (Haddad & Dippenaar-Schoeman, 2005; Dean & Milton, 1995).

Savanna Biome

A total of 23 739 records from 1260 localities were recorded in the South African Savanna Biome until the end of 2011. This includes 1230 species, represented by 381 genera and 62 families (Table 3). Of the 1230 spp., 366 spp. are endemic to the savanna and 322 spp. are near endemic (Foord *et al.*, 2011b). The Savanna Biome has been the most intensively studied in the Limpopo Province (Whitmore *et al.*, 2001, 2002a; Foord *et al.*, 2002, 2008, 2013; Foord & Dippenaar-Schoeman, 2003; Dippenaar-Schoeman & Leroy, 2003; Modiba *et al.*, 2005; Dippenaar *et al.*, 2008; Dippenaar-Schoeman *et al.*, 2009; Muelelwa *et al.*, 2010), but several studies have been published from KwaZulu-Natal (Lawrence *et al.*, 1980; Haddad *et al.*, 2006, 2010; Mgobozi *et al.*, 2008), Mpumalanga (Dippenaar-Schoeman & Leroy, 2003; Robertson *et al.*, 2011) and parts of Gauteng (Dippenaar-Schoeman *et al.*, 1989). The potential of spiders to serve as diversity surrogates was investigated by Foord *et al.* (2013), and spiders have also been included in several ecological studies on arthropods in the biome (Nicolai, 1989; Rivers-Moore & Samways, 1996; Blaum *et al.*, 2009; Lovell *et al.*, 2009, 2010; Jonsson *et al.*, 2010). An illustrated guide to the spiders of the Savanna Biome is also available (Dippenaar-Schoeman *et al.*, 2013b).

Succulent Karoo Biome

This biome is found in the western extreme of the country and only 51 families and 310 species have been recorded from the Succulent Karoo Biome (Table 3). To date, only a single publication on spider diversity has been produced from this biome (Dippenaar-Schoeman *et al.*, 2005b), highlighting our poor state of knowledge of its fauna. Three further studies investigated land-use impacts on invertebrates, including spiders (Seymour & Dean, 1999; Nchai, 2008; Lyons, 2009).

Thicket Biome

Thicket, the second smallest biome, covering only 2.5% of the area of South Africa, occurs in the coastal areas and adjacent inland parts from the Western Cape to KwaZulu-Natal, with most of the biome being found in the Eastern Cape. No published surveys are known from this biome but several surveys are presently underway. Spiders have been included in a single paper on arthropod diversity under different land use conditions (Fabricius *et al.*, 2003). To date, 66 spider families represented by 641 spp. have been recorded from thicket (Table 3), of which 90 are endemics and 96 near endemics. Surveys in the Addo Elephant National Park and Thyspunt are presently underway (Wiese & Dippenaar-Schoeman, 2014).

Provincial diversity

Most taxonomic research on South African arachnids, undertaken during the period from 1820 to 1960, was based on the fauna of the coastal provinces, as most of the practising arachnologists were stationed there. It was only in the late 1960s that the first long-term sampling started in the central and northern provinces of South Africa, with the appointment of arachnologists at the ARC in Pretoria (then Department of Agriculture) in 1967 and the National Museum in Bloemfontein. On a provincial level, the provinces need diversity data to do their conservation and development planning. From the SANSA database the following data is available (Table 4):

Eastern Cape

The Eastern Cape is the second largest province in South Africa and 195 sites have been sampled, with large areas that are still not sampled. A total of 837 species, 38.6% of all South African species, have been recorded from the province (Table 4). Two SANSA members are stationed in the Eastern Cape, resulting in good sampling efforts around Middelburg and Jeffrey's Bay. Staff and students of the University of the Free State have done extensive sampling in the Hogsback area, while the University of KwaZulu-Natal was involved in sampling in the Mkambathi Nature Reserve (Dippenaar-Schoeman *et al*., 2011). At least two areas in the province, the Amatola Mountains and the Pondoland region, show patterns characteristic of high levels of endemism for Archaeidae (Lotz, 2006), Eutichuridae (Lotz, 2002, 2015), Microstigmatidae (Griswold, 1985) and Salticidae (Wesołowska & Haddad, 2013; Wesołowska *et al.*, 2014), and may be of similar significance for other families.

Free State

The Free State is the third largest province (10.6%). A total of 4076 records from 170 localities are part of the SANSA database. A total of 55 families represented by 484 species have so far been recorded (Table 4). As part of a termite control project, the ARC sampled over a five-year period on the farm Lusthof near Edenville. Researchers from the University of the Free State and the National Museum have sampled extensively in the Free State. An extensive photo gallery of the Amohela-ho-Spitskop Conservancy near Clocolan is available online on the SANSA Virtual Museum.

Gauteng

Gauteng is by far the smallest province, covering only 1.4% of South Africa. A total of 350 sites in Gauteng have been sampled, represented by 6800 records, 56 families and 641 spp. in the SANSA database (Table 4). Although well sampled, only a few papers have been published from the province. Surveys were mainly undertaken by the Spider Unit of the ARC-PPRI, the Gauteng Department of Agriculture, Conservation and Environment (GDACE), and the SCSA. Several surveys in green areas in Tshwane and Johannesburg are currently underway, and many records have been generated from natural and anthropogenic habitats through public participation in these two cities during the last three decades.

KwaZulu-Natal

KwaZulu-Natal covers 7.6% of South Africa and 14 687 records from 210 sites are presently available in the SANSA database (Table 4). More than half of the South African species, 1122 from 63 families, have been sampled in the province. Dr Reginald Lawrence, one of the best known South African arachnologists, was stationed at the Natal Museum from 1935 to 1986, and he extensively sampled and described species from the province.

Many parts of the province have been well sampled. From 1967, the farm Vergeval near Pongola was sampled over a period of five years by the ARC as part of their Dieldrin project. Other areas that have been intensively sampled include urban and natural habitats in and around Richards Bay, Durban and Pietermaritzburg, as well as many conserved areas, including the Ngome State Forest, Ndumo Game Reserve, Tembe Elephant Park, iSimangaliso Wetlands Park, Mkuzi Game Reserve, Phinda Resource Reserve and the uKhahlamba-Drakensberg Park.

Limpopo

This province covers 10.6% of South Africa. It is the third best sampled province with 10 620 records from 226 sites (Table 4). A total of 928 species from 62 families are known. The first diversity surveys in the province were done on the farm Amsterdam near Dendron, where arachnids were sampled by the ARC (Dippenaar-Schoeman *et al*., 1978), resulting in the discovery of several new species. Another large dataset became available during surveys looking at the effect of chemical control of *Quelea* finches on the Springbok Flats (Van den Berg *et al*., 2002). The Soutpansberg Mountains and Northern Drakensberg have been identified as biodiversity hotspots with high levels of endemism for certain spider taxa (Griswold, 1991), as well as for Opiliones (Schönhofer, 2008) and Scorpiones (Foord *et al.*, 2015).

Mpumalanga

Mpumalanga covers a total of 6.5% of South Africa's surface. A total of 6216 records from 177 sites have been sampled, representing 697 species from 58 families (Table 4). Most of the surveys were conducted in agro-ecosystems (cotton) and orchards (avocado and macadamia). Other intensively sampled areas include the Kruger National Park and moist grasslands in the province. The SCSA is involved in surveys at the Witbank Nature Reserve and the Lowveld Botanical Gardens.

Northern Cape

Although South Africa's largest province (29.7%), only 1990 records from 124 sites have been sampled in the Northern Cape, with 490 spp. represented by 49 families (Table 4). Very few sites have been intensively sampled. The ARC did some locust research in the Hopetown area, the University of the Free State studied spider diversity in pistachio orchards near Prieska, and the University of Cape Town evaluated restoration techniques of two sites mined for alluvial diamonds in the western part of the province. One SANSA member was stationed at the Augrabies Falls National Park and a paper on the material sampled is in preparation. Other surveys were undertaken in three Diamond Route Reserves: Benfontein, Tswalu and Rooipoort.

North West

This province covers 9.5% of the surface of South Africa. Large areas still need to be sampled and only 2087 records from 89 sites are housed in the NCA (Table 4). There are 380 spp. from 52 families known so far. Very few large-scale surveys have been undertaken in the province, being largely limited to agro-ecosystems such as cotton and maize, and grasslands. All the data from the SANSA database were used to prepare a report on the diversity of arachno-fauna in the North West Province, reporting on all the orders (Power, 2014).

Table 4. Spider diversity in the different provinces of South Africa.

Province	Area covered (%)	No. of records	No. of sites	Families	Species	Total (%)
Eastern Cape	13.9	1046	195	67	837	38.6
Free State	10.6	4076	170	55	484	22.3
Gauteng	1.4	6800	350	56	641	29.5
KwaZulu-Natal	7.6	14687	210	63	1122	51.7
Limpopo	10.2	10620	226	62	928	42.8
Mpumalanga	6.5	6216	177	58	697	32.1
Northern Cape	29.7	1990	124	49	490	22.6
North West	9.5	2087	89	52	402	17.5
Western Cape	9.7	11842	307	68	966	44.5

Western Cape Province

This province covers 9.7% of the surface of South Africa. A total of 11 842 records from 307 sites are housed in the SANSA database (Table 4). There are 966 spp. from 68 families so far known. For the first time, spiders were included in the CapeNature Western Cape State of Biodiversity 2012 report (Turner, 2012; Veldtman, 2012). The most intensively sampled sites in the province are centred around Cape Town, the Cape winelands and the Cederberg Mountains, as well as several PAs. Public sampling for SANSA in the Western Cape resulted in good data from Gouritzmond (Borrelfontein), Hermanus, Oudtshoorn and Worcester. All spiders sampled during ERA surveys in the Beaufort West area are also housed in the NCA.

SPIDER DIVERSITY AND ECOLOGY

Spiders have formed the basis for several studies investigating the response of ecosystems to various drivers of change. Spiders have several qualities that make them ideal model organisms, as they are diverse, easily collected, important predators, sensitive to change at point localities, and adults are relatively easily identified up to morphospecies level (Coddington *et al.*, 1996; New, 1999).

Because of their high numbers in samples and availability of information on almost all spider families, spiders have become a popular group to include in ecological surveys of postgraduate students (Robertson *et al*., 2011). Most of the studies of spider ecology in South Africa are local scale studies focusing on spider assemblage responses to habitat complexity, landscape scale variables, ecosystem rehabilitation and plant invasions, and disturbance effects such as fire, grazing and chemical control. A variety of research on spiders has been undertaken by students from all the major universities in South Africa. The material collected is often deposited as voucher specimens in the NCA and other collections, and the primary collection and identification data provides valuable information on spider diversity.

Barcoding

The correct identification of many spider species is still problematic due to complex variation in morphology between the two sexes. A potential tool to overcome impediments in morphological species identification is provided by DNA barcoding, which is based on CO1 gene sequences (Hebert *et al*., 2003). A project for barcoding the southern African Arachnida has been registered at iBOL, in collaboration with the University of Johannesburg (Marais, 2010). SANSA team members formed part of the Toyota Enviro Outreach team who were able to collect in the iSimangaliso Wetland Park in 2011. The aim of the expedition was to collect as many specimens from various groups of animals and plants to sample for DNA barcoding. The DNA material will contribute to the International Barcode of Life (iBOL) project. Two main sampling sites were chosen, namely Kosi Bay and Maphelane Coastal Forest Reserve (Lyle, 2011a).

Several recent studies have used CO1 and other genes to support taxonomic studies including South African spiders, for which three examples are mentioned here. Miller *et al.* (2010a) investigated the phylogenetic relationships of the genus *Penestomus* and included 15 species from South Africa out of a total of 37 species sequenced (79 species were included in the phylogeny, including 42 previously sequenced species), and using four genes (CO1, H3, 18S and 28S). They deduced the genus was misplaced in Eresidae and established a new family Penestomidae for it, closely related to Zodariidae. They subsequently revised the family, which is endemic to South Africa and Lesotho (Miller *et al.*, 2010b).

Griswold *et al.* (2012) included five species of South African Phyxelididae and a single species of southern African *Ikuma* (Palpimanidae) in a molecular phylogeny focused on Madagascan Phyxelididae, based on 27 species and using the same four genes as the previous study. Their results suggested that the South African phyxelidids form a separate clade from the Madagascan species. Franzini *et al.* (2013) used CO1 and H3 genes to determine the number of *Cyrtophora* species (Araneidae) in South Africa. Although molecular data suggested between 3 and 10 species may occur in the country, genital and somatic morphology supports the existence of only two species.

Cave diversity

One of the first South African spiders sampled from caves was collected by Harington (1951) from the Cango cave, Oudtshoorn. A review of the diversity of caves in South Africa was undertaken by Dippenaar-Schoeman & Myburgh (2009). A total of 43 species of spiders from 32 genera and 21 families are presently known from 44 caves in South Africa. Of the species collected, only 10 species are regarded as true cave spiders (troglobites), while 18 are troglophiles, found both inside and outside caves. The rest of the species (14) are accidentals and they are found mainly around the entrances. A new survey in the Bakwena Cave in Irene, Gauteng started in 2009. This survey was organised by the University of Johannesburg and other interested parties, and continued over a period of one year. Three spider species have been collected so far (Durand *et al.*, 2012). Sharratt *et al.* (2000) reported 14 species of spiders from 13 families occurring in sandstone caves on the Cape Peninsula in the Western Cape, of which only three species are considered true troglobites, five are trogliphiles and six are trogloxenes.

Climate change

Three long-term survey projects, funded by the DST-NRF Centre for Invasion Biology at the University of Stellenbosch, are investigating the response of spiders to global climate change by assessing changes in assemblage composition along altitudinal gradients (Van Wilgen *et al.*, 2014). Since there is little information available on the monitoring of the effects of climate change on invertebrate diversity, these long-term surveys are the first to track individual species and assemblage responses to global climate change. This is done by investigating the effect of gradients on abundance and maturity of some invertebrate groups, such as spiders. This mainly uses pitfall sampling, with a view to track individual species and community responses to global climate change. Climate disruption will result in the uphill movement of species, which is particularly true for the tropics, where latitudinal temperature gradients are small (e.g. Chen *et al.*, 2009, 2011). Altitudinal transects across mountains could therefore provide the most cost effective and succinct picture of the response of organisms and biotic assemblages to global climate change in the tropics and subtropics.

The first of the three projects is monitoring arachnid species across the highest point in the Soutpansberg of the Limpopo Province, on the edge of the tropics and in the Savanna Biome, in collaboration with the University of Venda (Munyai & Foord, 2012). This study has a north-south orientation, and it complements two other long-term surveys in the Grassland Biome (Sani Pass) across the Drakensberg (Bishop *et al.*, 2014) and Fynbos Biome across the Cederberg mountains (Botes *et al.*, 2006a), both with an east-west orientation. All have an initial medium-term objective of monitoring the response of ants and spiders to the El Niño thermal oscillation in the Pacific Ocean, while several environmental variables are also recorded and related to the trends in assemblage structure.

The Cederberg study represents the first to document the changes of spider assemblages across a 2000m, east-west elevational gradient over a period of 10 years. The transect runs across an altitudinal transect covering the major vegetation types on both aspects of the Cederberg, encompassing the full range of vegetation. The transect ranged from sea level at Lambert's Bay, to Sneeukop (1926m a.s.l.), and down the eastern slopes to Wupperthal (approximately 500 m a.s.l.). Sampling was done in March and October every year at 18 different altitudes ranging from 251 m above sea level to 1919m. To date, more than 10 000 spider specimens have been identified from these samples (2004–2010) and they are all housed in the National Collection of Arachnida. They represent 228 species in 42 families, several of which are new (Foord & Dippenaar-Schoeman, 2014).

In a fourth unrelated study, Midgley (2012) studied epigeic invertebrates along an altitudinal gradient (three transects) in the Asante Sana Nature Reserve in the Sneeuberg Mountains in the Eastern Cape. He found that species richness and diversity of invertebrates was significantly lower at 1800m than at 1200 m, 1400 m and 1600 m, but not significantly lower than 2000m and 2200 m. Data for spiders indicated that there was poor correlation between species composition and environmental variable and altitude data, although the correlations were significantly different from 0. Several spider species influenced similarity patterns between altitudes, including *Proevippa biampliata* (Purcell) (Lycosidae), which was abundant at high altitudes, and *Diores* spp. (Zodariidae) and *Aneplasa* sp. (Gnaphosidae), which were most abundant at low and mid elevations.

Effect of exotic and invasive plant species on spider diversity

There is a paucity of studies examining direct impacts of introduced alien species on diversity, a key need for motivating for alien species control. In KwaZulu-Natal, a survey was conducted over a one-year period at Ngome State Forest to look at the effects of exotic pine plantations on ground-living spider assemblages (Van der Merwe *et al.*, 1996) as part of an MSc study. Five different habitat types – grass, open forest, dense forest, ecotone and pine – were sampled with 180 pitfall traps. Pine had the lowest spider diversity while grass had the highest spider diversity. However, variation in spider diversity within habitat types was considerable and an analysis of variance found no significant difference in mean values of spider diversity between habitat types. Consequently, the results do not unambiguously support the hypothesis that exotic vegetation has lower ground-living spider diversity than indigenous vegetation (Van der Merwe *et al.*, 1996). Based on this data, Dippenaar-Schoeman *et al.* (2006b) found that two sympatric microstigmatid species, *Microstigmata longipes* (Lawrence) and *M. zuluensis* (Lawrence), were more active in the indigenous forest, and were absent or present in low numbers in the open grassland and pine plantation, indicating a clear preference for indigenous forest habitats.

In a study of edge effects on arthropods, Pryke & Samways (2012b) also found little difference in spider species richness across a series of transects covering pine plantations, natural forests and grassland in the KwaZulu-Natal midlands, but found variable patterns in a broader-scale survey at sites in the midlands and northern KwaZulu-Natal (Pryke & Samways, 2012c).

Also in KwaZulu-Natal, Mgobozi *et al.* (2008) sampled spiders with pitfall traps and vegetation beating in the Hluhluwe-iMfolozi Park and found significant impacts of an invasive shrub (*Chromolaena odorata*) on spider assemblages, richness and diversity in a South African savanna. *Chromolaena odorata* is a non-indigenous perennial shrub that radically alters native vegetation structure and diversity. They cited the decrease of habitat heterogeneity as the most likely cause of the reduction of spider species richness and abundance in patches of *C. odorata*, and following clearing interventions of the weed, spider assemblages returned to compositions that were quite similar to those occurring in native vegetation.

In the Western Cape, Pryke & Samways (2009) investigated the invertebrate assemblages (including spiders) in six habitat types around Cape Town: alien pine plantations, recovering indigenous forests and fynbos, natural indigenous forests and fynbos, and a botanical garden. Pines had the lowest invertebrate species richness and abundance, while the botanical garden had the highest. Natural fynbos vegetation was more similar to pine plantations than to recovering fynbos, while recovering forest was more similar to pines than to any other site. They suggested that the response of invertebrates to rehabilitation disturbance is similar to a response to fire, with some species colonising the fynbos soon after pine clearance, while natural climax species take much longer to establish themselves. Their results support the prioritisation of conservation measures for the remaining indigenous forest fragments, support initiatives to remove alien pines in urban areas context, and highlight the conservation value of urban botanical gardens of indigenous plants (Pryke & Samways, 2009).

In a separate study in the Western Cape, Magoba & Samways (2012) investigated the effects of vineyards and invasive alien trees on arthropods, including spiders. They found that sites with invasive alien trees had the lowest arthropod species richness and abundance, while sites cleared of alien vegetation had the highest abundance and species richness, followed by natural fynbos. Assemblage structure was significantly different between habitat types, although fynbos and vineyards grouped together, indicating that the latter have less impact on assemblage structure than alien trees do. Clearing alien trees creates conditions that encourage the establishment of indigenous arthropod species.

In the Mpumalanga Province, a study was conducted to investigate the effect of the invasive cactus, *Opuntia stricta*, on beetle and spider species assemblages in the Kruger National Park. A total of 72 beetle and 128 spider species were collected. Spider assemblages did not differ across treatments, suggesting that the current densities of *O. stricta* do not significantly affect spider species richness, density or assemblages. However, beetle assemblages were significantly different from uninvaded control sites, and are clearly negatively impacted (Robertson *et al.*, 2011).

Effect of fire and grazing on diversity

There is a lack of studies globally on the effects of long-term burning regimes on fauna, especially invertebrates. This is particularly alarming since fire-driven biomes such as grassland and savanna possess an enormous number and diversity of invertebrates, all of which have pivotal roles to play in ecosystem functioning. Multi-taxon arthropod studies have shown variable effects of burning on the abundance, species diversity and community composition of invertebrates (Pryke & Samways, 2012a). Monitoring invertebrate responses to fire (e.g. frequency and intensity) is also important within biomes where fire is a key habitat management tool, such as savanna and fynbos (Parr *et al.*, 2004).

Few studies have investigated the impacts on spider diversity and community structure as a result of both these management practices in South Africa. A study by Pryke & Samways (2012a) showed that the fynbos invertebrates in the Table Mountain National Park demonstrated differential short-term resilience to fire, especially with regard to species richness and abundance. The response of spiders to fire indicated no significant differences between sites and treatments for species richness and assemblage similarity, and only occasionally were differences found in abundance between fire regimes.

A study conducted in the Mpumalanga grasslands on the eastern escarpment of South Africa sampled ground-dwelling spiders from five study sites, which varied from either being burnt annually and/or grazed heavily on communal land with no set management. The variations between sites were assessed based on spider species composition and assemblage structure. Grazing intensity and fire frequency had no measurable effect on ground-dwelling spider abundance, diversity or assemblage structure. Only when rare or single species occurrence was included, was there some form of association with sites (Jansen *et al.*, 2013).

In KwaZulu-Natal, Lubin & Crouch (2003) studied the effects of fire on two social spider species in a savanna habitat. Nests of the genus *Stegodyphus* (Eresidae) are a prominent feature of African savannas and their size and visibility make them potentially good indicators of ecological consequences of fire. Analysis of five years of nest mortality data together with information on the burning regime in Spioenkop Nature Reserve indicates that colony extinction in *S. mimosarum* is independent of the burning regime, while burning is a significant cause of colony mortality in *S. dumicola*. The different responses of the two species are likely a result of different colony dynamics and nesting sites.

In the central Free State, an arachnid fauna survey was carried out at the Erfenis Dam Nature Reserve (Fourie, 2010). Initially, the project aimed to assess the impact of controlled burning on the ground-dwelling arachnid fauna, but the opportunity was taken to investigate the spider faunas of three common tree species and also the spider communities in four contrasting grassland types in the reserve (Fourie *et al.*, 2013). Haddad *et al.* (in press) found significantly lower abundance and species richness in the burnt grassland compared to undisturbed grassland. Only one of the nine most abundant spider families (Caponiidae) was more common in the burnt sites. However, most of the dominant families had similar abundances in the burnt and unburnt areas within a year post-fire (Haddad *et al.*, in press).

In the Kruger National Park a study is underway to address the paucity of studies on the effects of long-term burning regimes on invertebrates, by making use of the long-term fire experiment in Kruger National Park, South Africa, initiated in 1954. Spiders are being used as a focus group for the study, as they are important predators that play critical roles in ecosystem functioning and are a highly diverse group, known to be sensitive to changes in vegetation structure (Reynolds, 2014).

In KwaZulu-Natal, the short-term response of grassland invertebrate communities to fire in relation to distance from the edge of a burn, were examined (Uys *et al.*, 2006). They tried to establish which species survive fire and the dynamics of the post-fire recolonisation process, and thereby contribute to establishing the ideal area of a prescribed burn for invertebrate conservation. Burning appeared to minimally impact on wingless invertebrates such as spiders, suggesting they tolerated fire by finding refuge. Invertebrate community structure changed with increasing distance from burn edge in two weeks, but not 12 weeks post-burn. A distance of 280 m from burn edge appears to allow sufficient recolonisation to maintain invertebrate diversity.

Two studies have investigated the impacts of foraging and habitat alterations by African elephants on arthropod assemblages. In Tembe Elephant Park in northern KwaZulu-Natal, Haddad *et al.* (2010) found that elephant-induced changes to the vegetation structure of sand forest did not result in drastic changes in spider assemblages, as undisturbed and disturbed sand forests had similar abundance, species richness and assemblage structures, although the abundance of individual species often differed considerably between habitats. This contrasts with the results for dung beetles, which found assemblages in elephant disturbed sand forest more similar to mixed woodlands than undisturbed sand forest (Botes *et al.*, 2006b). In the Kruger National Park, Mpumalanga, Jonsson *et al.* (2010) found that spider abundance was highest in partial-exclosure plots compared to control plots that were exposed to large herbivore grazing (elephants and giraffes) and full-exclosure plots in three contrasting habitat types, concluding that medium-sized herbivores may positively affect spider abundance.

Micro-scale heterogeneity

There is a drastic shortage of published data on the factors affecting spider heterogeneity in different habitat types, as well as the utilisation of different microhabitats by different species (Foord *et al.*, 2011b). Understanding the role of these factors in shaping the species diversity of habitats and the relative abundances of different species is critical to better implementing conservation measures for spiders and understanding their spatial distribution within habitats.

Foord *et al.* (2008) investigated fine-scale variation in spider assemblages in five representative vegetation types in the western Soutpansberg, Limpopo Province. The vegetation types were assessed in terms of their family and species composition, as well as levels of endemicity, and differences were related to differences in the vegetation structure. They collected 297 species (49 families) in an area less than 450 ha in extent. Analysis of the results suggests that taxa endemic to the Soutpansberg are associated with Tall Forest and, to a lesser extent, Woodland. Woodland had the highest species diversity, and much of the variation observed in spider assemblage structure could be explained by these two vegetation types. They concluded that because vegetation structure variables explained significant variation in spider assemblages, human influence through bush encroachment could result in changes in the spider assemblages to those of Short Forest and Mosaic Woodland vegetation types, which could impact on diversity maintenance and heterogeneity (Foord *et al.*, 2008).

Optimised sampling protocol

Invertebrates are often neglected in conservation planning because of a lack of taxonomic and distributional data. Coddington *et al.* (1991) proposed a sampling protocol for the rapid assessment of invertebrate diversity that can be structured to provide relative abundances of species at sites and enables comparisons between assemblages in disparate regions (Toti *et al.*, 2000).

To design an optimised sampling protocol for standardised inventories in the Savanna Biome, Muelelwa *et al.* (2010) undertook a semi-quantitative inventory of spider diversity in the Blouberg Nature Reserve and Western Soutpansberg Conservancy situated in the Limpopo Province. They found that collector experience had no effect on the results of the inventory, whereas time of day had a very small yet significant effect. Seasonality only affected abundance and richness, but not assemblage composition. Sampling methods used had the biggest effect on the results (Muelelwa *et al.*, 2010; also see Whitmore, 2000). They proposed an optimised sampling protocol for different levels of inventory completeness that considered complementarity and effectiveness of different sampling techniques (Muelelwa *et al.*, 2010).

One of the central questions left unanswered by this study is to what extent habitat structure affects the optimal protocol. Future studies should focus on optimal designs for grasslands through to shrublands, thicket, open woodland and forests. These protocols should aim to utilise the minimum amount of resources and allow the use of inexperienced collectors. The latter should provide an incentive for the use of volunteers and amateur arachnologists.

Rehabilitation and relocation

Coastal dune forest covers approximately 1% of the land area of KwaZulu-Natal, South Africa. It is a habitat type seriously threatened by human population expansion and development. Only one study has been undertaken to study spider species present in different stands of rehabilitated (2, 8 and 16 years), revegetated (40 years) and unmined coastal dune forest (~100 years) at Richards Bay, after mining by a local mining company, Richards Bay Minerals (RBM). Surprisingly, the abundance and species richness of spiders in both the ground and herbaceous layers was highest in the stands that had only recently been rehabilitated (2–8 years), while the unmined forest had the lowest species richness and abundance (Dippenaar-Schoeman & Wassenaar, 2002, 2006).

Lyons (2009) investigated restoration of sites mined for alluvial diamonds in the Succulent Karoo of the Northern Cape, performing a broad-scale survey of arthropods. A total of 185 spiders were collected, represented by 21 families and 51 species, which represented approximately 10% of all of the arthropod species collected. She found that sites restored seven years previously had significantly lower species richness than reference sites of natural habitat, suggesting that the recovery of arthropod richness is dependent on several factors, including soil characteristics, plant species richness, and plant cover. She concluded that soil arthropods may be a suitable surrogate for studying rehabilitation processes, as their response to treatments is similar to that of the entire arthropod assemblage.

Surrogacy

The huge number of invertebrate species, paucity of available data and lack of accessible resources to carry out comprehensive surveys of invertebrates necessitates the use of surrogates to represent invertebrate diversity in conservation planning, and to facilitate rapid diversity assessments (Lovell *et al.*, 2007). However, to date there still remains no consensus amongst researchers of the criteria for selecting appropriate surrogates, despite the attention that this topic has received in recent research (e.g. Heino & Soininen, 2007; Lovell *et al.*, 2007; Williams *et al.*, 2007; Uys *et al.*, 2010). Two recent studies of invertebrates in South Africa provide useful examples of the development of surrogate use.

Lovell *et al.* (2007) conducted a study in the Mkhuze Game Reserve, Phinda Private Game Reserve and False Bay Park in north-eastern KwaZulu-Natal, and examined the use of species density and species assemblage patterns to identify potential coarse-filter surrogates at a local scale using nine invertebrate taxa, including three families of spiders (Araneidae, Oxyopidae and Thomisidae). They found that the use of higher taxa to represent lower taxa shows good potential as a surrogate, but only in species-poor genera or families, and only in regions where the diversity is well documented. Further, they suggested that the lack of congruency between invertebrate taxa supports the use of multiple taxa when incorporating invertebrates in conservation planning. They proposed the use of species assemblage patterns in conjunction with measures of species density for conservation planning, particularly when the areas under consideration consist of diverse habitats and display a high species turnover (Lovell *et al.*, 2007).

Foord *et al.* (2013) investigated the performance of a number of surrogate measures, including higher taxa (genus, family), cross-taxon surrogates that are subsets of the spider assemblages (certain spider families), or non-overlapping groups (woody vegetation and birds), and the use of morphospecies. Their study, based on datasets from four protected areas in the Limpopo Province (Dippenaar *et al.*, 2008; Foord *et al.*, 2008; Muelelwa *et al.*, 2010), aimed to assess surrogate measures based on their predictive power for species richness and the extent to which conservation planning that maximises representation of the surrogate is effective in representing spider diversity. They found that generic richness as a higher taxon surrogate, as well as the combined richness of the families Thomisidae and Salticidae, were the best estimators of total species richness. Based on the surrogacy efficiency criterion, genera and the family Salticidae had species accumulation indices that were significantly larger than 95% confidence intervals of a random curve, while woody vegetation and birds turned out to be poor surrogates for spider diversity. They suggested that while the surrogates they identified provide a viable alternative to whole assemblage analysis, they should be used with caution. The use of Salticidae and Thomisidae as surrogates could provide a feasible indication of spider diversity in the South African Savanna Biome (Foord *et al.*, 2013).

SPIDERS IN ANTHROPOGENIC HABITATS

Spider diversity in urban and suburban areas

Interest in the invertebrate faunas of urban and suburban areas has increased in the last 10–15 years, especially in Europe and North America (Gardiner *et al.*, 2013). Several factors are responsible for the progressive decline in species richness across the anthropogenic gradient from rural habitats to the urban core, including habitat fragmentation, air and soil pollution, increased average ambient temperatures, and other indicators of anthropogenic disturbance (McKinney, 2002). Despite the heavy impacts of urban activities on diversity, green spaces can be potential corridors for the dispersal of wildlife and reservoirs for diversity (Wilby & Perry, 2006; Hostetler *et al.*, 2011).

Very little indeed has been published on spiders of urban areas in tropical regions, and little literature relevant to tropical or sub-tropical areas is available. The first paper on spiders in a South African urban area was a survey by Tucker (1920a) in the Kirstenbosch Botanical Garden, Cape Town. A second botanical garden was sampled by Clark & Samways (1997) in Pietermaritzburg. They sampled arthropods from only two microhabitats (a fallow area and a lawn) on a single occasion, using small pitfall traps, sticky traps, a malaise trap and sweep netting. A third botanical garden sampled is the periurban Free State National Botanical Gardens, where staff and students of the University of the Free State and National Museum in Bloemfontein have collected extensively, including intensive surveys from the leaf litter and foliage strata (Butler & Haddad, 2011; Neethling & Haddad, 2013).

Pryke & Samways (2009) investigated the invertebrate response (including spiders) to alien pine plantations, their removal in comparison with natural vegetation, recovering indigenous forests and Kirstenbosch Botanical Garden around Cape Town. Their study strongly supports the removal of alien pines in an urban context, and also emphasises that an urban botanical garden of indigenous plants has major invertebrate conservation value. Other surveys in urban areas include a three-year survey at the Rietondale Research Station, an area close to the centre of Pretoria by Van den Berg & Dippenaar-Schoeman (1991b), who looked at spiders associated with harvester termites. Whitmore *et al.* (2002b) investigate arthropod diversity on road islands in Durban, KwaZulu-Natal, and found that spider abundance was markedly higher on grassy road islands that were regularly mowed than on structurally enhanced road islands, i.e. those which included indigenous and exotic shrubs, herbs and trees.

Presently several SANSA projects are underway focusing on surveys in protected green areas in Pretoria and Johannesburg (Dippenaar-Schoeman, 2014b; Faiola *et al*. 2014; Kelly *et al*. 2014; Webb & Dippenaar-Schoeman, 2014).

Invasive spider species

Trade and travel at a global scale have resulted in the inadvertent transfer of biological species. The establishment of species outside their native ranges, and the potential damage they may cause to indigenous fauna and flora, is one of the major issues in modern conservation research (Picker & Griffiths, 2011). Risk assessments that predict the possibility of spread, identifying suitable habitats for these species and their possible impact on the native fauna and flora, forms the basis of these assessments (Andersen *et al.*, 2004; Allen *et al*., 2006).

At least 44 species with cosmopolitan distribution are known from South Africa (Foord *et al*., 2011b; Haddad *et al.*, 2013), of which some of the invasive species were reported on by Dippenaar *et al*. (2011). At least three invasive spider species have been recorded from South Africa during the last decade, and include *Badumna longinqua* (L. Koch) (Desidae), *Dictyna civica* (Lucas) (Dictynidae) and *Crossopriza lyoni* (Blackwall) (Pholcidae). At least in the case of *B. longinqua* and *D. civica*, where dense infestations occur, such as in Port Elizabeth residential areas and around buildings at the Roodeplaat campus of the ARC – Plant Protection Research in Pretoria, respectively, almost all indigenous web-building spiders have been displaced by these invasive species. These three species were probably accidental introductions, but the invasiveness of tarantulas that form part of the pet trade, as well as the extent of this trade in South Africa, is unknown. No known invasive tarantulas have been reported yet in South Africa, but the fact that it is not illegal to trade these species, coupled with changing environments, does not preclude the establishment of viable populations.

It is important to note that species invasions are not just one-way traffic. Several South African spiders (or Afrotropical species, including South Africa) have been introduced to other countries, with potential negative effects for their indigenous fauna. To date, five African spider species have been introduced into Europe, representing 21% of the species introduced to the continent (Nentwig & Kobelt, 2010). The subsequent recent introduction of *Cheiracanthium furculatum* (Eutichuridae) into Europe (Bosselaers, 2013; Bayer, 2014) is also a matter of concern. Currently, the threat of introduced South African species on indigenous spider faunas is poorly known. For example, the theridiid *Steatoda capensis* Hann has been introduced to New Zealand, where there is conflicting evidence of it displacing populations of the local species

Latrodectus katipo Powell (Hann, 1990; Brockerhoff *et al.*, 2010; Costall & Death, 2010). There is considerable scope for further study into the impacts of invasive species on local spiders, both in South Africa as well as internationally.

SPIDER BIOLOGY AND BEHAVIOUR

A number of studies have investigated the biology and behaviour of particular groups of spiders. These have covered a broad range of taxa, and have dealt with subjects including microhabitat preferences, predation ecology, sociality, burrow and web construction, amongst others. Many of the specimens included in these studies were collected and deposited in museum collections, providing distribution data that was included in the SANSA project and FASSA.

Microhabitat utilisation and preferences

Plant-, litter- and lichen-dwellers

On Robben Island a study was undertaken to examine the potential importance of lichens in enriching spider diversity and abundance. Seasonal trends in overall species richness and abundance indicated that the relative density of spiders was greater in lichens than in bushes. The results suggest that habitat structure, such as branch size and epiphytic lichen abundance, can explain the greater number of spiders in lichen-rich patches of the island (Mukherjee *et al.*, 2010).

Butler & Haddad (2011) investigated the spider assemblages in the leaf litter of three tree species in the central Free State. They found significant differences in both species richness and abundance of spiders between the three tree species. Of the ten most abundant species collected, all but two showed significant preferences for the litter of a particular tree. They concluded that litter structure (leaf size, litter depth and interstitial space) were the factors most likely contributing to the observed differences in the spider assemblages. In contrast, Neethling & Haddad (2013) found no significant differences between abundance and species richness of arboreal spiders associated with four tree species at the same locality. While most of the common species did not show particular preferences for particular plants, *Oxyopes* spp. (Oxyopidae) and *Misumenops rubrodecoratus* (Thomisidae) showed a clear preference for *Acacia karroo* foliage. Although not a quantitative study, Dippenaar-Schoeman *et al.* (2009) also recorded different species of spiders occurring on five tree species in the Limpopo Province, of which only *Tmarus cameliformis* Millot (Thomisidae) was collected on all five species.

Vasconcellos-Neto *et al.* (2007) reported on the association of *Peucetia* species with plants with glandular trichomes, and included data on four species from South Africa (*P. transvaalica* Simon, *P. nicolae* Van Niekerk & Dippenaar-Schoeman, *P. viridis* (Blackwall) and *P. maculifera* Pocock) that are associated with such plants. One of these species, *P. viridis*, is not restricted to plants with glandular hairs, but also occurs on, for example, *Acacia* trees. Haddad & Dippenaar-Schoeman (2001) studied egg parasitism on *Peucetia striata* Karsch in a grassland habitat, and only collected it from the glandular plant *Melolobium candicans* bushes and no other woody plants, clearly indicating a preference for such plants.

Haddad (2010) provided an example of how understanding the microhabitat preferences of a species can optimise its sampling and improve knowledge of its distribution. *Poachelas* spiders are very rarely collected using conventional sampling methods in grasslands (e.g. pitfalls and sweep-netting), while focused searching at the base of grass tussocks (especially *Themeda triandra* and *Cymbopogon* spp.) often provides considerable numbers of these spiders. Initially, *Poachelas striatus* Haddad & Lyle was described from only three localities in the central Free State (Haddad & Lyle, 2008), but hand collecting in grass tussocks elsewhere in the country resulted in many additional records from the Free State, as well as the first records from the Northern Cape, Eastern Cape and Mpumalanga, extending the distribution of the species to more than 900 km (Haddad, 2010).

In contrast to most zodariid spiders that are ground-dwelling, members of the genus *Chariobas* are often associated with grasses and restios. Leroy & Jocqué (1993) provided a description of the retreat construction of these spiders, which is done by spinning a silken tube between the stalks of these plants, in which the spiders reside.

Ground-dwellers

In the case of trapdoor spiders, a group of conservation importance, Engelbrecht (2013) identified the factors that affected species richness and activity patterns of these mygalomorphs. He showed that different species are active during different periods of the year, and that each species' activity patterns also differed between sites. Soil moisture was the only significant predictor of spider activity amongst seven environmental factors analysed, and spiders were predominantly active under wet conditions following rainfall. He further recommended that pitfall trapping be undertaken during several intervals over the course of the year to achieve a near complete inventory for each site. Soil type (clayey or sandy) was found to affect the efficacy of active searching, although pitfall trapping yielded a greater number of species at all of the sites. Soil type may also be an important consideration when sampling mygalomorph trapdoor spiders, with evidence of varying degrees of preference provided by Fourie *et al.* (2011) and Engelbrecht & Prendini (2012). Various other authors have provided details of the burrow structures (Van Dam & Roberts, 1917; Dippenaar-Schoeman & Jocqué, 1997; Leroy & Leroy, 2000, 2005; Dippenaar-Schoeman, 2002b) of various South African mygalomorph spiders.

Structures such as abandoned mammal burrows and termitaria form microhabitats that can be secondarily utilised by a wide variety of organisms in an environment. Heidger (1988) studied spiders associated with abandoned mammal burrows in Limpopo Province, and found three species of web-builders occupied these burrows (*Benoitia ocellata* (Pocock), *Euprosthenops proximus* Lessert and *Smeringopus pallidus* (Blackwall)). Burrows of small mammals such as gerbils only hosted a single individual, while larger burrows of springhares, warthogs and aardvark often contained more than one spider. In contrast, abandoned *Trinervitermes trinervoides* termitaria in the Free State hosted a rich diversity of spiders, 82 species from 21 families, with only two of these spiders being considered as termitophiles (*Heliophanus termitophagus* Wesołowska & Haddad and an undescribed oonopid), as they were the only species not collected in other microhabitats in the surrounding grassland (Haddad & Dippenaar-Schoeman, 2002, 2006b).

In a study of arthropods associated with shells of *Trigonephrus* land snails in arid western South Africa, Gess & Gess (1999) considered the spiders as residents (one of five association categories), i.e. constructing silk structures in the shells that they occupied. Spiders were found in between 9 and

21% of the shells examined in three areas. In some places, *Cheiracanthium simplicitarse* Simon were the only spiders found, while other sites' shells were occupied by salticid spiders. Lamoral (1968) studied intertidal spiders in the Western Cape, focusing on *Desis formidabilis* (O. P.-Cambridge) and *Amaurobioides africanus* Hewitt, and studied a wide variety of biological and physiological aspects of both species, including their utilisation of mollusc shells and rock structures as nesting sites.

Myrmecomorphy and myrmecophagy

Myrmecomorphy involves the evolution of morphological, behavioural and chemical traits to imitate and closely associate with ants, and many examples can be found amongst spider families (Cushing, 1997, 2012). Amongst the South African fauna, myrmecomorphy can be found in several genera of Salticidae, including *Belippo*, *Kima*, *Myrmarachne* and *Natta* (Wesołowska & Szeremeta, 2001; Wesołowska & Haddad, 2009, 2013); the zodariid genera *Ranops*, *Diores*, *Palfuria*, amongst others (Jocqué, 1990, 1991); the corinnid genera *Apochinomma*, *Corinnomma* and *Merenius* (Haddad, 2006a; Haddad & Louw, 2012; Haddad, 2013); the trachelid genus *Spinotrachelas* (Haddad, 2006b; Lyle, 2011b); the thomisid genus *Sylligma* (Lewis & Dippenaar-Schoeman, 2011); the gnaphosid genera *Aphantaulax* and *Micaria*, and several genera of Linyphiidae. Several species of *Seothyra* (Eresidae) mimic ants or velvet ants (Dippenaar-Schoeman, 1990), as do species of the salticid genus *Mexcala* (Wesołowska, 2009), while three species of *Graptartia* (Corinnidae) are exclusive mimics of velvet ants (Haddad, 2004).

Myrmecophagy, the consumption of ants, is less well studied in South Africa. Pekár & Haddad (2011) studied the diet of the salticid *Mexcala elegans* Peckham & Peckham, and found that it consumes a variety of different ants under field conditions, and no other arthropod prey, but under laboratory conditions they captured other arthropods with similar efficiency to ants. The thomisid *Sylligma ndumi* Lewis & Dippenaar-Schoeman has been observed feeding on its model ant *Myrmicaria natalensis* (F. Smith) in the field (Lewis & Dippenaar-Schoeman, 2011), while the cosmopolitan spiders *Oecobius navus* Blackwall (Oecobiidae), *Euryopis episinoides* (Walckenaer) and *E. funebris* (Rentz) (Theridiidae), which regularly feed on ants in Europe, Australia and America (Carico, 1978; Gertsch, 1979; Voss *et al.*, 2007; Liznarova *et al.*, 2013), have also been observed feeding extensively on ants in South Africa (Haddad, pers. obs.).

Termitophily and termitophagy

Members of the family Ammoxenidae are of particular interest as they are specialist feeders of harvester termites. Several studies have been done on *Ammoxenus* foraging and feeding behaviour (Dean, 1988; Dippenaar-Schoeman *et al.*, 1996a, b; Dippenaar-Schoeman & Harris, 2005; Petráková *et al.*, 2015). Other studies on termitophagous spiders include some *Diores* spp. of the Zodariidae (Jocqué, 1990; Jocqué & Dippenaar-Schoeman, 1992), and *Heliophanus termitophagus* (Wesołowska & Haddad, 2002) and *Stenaelurillus natalensis* Haddad & Wesołowska (Haddad & Wesołowska, 2006) of the Salticidae. Although detailed studies of termitophagy by *Microheros termitophagus* Wesołowska & Cumming (Salticidae) were undertaken in Zimbabwe (Wesołowska & Cumming, 1999), this species also occurs in northern South Africa and feeds on termites here too (Van den Berg & Dippenaar-Schoeman, 1991b, as *Phlegra* sp.).

In a ground-breaking study on predation biology, Petráková *et al.* (2015) used Next Generation Sequencing for molecular analysis of the gut contents of *Ammoxenus amphalodes* Dippenaar & Meyer, comparing them to sequences of available prey in a grassland habitat. Their results showed that 99.8% of the extracted sequences belonged to *Hodotermes mossambicus* (Hagen) termites, providing the first solid evidence of a monophagous true predator. This was supported by data from behavioural experiments, which showed *A. amphalodes* to only accept *H. mossambicus* as prey.

Studies of the diversity and spiders associated with abandoned *Trinervitermes trinervoides* mounds indicate that most species collected are general ground- or web-dwelling grassland spiders (Haddad & Dippenaar-Schoeman, 2002, 2006b), and only two species could be identified, *H. termitophagus* and an undescribed species of Oonopidae, which are restricted to the mounds and are possibly termitophiles. Preliminary observations of the diet of several species indicate that most are able to capture *T. trinervoides* or *Hodotermes mossambicus* worker termites (Haddad & Dippenaar-Schoeman, 2006b).

Diversity of social spiders

Amongst spiders, there are varying degrees of sociality and aggregation, although the species involved in such behaviour represent a small proportion of the global spider diversity (Whitehouse & Lubin, 2005). Eresids are a group of considerable arachnological interest, primarily because of the evolution of subsocial and quasisocial species from solitary ancestors in the genus *Stegodyphus*, behaviour that is absent in all of the other genera of the family (Kraus & Kraus, 1988; Lubin & Bilde, 2007; Miller *et al.*, 2012). Not surprisingly, the rich eresid fauna of South Africa has led to considerable research being undertaken here, to the point that *Stegodyphus* are undoubtedly the best studied genus in the country with regards to their biology and diversity. The Afrotropical representatives of the genus have not only been studied extensively in South Africa, but also in Namibia, Tanzania and Swaziland.

Included amongst the aspects of *Stegodyphus* biology studied so far in South Africa are the factors affecting foraging activity and prey capture (Dewar & Koopowitz, 1970; Ward & Enders, 1985; Crouch & Lubin, 2000; Ainsworth *et al.*, 2002; Ruch *et al.*, 2009a, 2012; Majer *et al.*, 2013), colony longevity (Crouch & Lubin, 2001), reproduction (Ruch *et al.*, 2009b), dispersal behaviour (Wickler & Seibt, 1986; Crouch *et al.*, 1998; Bodasing *et al.*, 2002; Lubin *et al.*, 2009; Keiser *et al.*, 2014a), responses to fire (Lubin & Crouch, 2003), intraspecific behavioural interactions (Seibt & Wickler, 1988a,b; Laskowski & Pruitt, 2014; Modlmeier *et al.*, 2014; Keiser *et al.*, 2014a,b), parasitism (Henschel *et al.*, 1996), and nest effects on physiology (Seibt & Wickler, 1990).

Several other aspects have been investigated. Gene flow and genetic variation have been studied in *S. mimosarum* and *S. dumicola*, and the impacts this has on population dynamics (Johannesen *et al.*, 2009a,b), while Johannesen *et al.* (2007) performed a molecular phylogeny of the genus to assess patterns in the evolution of sociality. Crouch & Malan (2002) also investigated the use of *Stegodyphus* webs as nest-lining material by a small raptor. Griswold & Meikle-Griswold (1987) described *Archaeodictyna ulova*, a kleptoparasite in *Stegodyphus* nests, and found that the host spiders tolerated *A. ulova* and showed no aggression towards them, even when feeding on the same prey item (Griswold & Meikle, 1990).

Web-building behaviour

The orb-web spiders (Araneidae) have some interesting behaviour, especially where adapted or reduced webs are concerned, as exemplified by the Cyrtarachninae. The hedgehog spider (*Pycnacantha tribulus* (Fabricius)) has a reduced orb-web, and only makes a trapezium web at night from which it hangs and captures flying moths using the forelegs (Dippenaar-Schoeman & Leroy, 1996). Notes on two species of bolas spiders were provided by Akerman (1923), Roff & Dippenaar-Schoeman (2005) and Leroy *et al.* (1998), who found that the spiders hung from a trapeze suspended from vegetation using their fourth legs and swung a capture line with one to three sticky droplets at the end using the fourth legs. The bird-dropping spider *Pasilobus dippenaarae* Roff & Haddad builds a horizontal web comprising only two sectors of an orb-web (Roff & Haddad, 2015).

Kuntner *et al.* (2008) studied the web-building behaviour and habitat preferences of the nephilid spider *Clitaetra irenae* in northern KwaZulu-Natal, and showed that the species has considerable habitat flexibility as long as the tree canopy is at least partially closed. Web orientation on trees was also affected by the degree of canopy closure. Further, they demonstrated ontogenetic shifts in web structure, from a simple orb-web in early instars to a ladder web in adult females.

Effect of natural enemies on spider diversity

Very little is known of the natural enemies of spiders in South Africa and how they may affect spider diversity. Amongst the Arthropoda, some of the best examples of spider predators and parasites come from the orders Hymenoptera, Diptera and Neuroptera (Van Helsdingen, 2011). These can be broadly separated into spider parasites/predators and egg parasites/predators.

Amongst the first group, Croeser (1996) indicated that pompilid wasps are confirmed predators of *Palystes* spp. (Sparassidae), with a detailed report by Gess & Gess (1980a) indicating that *Tachypompilis ignitus* (Smith) preys exclusively on these spiders. In contrast, *Batozonellus fuliginosus* (Klug) preys on araneid spiders, particularly *Araneus* and *Caerostris* (Gess & Gess, 1980a), *Dichragenia neavei* (Kohl) nests were provisioned with *Palystes* sp. and Lycosidae spiders (Gess & Gess, 1976), while *D. pulchricoma* (Arnold) utilised a broader spectrum of prey, including Lycosidae (54%), Pisauridae (31%), Sparassidae (13%) and Salticidae (2%) (Gess & Gess, 1974). Griswold & Meikle (1990) reported that *Pseudopompilus funereus* Arnold landed on webs of *Stegodyphus* and captured one of the spiders that tried to attack it, before escaping the web and depositing an egg on its spider prey. Henschel *et al.* (1996) also investigated pompilid parasitism of two *Stegodyphus* species, including *S. dumicola* from KwaZulu-Natal.

Amongst Sphecidae wasps, in the Eastern Cape *Chalybion tibiale* (Fabricius) provisioned nests mainly with araneid and nephilid spiders of various genera, with smaller numbers of Theridiidae and Zodariidae also captured (Gess & Gess, 1980b). Nel *et al.* (2014) provided a detailed account of the biology of *C. spinolae* Lepeletier in the Western Cape and found that the diet comprises exclusively of *Latrodectus* spiders. This confirmed the earlier results of Gess *et al.* (1982), who found that *C. spinolae* captured *Latrodectus* only at a site in the Eastern Cape. Several other spiders have been found with suspected ichneumonid or pompilid larvae externally on the abdomen, including the salticids *Heliophanus pistaciae* (Haddad, 2003) and *Pseudicius venustulus* Wesołowska & Haddad (Wesołowska & Haddad, 2009), and the sparassid *Olios sjostedti* Lessert (Jäger, 2014), while lycosids are perhaps the most regularly encountered hosts for these hymenopteran larvae (Dippenaar-Schoeman, pers. obs.; Haddad, pers. obs.).

Several species of Acroceridae flies, which are all internal parasites of spiders (Barraclough & Londt, 2008), have been studied. Barraclough (1984) provided the first host records for South African acrocerids, with two species raised from *Moggridgea crudeni* Hewitt (Migidae) and an undetermined gnaphosid spider. Schlinger (1987) subsequently recorded a third acrocerid parasitising a *Machadonia* (=*Griswoldia*, Zoropidae) species in South Africa, while Barraclough & Croucamp (1997) described a new species that was raised from a subadult male *Cheiracanthium* (Eutichuridae), and provided details of its developmental biology.

A second important group of natural enemies includes egg parasites and predators. Considerable research has been done on *Echthrodesis lamorali* Masner (Platygastridae), an egg parasite of the intertidal spiders *Desis formidabilis* (Desidae) and *Amaurobioides africanus* (Anyphaenidae). This wasp was first recorded from *D. formidabilis* eggs by Masner (1968) and Lamoral (1968). Recent biological studies suggest that *E. lamorali* is restricted in its distribution to the Cape Peninsula, despite the more widespread distribution of its hosts (Van Noort, 2009, 2011; Owen *et al.*, 2014; Van Noort *et al.*, 2014). Haddad & Dippenaar-Schoeman (2001) reported a *Psyllaephagus* sp. (Encyrtidae) parasitising the egg sacs of *Peucetia striata* (Oxyopidae), while Haddad (2003) collected an *Odontacolus* sp. (Platygastridae) parasitising the eggs of the jumping spider *Heliophanus pistaciae*; most host records for this wasp genus come from salticid or clubionid spiders (Valerio *et al.*, 2013).

Despite a rich diversity of Mantispidae (Neuroptera) in the Afrotropical Region, little remains known of the biology and hosts of individual species (Snyman *et al.*, 2012). While mantispids are widely regarded as important predators of spider eggs (Redborg, 1998), only Croeser (1996) has reported *Climaciella erichsoni* Guérin-Méneville and other unidentified predators of *Palystes* eggs in South Africa, while *Pseudoclimaciella* spp. and *Afromantispa tenella* (Erichson) have also been reared from *Palystes* egg sacs (Louwtjie Snyman, University of Pretoria, pers. comm.).

Spiders also contribute to the diet of various predatory vertebrates in South Africa, including reptiles (e.g. Nagy *et al.*, 1984; Clusella-Trullas & Botes, 2008; Measey *et al.*, 2011; Edwards *et al.*, 2013), mammals (e.g. Channing, 1984; Kerley, 1989) and birds (e.g. Kopij, 2000; Radford, 2008).

AWARENESS, OUTPUTS AND CAPACITY BUILDING

One of the main aims of SANSA is to create awareness of the importance of arachnids and the SANSA project to the public and other scientists. Several aspects were included as part of the project, including the distribution of high quality and easy-to-understand information about arachnids through the SANSA website as well as educational outreach and training programmes to communities and schools (Spider Educare Programme) (Figure 4). Target audiences were identified and packages compiled to allow dissemination of information through magazine and newspaper articles, pamphlets, and TV and radio talks. Outputs also included books (Dippenaar-Schoeman & Jocqué, 1997; Leroy & Leroy, 2000; Dippenaar-Schoeman, 2002b, 2014a; Dippenaar-Schoeman & Van den Berg, 2010; Holm & Dippenaar-Schoeman, 2010; Dippenaar-

Figure 4. SANSA awareness activities: (a) a group of school children attending a spider course at Ezemvelo Nature Reserve; (b) SANBI interns attending the introductory course on arachnids.

Schoeman *et al.*, 2013b; Dippenaar-Schoeman & Haddad, 2014) and chapters in books (Dippenaar-Schoeman, 2002c; Dippenaar *et al.*, 2011; Foord *et al.*, 2011a), as well as CDs on medically important arachnids, and general information about spiders. Five wall posters on medically important arachnids, spiders in and around the house and interesting common spiders were also made available to the public. An electronic newsletter and website on SANSA activities are now available.

Courses and workshops form an important part of the awareness and training component of SANSA. Annually, special workshops at the ARC are organised for members of SCSA to train to identify spiders, to use microscopes and to sort and label specimens. Identification workshops are also presented on request for groups such as interns, students and interested public members. At universities regular courses are presented to students.

Although considerable effort has been put into promoting SANSA to local and international colleagues at congresses, there has been limited success in generating the necessary interest to address the considerable taxonomic impediment for the South African fauna. During the last two decades, several international colleagues have played a major role in revising and describing African spiders, including those from South Africa. Without their inputs, our knowledge of the country's arachnid fauna would undoubtedly be considerably poorer. To address this, future efforts need to focus on expanding collaborative research between local and international arachnologists, student training, as well as to devlop a culture (which is indeed very well established in Europe) of amateur arachnologists being more involved in taxonomic research, under the guidance and mentorship of local taxonomists. Only through such initiatives will the necessary capacity be developed to describe South Africa's rich spider fauna.

CONCLUSION

Through the two online biodiversity informatics systems, SANSA has contributed towards a better understanding of the South African spider fauna, and serves as a valuable tool in the training and awareness of the public. South African spider systematics and ecology are in an exploratory phase, and the traditional approach to mapping diversity has enabled spider ecological research results in the country to generate species lists that are often resolved to species level. This descriptive phase provides the foundations for more integrative work between taxonomists and ecologists in future, and any attempts to ignore the importance of providing baseline diversity and taxonomic data will hamper subsequent attempts to develop a deeper understanding and appreciation of this unique heritage.

This has set the stage for addressing some of the most fundamental questions in arachnid diversity. The next step should include global collaborative research with standardised sampling and focused research questions at multiple sites throughout the world. Future research would have to focus on the role of spider diversity in ecosystem function by exploring the relationship between taxonomic and functional diversity. Although ecological research has focused on the drivers of spider diversity, we should now develop models that would allow prediction of assemblage responses to global change drivers. Linking taxonomic and functional diversity would allow us to predict the implication of these changes to ecosystem processes, functioning and services. By focusing on globally significant research questions we might just provide relevant local insights into the importance of spider diversity to ecosystems.

REFERENCES

Adenle, A.A. 2012. Failure to achieve 2010 biodiversity's target in developing countries: How can conservation help? *Biodiversity and Conservation* 21: 2435–2442.

Ainsworth, C., Slotow, R., Crouch, T. & Lubin, Y. 2002. Lack of task differentiation during prey capture in the group-living spider *Stegodyphus mimosarum*. *Journal of Arachnology* 30: 39–46.

Akerman, C. 1923. A comparison of the habits of a South African spider, *Cladomelea*, with those of an Australian *Dicrostichus*. *Annals of the Natal Museum* 5: 83–88.

Allen, C.R., Johnson, A.R. & Parris, L. 2006. A framework for spatial risk assessments: potential impacts of nonindigenous invasive species on native species. *Ecology and Society* 11 (39): 1–13.

Andersen, M.C., Adams, H., Hope, B. & Powell, M. 2004. Risk assessment for invasive species. *Risk Analysis* 24: 787–793.

Balmford, A. & Gaston, K.J. 1999. Why biodiversity surveys are good value. *Nature* 398: 204–205.

Barraclough, D.A. 1984. Review of some Afrotropical Acroceridae, with descriptions of eight new species from South Africa (Diptera: Brachycera). *Journal of the Entomological Society of Southern Africa* 47: 45–66.

Barraclough, D.A. & Croucamp, W. 1997. A new South African species of *Ogcodes* Latreille (Diptera: Acroceridae) reared from a sac spider of the genus *Cheiracanthium* Koch (Miturgidae). *Annals of the Natal Museum* 38: 55–60.

Barraclough, D.A. & Londt, J.G.H. 2008. Order Diptera. In Scholtz, C. H. & Holm, E. (Eds), *Insects of southern Africa*, 2nd edn. Durban, Butterworths. pp. 283–321.

Bayer, S. 2014. Miscellaneous notes on European and African *Cheiracanthium* species (Araneae: Miturgidae). *Arachnologische Mitteilungen* 47: 19–34.

Bengtsson, J., Jones, H. & Setala, H. 1997. The value of biodiversity. *Trends in Ecology and Evolution* 12: 334–336.

Bishop, T.R., Robertson, M.P., Van Rensburg, B.J. & Parr, C.L. 2014. Elevation-diversity patterns through space and time: ant communities of the Maloti-Drakensberg Mountains of southern Africa. *Journal of Biogeography* 41: 2256–2268.

Blaum, N., Seymour, C., Rossmanith, E., Schwager, M. & Jeltsch, F. 2009. Changes in arthropod diversity along a land use driven gradient of shrub cover in savanna rangelands: identification of suitable indicators. *Biodiversity and Conservation* 18: 1187–1199.

Bodasing, M., Crouch, T. & Slotow, R. 2002. The influence of starvation on dispersal in the social spider, *Stegodyphus mimosarum* (Araneae, Eresidae). *Journal of Arachnology* 30: 373–382.

Bosselaers, J. 2013. An alien in the grapes: a potentially aggressive African spider imported into Belgium. *Nieuwsbrief van de Belgische arachnologische Vereniging* 28: 22–28.

Botes, A., McGeoch, M.A., Robertson, H.G., Van Niekerk, A., Davids, H. P. & Chown, S.L. 2006a. Ants, altitude and change in the northern Cape Floristic Region. *Journal of Biogeography* 33: 71–90.

Botes, A., McGeoch, M.A. & Van Rensburg, B.J. 2006b. Elephant and human-induced changes to dung beetle (Coleoptera: Scarabaeidae) assemblages in the Maputaland Centre of Endemism. *Biological Conservation* 130: 573–583.

Botha, M., Siebert, S.J. & Van den Berg, J. 2014. Surprisingly high arthropod diversity in agro-ecosystems. *SANSA News* 21: 8.

Brockerhoff, E.G., Barratt, B.I.P., Beggs, J.R., Fagan, L.L., Kay, M.K., Phillips, C.B. & Vink, C.J. 2010. Impacts of exotic invertebrates on New Zealand's indigenous species and ecosystems. *New Zealand Journal of Ecology* 34: 158–174.

Buschke, F.T. & Seaman, M.T. 2011. Functional feeding groups as a taxonomic surrogate for a grassland arthropod assemblage. *African Invertebrates* 52: 217–228.

Butchart, S.H.M., Walpole, M., Collen, B., Van Strien, A., Scharlemann, J. P.W., Almond, R.E.A., Baillie, J.E.M., Bomhard, B., Brown, C., Bruno, J., Carpenter, K.E., Carr, G.M., Chanson, J., Chenery, A.M., Csirke, J., Davidson, N.C., Dentener, F., Foster, M., Galli, A., Galloway, J.N., Genovesi, P., Gregory, R.D., Hockings, M., Kapos, V., Lamarque, J.-F., Leverington, F., Loh, J., McGeoch, M.A., McRae, L., Minasyan, A., Morcillo, M.H., Oldfield, T.E.E., Pauly, D., Quader, S., Revenga, C., Sauer, J.R., Skolnik, B., Spear, D., Stanwell-Smith, D., Stuart, S.N., Symes, A., Tierney, M., Tyrrell, T.D., Vie, J.-C. & Watson, R. 2010. Global biodiversity: indicators of recent declines. *Science* 328: 1164–1168.

Butler, V.P. & Haddad, C.R. 2011. Spider assemblages associated with leaf litter of three tree species in central South Africa (Arachnida: Araneae). *African Journal of Ecology* 49: 301–310.

Butler, V.P. & Haddad, C.R. 2014. Ground-dwelling spider assemblages in contrasting habitats of the Amanzi Private Game Reserve, South Africa. Abstracts of the 11*th* Colloquium of the African Arachnological Society, Amanzi Private Game Reserve, South Africa: 2.

Carico, J.E. 1978. Predatory behavior in *Euryopis funebris* (Hentz) (Araneae: Theridiidae) and the evolutionary significance of web reduction. *Symposia of the Zoological Society of London* 42: 51–58.

Channing, A. 1984. Ecology of the namtap *Graphiurus ocularis* (Rodentia: Gliridae) in the Cedarberg, South Africa. *South African Journal of Zoology* 19: 144–149.

Chao, A. & Jost, L. 2012. Coverage-based rarefaction and extrapolation: standardizing samples by completeness rather than size. *Ecology* 93: 2533–2547.

Chen, I.C., Shiu, H.J., Benedick, S., Holloway, J.D., Chey, V.K., Barlow, H.S., Hill, J.K. & Thomas, C.D. 2009. Elevation increases in moth assemblages over 42 years on a tropical mountain. *Proceedings of the National Academy of Sciences of the United States of America* 106: 1479–1483.

Chen, I.C., Hill, J.K., Shiu, H.J., Holloway, J.D., Benedick, S., Chey, V.K., Barlow, H.S. & Thomas, C.D. 2011. Asymmetric boundary shifts of tropical montane Lepidoptera over four decades of climate warming. *Global Ecology and Biogeography* 20: 34–45.

Clark, T.E. & Samways, M.J. 1997. Sampling arthropod diversity for urban ecological landscaping in a species-rich southern hemisphere botanic garden. *Journal of Insect Conservation* 1: 221–234.

Clusella-Trullas, S. & Botes, A. 2008. Faecal analysis suggests generalist diets in three species of Western Cape cordylids. *African Zoology* 43: 125–130.

Coates, T.J.D. 1972. The influence of some natural enemies and pesticides on various populations of *Tetranychus cinnabarinus* (Boisduval), *T. lombardini* Baker and Pritchard and *T. luderti* Zacher (Acari: Tetranychidae), with aspects of their biologies. Unpublished DSc thesis, Rand Afrikaanse Universiteit.

Coates, T.J.D. 1974. The influence of some natural enemies and pesticides on various populations of *Tetranyhus cinnabarinus* (Boisduval), *T. lombardini* Baker & Pritchard and *T. ludeni* Zacher (Acari: Tetranychidae) with aspects of their biologies. Entomology Memoir 42, Department of Agricultural Technical Services, Republic of South Africa.

Coddington, J.A., Griswold, C.E. & Davila, D.S. 1991. Designing and testing sampling protocols to estimate biodiversity in tropical ecosystems. In Dudley, E.C. (Eds), *The Unity of Evolutionary Biology: Proceedings of the Fourth International Congress of Systematics and Evolutionary Biology.* Portland, OR, Dioscorides Press. pp. 44–60.

Coddington, J.A., Young, L.H. & Coyle, F.A. 1996. Estimating spider species richness in a southern Appalachian Cove Hardwood forest. *Journal of Arachnology* 24: 111–128.

Coetzee, J.H., Dippenaar-Schoeman, A.S. & Van den Berg, A. 1990. Spider assemblages on five species of Proteaceous plants in the fynbos biome of South Africa. *Phytophylactica* 22: 443–447.

Coetzer, W., Gon, O., Hamer, M. & Parker-Allie, F. 2012. A new era for specimen databases and biodiversity information management in South Africa. *Biodiversity Informatics* 8: 1–11.

Combrink, A.S. & Kyle, R. 2006. A Handbook on the Rare, Threatened & Endemic Species of the Greater St Lucia Wetland Park. Unpublished internal report, Ezemvelo KZN Wildlife.

Combrink, X. 2007. Greater St Lucia Wetland Park rare, threatened & endemic species project. *SANSA Newsletter* 3: 4.

Convention on Biological Diversity, 2006. Guide to the Global Taxonomy Initiative. http://www.cbd.int/doc/publications/cbd-ts-30.pdf (accessed 2 December 2014).

Costall, J.A. & Death, R.G. 2010. Population monitoring of the endangered New Zealand spider, *Latrodectus katipo*, with artificial cover objects. *New Zealand Journal of Ecology* 34: 253–258.

Craemer, C. 2006. Spiders a problem on export grapes. *Plant Protection News* 67: 10.

Croeser, P.M.C. 1996. A revision of the African huntsman spider genus *Palystes* L. Koch 1875 (Araneae: Heteropodidae). *Annals of the Natal Museum* 37: 1–122.

Crouch, T. & Lubin, Y. 2000. Effects of climate and prey availability on foraging in the social spider *Stegodyphus mimosarum* (Araneae, Eresidae). *Journal of Arachnology* 28: 158–168.

CROUCH, T. & LUBIN, Y. 2001. Population stability and extinction in a social spider *Stegodyphus mimosarum* (Araneae: Eresidae). *Biological Journal of the Linnean Society* 72: 409–417.

CROUCH, T. & MALAN, G. 2002. The use of social *Stegodyphus* spider retreats as nest-lining by pale chanting-goshawks (*Melierax canorus*): is it about preference? *African Zoology* 37: 61–66.

CROUCH, T., LUBIN, Y. & BODASING, M. 1998. Dispersal in the social spider *Stegodyphus mimosarum* Pavesi, 1883 (Araneae: Eresidae). *Durban Museum Novitates* 23: 52–55.

CUSHING, P.E. 1997. Myrmecomorphy and myrmecophily in spiders: a review. *Florida Entomologist* 80: 165–193.

CUSHING, P.E. 2012. Spider-ant associations: an updated review of myrmecomorphy, myrmecophily, and myrmecophagy in spiders. *Psyche* 2012 (151989): 1–23.

DEAN, W.R.J. 1988. Spider predation on termites (Hodotermitidae). *Journal of the Entomological Society of Southern Africa* 51: 147–148.

DEAN, W.R.J. & MILTON, S.J. 1995. Plant and invertebrate assemblages on old fields in the arid southern Karoo, South Africa. *African Journal of Ecology* 33: 1–13.

DEWAR, M. & KOOPOWITZ, H. 1970. Behaviour of South African social spiders: prey capture. *American Zoologist* 10: 476–477.

DIPPENAAR, A.S., UECKERMANN, E. & PICKER, M. 2011. Spiders, mites, ticks. In Picker, M. & Griffiths, C. (Eds), *Invasive and Alien Animals – a South African Perspective*. Cape Town, Struik Publishers. pp. 150–159.

DIPPENAAR-SCHOEMAN, A.S. 1976. An ecological study of the spider population in strawberries with special reference to the role of *Pardosa crassipalpis* Purcell (Araneae: Lycosidae) in the control of *Tetranychus cinnabarinus* (Boisduval). Unpublished MSc thesis, Rand Afrikaanse Universiteit.

DIPPENAAR-SCHOEMAN, A.S. 1977. The biology of *Pardosa crassipalpis* Purcell (Araneae: Lycosidae). *Journal of the Entomological Society of southern Africa* 40: 225–236.

DIPPENAAR, S., DIPPENAAR-SCHOEMAN, A.S., MODIBA, M.A. & KHOZA, T.T. 2008. A checklist of spiders (Arachnida, Araneae) of the Polokwane Nature Reserve, Limpopo Province, South Africa. *Koedoe* 50: 10–17.

DIPPENAAR-SCHOEMAN, A.S. 1979. Spider communities in strawberry beds: seasonal changes in numbers and species composition. *Phytophylactica* 11: 1–4.

DIPPENAAR-SCHOEMAN, A.S. 1988. Annotated check list of the spiders (Araneae) of the Mountain Zebra National Park. *Koedoe* 31: 151–160.

DIPPENAAR-SCHOEMAN, A.S. 1990. A revision of the African spider genus *Seothyra* Purcell (Araneae: Eresidae). *Cimbebasia* 12: 135–160.

DIPPENAAR-SCHOEMAN, A.S. 1998. Spiders as predators of citrus pests. In Bedford, E.C.G., Van den Berg, M.A. & De Villiers, E.A. (Eds), *Citrus pests in the Republic of South Africa*. Pretoria, Agricultural Research Council. pp. 34–35.

DIPPENAAR-SCHOEMAN, A.S. 2001. Spiders as predators of pests of tropical and non-citrus subtropical crops. In Van den Berg, M.A., De Villiers, E. A. & Joubert, P.H. (Eds), *Pests of Tropical and non-citrus Subtropical Crops in the Republic of South Africa*. Nelspruit, ARC-Institute for Tropical and Subtropical Crops. pp. 14–17.

DIPPENAAR-SCHOEMAN, A.S. 2002a. Status of South African Arachnida Fauna. Proceedings of the symposium on the Status of South African species organized by the Endangered Wildlife Trust (EWT) of South Africa, Rosebank, 4–7 September 2001.

DIPPENAAR-SCHOEMAN, A.S. 2002b. *The Baboon and Trapdoor Spiders of Southern Africa: An identification manual*. Plant Protection Research Institute Handbook No. 13. Pretoria, Agricultural Research Council.

DIPPENAAR-SCHOEMAN, A.S. 2002c. Araneae. In De Moor, I.J., Day, J.A. & De Moor, F.C. (Eds), *Guide to the Freshwater Invertebrates of Southern Africa*. Pretoria, Water Research Commission.

DIPPENAAR-SCHOEMAN, A.S. 2006. New records of 43 spider species from the Mountain Zebra National Park, South Africa (Arachnida: Araneae). *Koedoe* 49: 23–28.

DIPPENAAR-SCHOEMAN, A.S. 2011. South African National Survey of Arachnida (SANSA) – second phase completed. *Plant Protection News* 87: 7–8.

DIPPENAAR-SCHOEMAN, A.S. 2013. First national species lists of South African arachnids available. *Plant Protection News* 95: 6.

DIPPENAAR-SCHOEMAN, A.S. 2014a. *Field Guide to the Spiders of South Africa*. Pretoria, Lapa.

DIPPENAAR-SCHOEMAN, A.S. 2014b. SANSA atlassing surveys: Gauteng Province. *SANSA Newsletter* 21: 2–3.

DIPPENAAR-SCHOEMAN, A.S. & CRAEMER, C. 2000. The South African National Survey of Arachnida. *Plant Protection News* 56: 11–12.

DIPPENAAR-SCHOEMAN, A.S. & GONZÁLEZ REYES, A.X. 2006. South African National Survey of Arachnida (SANSA): Solifugae (sun-spiders) of the national parks and reserves of South Africa (Arachnida, Solifugae). *Koedoe* 49: 29–38.

DIPPENAAR-SCHOEMAN, A.S. & HADDAD, C.R. 2006. What is the South African National Survey of Arachnida (SANSA) all about? *SANSA Newsletter* 1: 1–3.

DIPPENAAR-SCHOEMAN, A.S. & HADDAD, C.R. 2007. Maloti-Drakensberg Transfontier Conservation and Development Project (MDTP). *SANSA Newsletter* 2: 8.

DIPPENAAR-SCHOEMAN, A.S. & HADDAD, C.R. 2008. SANSA surveys: procedure, gap analysis, survey teams and the public. *SANSA Newsletter* 5: 4–8.

DIPPENAAR-SCHOEMAN, A.S. & HADDAD, C.R. 2011. Virtual Museum interesting stories. *SANSA Newsletter* 14: 7–8.

DIPPENAAR-SCHOEMAN, A.S. & HADDAD, C.R. 2014. *Spiders of the Grassland Biome*. Plant Protection Research Institute Handbook No. 19. Pretoria, ARC – Plant Protection Research Institute.

DIPPENAAR-SCHOEMAN, A.S. & HARRIS, R. 2005. Food storage by a wandering ground spider (Araneae: Ammoxenidae: *Ammoxenus*). *Journal of Arachnology* 33: 850–851.

DIPPENAAR-SCHOEMAN, A.S. & HARVEY, M. 2000. A check list of the pseudoscorpions of South Africa (Arachnida: Pseudoscorpiones). *Koedoe* 43: 89–102.

DIPPENAAR-SCHOEMAN, A.S. & JOCQUÉ, R. 1997. *African Spiders, An identification manual*. Plant Protection Research Institute Handbook No. 9. Pretoria, Agricultural Research Council.

DIPPENAAR-SCHOEMAN, A.S. & LEROY, A. 1996. Notes on the biology of *Pycnacantha tribulus*, another araneid without an orbweb (Araneae: Araneidae). *Revue Suisse de Zoologie* vol. hors série: 165–171.

DIPPENAAR-SCHOEMAN, A.S. & LEROY, A. 2003. A check list of the spiders of the Kruger National Park, South Africa (Arachnida: Araneae). *Koedoe* 46: 91–100.

DIPPENAAR-SCHOEMAN, A.S. & LYLE, R. 2014. Several SANSA projects underway –three new projects in Gauteng. *SANSA Newsletter* 20: 10.

DIPPENAAR-SCHOEMAN, A.S. & MYBURGH, J.G. 2009. A review of the cave spiders (Arachnida: Araneae) from South Africa. *Transactions of the Royal Society of South Africa* 64: 53–61.

DIPPENAAR-SCHOEMAN, A.S. & VAN DEN BERG, A. 1988. Common names of spiders (Araneae) of southern Africa. *Koedoe* 31: 161–201.

DIPPENAAR-SCHOEMAN, A.S. & VAN DEN BERG, A.M. 2010. *Spiders of the Kalahari*. Plant Protection Research Institute Handbook No. 17. Pretoria, Agricultural Research Council.

DIPPENAAR-SCHOEMAN, A.S. & WASSENAAR, T. 2002. A checklist of the ground-dwelling spiders of coastal dune forests at Richards Bay, South Africa (Arachnida: Araneae). *Bulletin of the British Arachnological Society* 12: 275–279.

DIPPENAAR-SCHOEMAN, A.S. & WASSENAAR, T. 2006. A checklist of spiders from the herbaceous layer of a coastal dune forest ecosystem at Richards Bay, KwaZulu-Natal, South Africa (Arachnida: Araneae). *African Invertebrates* 47: 63–70.

Dippenaar-Schoeman, A.S., Genis, N.D.L., Van Ark, H. & Viljoen, J.H. 1978. The effect of Dieldrin coverspraying on some South African spiders and scorpions. *Phytophylactica* 10: 115–122.

Dippenaar-Schoeman, A.S., Van den Berg, A.M. & Van den Berg, A. 1989. Species composition and relative seasonal abundance of spiders from the field and tree layers of the Roodeplaat Dam Nature Reserve. *Koedoe* 32: 51–60.

Dippenaar-Schoeman, A.S., De Jager, M. & Van den Berg, A. 1996a. Behaviour and biology of two species of termite-eating spiders, *Ammoxenus amphalodes* and *A. daedalus* (Araneae: Ammoxenidae), in South Africa. *African Plant Protection* 2: 15–17.

Dippenaar-Schoeman, A.S., De Jager, M. & Van den Berg, A. 1996b. *Ammoxenus* species (Araneae: Ammoxenidae) – specialist predators of harvester termites in South Africa. *African Plant Protection* 2: 103–109.

Dippenaar-Schoeman, A.S., Van den Berg, A.M. & Van den Berg, A. 1999a. Spiders in South African cotton fields: species diversity and abundance (Arachnida: Araneae). *African Plant Protection* 5: 93–103.

Dippenaar-Schoeman, A.S., Leroy, A., De Jager, M. & Van den Berg, A. 1999b. A check list of the spider fauna of the Karoo National Park, South Africa (Arachnida: Araneae). *Koedoe* 42: 31–42.

Dippenaar-Schoeman, A.S., Van den Berg, M.A. & Van den Berg, A.M. 2001a. Spiders in macadamia orchards in the Mpumalanga Lowveld of South Africa: species diversity and abundance (Arachnida: Araneae). *African Plant Protection* 7: 36–46.

Dippenaar-Schoeman, A.S., Van den Berg, M.A. & Van den Berg, A.M. 2001b. Salticid spiders in macadamia orchards in the Mpumalanga Lowveld of South Africa (Arachnida: Araneae: Salticidae). *African Plant Protection* 7: 47–51.

Dippenaar-Schoeman, A.S., Van den Berg, A.M., Van den Berg, M.A. & Foord, S.H. 2005a. Spiders in avocado orchards in the Mpumalanga Lowveld of South Africa: species diversity and abundance (Arachnida: Araneae). *African Plant Protection* 11: 8–16.

Dippenaar-Schoeman, A.S., Van der Walt, A.E., Le Roux, E. & Van den Berg, A. 2005b. The spiders of the Swartberg Nature Reserve in South Africa (Arachnida: Araneae). *Koedoe* 48: 77–86.

Dippenaar-Schoeman, A.S., González Reyes, A.X. & Harvey, M. 2006a. A check-list of the Solifugae (sun-spiders) of South Africa (Arachnida, Solifugae). *African Plant Protection* 12: 70–92.

Dippenaar-Schoeman, A.S., Van der Merwe, M. & Van den Berg, A.M. 2006b. Habitat preferences and seasonal activity of the Microstigmatidae from Ngome State Forest, South Africa (Arachnida: Araneae). *Koedoe* 49: 85–89.

Dippenaar-Schoeman, A.S., Jones, A., Haddad, C.R. & Lotz, L.N., 2008. SANSA surveys in the Free State: the spider fauna of the Mpetsane Conservation Estate (Arachnida: Araneae). *SANSA Newsletter* 5: 12.

Dippenaar-Schoeman, A., Van den Berg, A. & Prendini, L. 2009. Spiders and Scorpions (Arachnida: Araneae, Scorpiones) of the Nylsvley Nature Reserve, South Africa. *Koedoe* 51 (161): 1–9.

Dippenaar-Schoeman, A.S., Haddad, C.R., Foord, S.H., Lyle, R., Lotz, L. N., Helberg, L., Mathebula, S., Van den Berg, A., Van den Berg, A.M., Van Niekerk, E. & Jocqué, R. 2010. *First Atlas of the Spiders of South Africa*. South African National Survey of Arachnida Technical Report version 1.

Dippenaar-Schoeman, A.S., Hamer, M. & Haddad, C.R. 2011. Spiders (Arachnida: Araneae) of the vegetation layer of the Mkambati Nature Reserve, Eastern Cape, South Africa. *Koedoe* 53 (1058): 1–10.

Dippenaar-Schoeman, A.S., Lyle, R. & Van den Berg, A.M. 2012. Bioinformatics on the spiders of South Africa. *Serket* 13: 121–127.

Dippenaar-Schoeman, A.S., Van den Berg, A.M., Haddad, C.R. & Lyle, R. 2013a. Spiders in South African agroecosystems: a review. *Transactions of the Royal Society of South Africa* 68: 57–74.

Dippenaar-Schoeman, A.S., Foord, S.H. & Haddad, C.R. 2013b. *Spiders of the Savanna Biome of South Africa*. Thohoyandou, University of Venda and Pretoria, ARC – Plant Protection Research Institute.

Drinkrow, D.R., Cherry, M.I. & Siegfried, W.R. 1994. The role of natural history museums in preserving biodiversity in South Africa. *South African Journal of Science* 90: 470–479.

Durand, F., Swart, A., Marais, W., Jansen van Rensburg, C., Habig, J., Dippenaar- Schoeman, A., Ueckerman, E., Jacobs, R., De Wet, L., Tiedt, L. & Venter, E. 2012. Die karst-ekologie van die Bakwenagrot (Gauteng). *Suid-Afrikaanse Tydskrif vir Natuurwetenskap en Tegnologie* 31 (1): 1–17.

Eardley, C.D. & Dippenaar, A.S. 1996. Collection and preparation of material. I. Collecting methods. In Uys, V.M. & Urban, R.P. (Eds), *How to Collect and Preserve Insects and Arachnids*. Plant Protection Research Institute Handbook No. 7. Pretoria, Agricultural Research Council. pp. 23–35.

Edwards, S., Tolley, K.A., Vanhooydonck, B., Measey, G.J. & Herrel, A. 2013. Is dietary niche breadth linked to morphology and performance in Sandveld lizards *Nucras* (Sauria: Lacertidae)?. *Biological Journal of the Linnean Society* 110: 674–688.

Engelbrecht, I.A. 2010. Invertebrate species inventories in protected area management: are they useful? *African Entomology* 18: 235–245.

Engelbrecht, I. 2013. Pitfall trapping for surveying trapdoor spiders: the importance of timing, conditions and effort. *Journal of Arachnology* 41: 133–142.

Engelbrecht, I. & Prendini, L. 2012. Cryptic diversity of South African trapdoor spiders: three new species of *Stasimopus* Simon, 1892 (Mygalomorphae, Ctenizidae), and redescription of *Stasimopus robertsi* Hewitt, 1910. *American Museum Novitates* 3732: 1–42.

Fabricius, C., Burger, M. & Hockey, P.A.R. 2003. Comparing biodiversity between protected areas and adjacent rangeland in xeric succulent thicket, South Africa: arthropods and reptiles. *Journal of Applied Ecology* 40: 392–403.

Faiola, J., Dippenaar-Schoeman, A.S., Lyle, R., Cowan, P. & Brits, M. 2014. Survey of the arachnids of the Kliprivierberg Nature Reserve, Johannesburg. Abstracts of the 11th Colloquium of the African Arachnological Society, Amanzi Private Game Reserve, South Africa: 6.

Faith, D.P., Collen, B., Ariño, A.H., Koleff, P., Guinotte, J., Kerr, J. & Chavan, V. 2013. Bridging biodiversity data gaps: recommendations to meet users' data needs. *Biodiversity Informatics* 8: 41–58.

Foord, S.H. & Dippenaar-Schoeman, A.S. 2003. Spiders (Araneae). In Berger, K., Craffort, J.E., Graiger, I., Graiger, M.J., Hahn, N. & Macdonald, I. (Eds), *A First Synthesis of the Environmental, Biological and Cultural Assets of the Soutpansberg*. Makhadu, Leach Printers & Signs. pp. 45–50.

Foord, S.H. & Dippenaar-Schoeman, A.S. 2014. Space-time interactions and variability in spider diversity along an elevational transect in a Floristic Kingdom sensitive to climate change. Abstracts of the 11*th* Colloquium of the African Arachnological Society, Amanzi Private Game Reserve, South Africa: 7.

Foord, S.H. & Dippenaar-Schoeman, A.S. in review. Spider assemblage stability in a Floristic Kingdom sensitive to climate change. *Journal of Biogeography.*

Foord, S.H., Dippenaar-Schoeman, A.S. & Van der Merwe, M. 2002. A check list of the spider fauna of the Western Soutpansberg, South Africa (Arachnida: Araneae). *Koedoe* 45: 35–43.

Foord, S.H., Mafadza, M.M., Dippenaar-Schoeman, A.S. & Van Rensburg, B.J. 2008. Micro-scale heterogeneity of spiders (Arachnida: Araneae) in the Soutpansberg, South Africa: a comparative survey and inventory in representative habitats. *African Zoology* 43: 156–174.

Foord, S.H., Dippenaar-Schoeman, A.S. & Haddad, C.R. 2011a. South African spider diversity: African perspectives on the conservation of a mega-diverse group. In Grillo, O. & Venora, G. (Eds), *Changing Diversity in Changing Environment*. Rijeka, InTech Publishing. pp. 163–182.

Foord, S.H., Dippenaar-Schoeman, A.S., Haddad, C.R., Lotz, L.N. & Lyle, R. 2011b. The faunistic diversity of spiders (Arachnida, Araneae) of the Savanna Biome in South Africa. *Transactions of the Royal Society of South Africa* 66: 170–201.

FOORD, S.H., DIPPENAAR-SCHOEMAN, A.S. & STAM, E.M. 2013. Surrogates of spider diversity, leveraging the conservation of a poorly known group in the Savanna Biome of South Africa. *Biological Conservation* 161: 203–212.

FOORD, S.H., GELEBE, V. & PRENDINI, L. 2015. Effects of aspect and altitude on scorpion diversity along an environmental gradient in the Soutpansberg, South Africa. *Journal of Arid Environments* 113: 114–120.

FORBANKA, D.N. & NIBA, A.S. 2013. Distribution and diversity of epigaeic invertebrate assemblages in Silaka Nature Reserve, Eastern Cape, South Africa. *African Entomology* 21: 58–69.

FOURIE, R. 2010. Spider ecology in the Erfenis Dam Nature Reserve, Free State Province (Arachnida: Araneae). Unpublished MSc thesis, University of the Free State.

FOURIE, R., HADDAD, C.R. & JOCQUÉ, R. 2011. A revision of the purse-web spider genus *Calommata* Lucas, 1837 (Araneae: Atypidae) in the Afrotropical Region. *ZooKeys* 95: 1–28.

FOURIE, R., HADDAD, C.R., DIPPENAAR-SCHOEMAN, A.S. & GROBLER, A. 2013. Ecology of the plant-dwelling spiders (Arachnida: Araneae) of the Erfenis Dam Nature Reserve, South Africa. *Koedoe* 55 (1113): 1–9.

FRANZINI, P.Z.N., DIPPENAAR-SCHOEMAN, A.S., YESSOUFOU, K. & VAN DER BANK, F.H. 2013. Combined analyses of genetic and morphological data indicate more than one species of *Cyrtophora* (Araneae: Araneidae) in South Africa. *International Journal of Modern Biological Research* 1: 21–34.

GAIGHER, R. 2008. The effect of different vineyard management systems on the epigaeic arthropod assemblages in the Cape Floristic Region, South Africa. Unpublished MSc thesis, University of Stellenbosch.

GAIGHER, R. & SAMWAYS, M.J. 2010. Surface-active arthropods in organic vineyards, integrated vineyards and natural habitat in the Cape Floristic Region. *Journal of Insect Conservation* 14: 595–605.

GAIGHER, R. & SAMWAYS, M.J. 2014. Landscape mosaic attributes for maintaining groundliving spider diversity in a biodiversity hotspot. *Insect Conservation and Diversity* 7: 470–479.

GARDINER, M.M., BURKMAN, C.E. & PRAJZNER, S.P. 2013. The value of urban vacant land to support arthropod biodiversity and ecosystem services. *Environmental Entomology* 42: 1123–1136.

GERTSCH, W.J. 1979. *American Spiders*. San Francisco, Van Nostrand Reinhold.

GESS, F.W. & GESS, S.K. 1974. An ethological study of *Dichragenia pulchricoma* (Arnold) (Hymenoptera: Pompilidae), a southern African spider-hunting wasp which builds a turreted subterranean nest. *Annals of the Cape Provincial Museums* 9: 187–214.

GESS, F.W. & GESS, S.K. 1976. Ethological notes on *Dichragenia neavei* (Kohl) (Hymenoptera: Pompilidae), an African spider-hunting wasp building a turreted, subterranean nest. *Annals of the Cape Provincial Museums* 11: 129–134.

GESS, F.W. & GESS, S.K. 1980a. Spider vanquishers: the nesting of *Tachypompilus ignitus* (Smith) and *Batozonellus fuliginosus* (Klug). *Eastern Cape Naturalist* 69: 4–7.

GESS, F.W. & GESS, S.K. 1980b. The whited sepulcher – the nesting of *Chalybion tibiale* (Fabr.). *Eastern Cape Naturalist* 70: 11–14.

GESS, F.W. & GESS, S.K. 1999. The use by wasps, bees and spiders of shells of *Trigonephrus* Pilsb. (Mollusca: Gasteropoda: Dorcasiidae) in desertic winter-rainfall areas in southern Africa. *Journal of Arid Environments* 43: 143–153.

GESS, F.W., GESS, S.K. & WEAVING, A.J.S. 1982. Some aspects of the ethology of *Chalybion (Hemichalybion) spinolae* (Lepeltier) (Hymenoptera: Sphecidae: Sphecinae) in the Eastern Cape Province of South Africa. *Annals of the Cape Provincial Museums* 14: 139–149.

GRISWOLD, C.E. 1985. A revision of the African spiders of the family Microstigmatidae (Araneae: Mygalomorphae). *Annals of the Natal Museum* 27: 1–37.

GRISWOLD, C.E. 1991. Cladistic biogeography of Afromontane spiders. *Australian Systematic Botany* 41: 173–189.

GRISWOLD, C.E. & MEIKLE, T.C. 1990. Social life in a web. *Natural History* 89: 6–10.

GRISWOLD, C.E. & MEIKLE-GRISWOLD, T. 1987. *Archaeodictyna ulova* new species, (Araneae: Dictynidae), a remarkable kleptoparasite of group-living eresid spiders (*Stegodyphus* spp., Araneae: Eresidae). *American Museum Novitates* 2897: 1–11.

GRISWOLD, C.E., WOOD, H.M. & CARMICHAEL, A.D. 2012. The lace web spiders (Araneae, Phyxelididae) of Madagascar: phylogeny, biogeography and taxonomy. *Zoological Journal of the Linnean Society* 164: 728–810.

HADDAD, C.R. 2003. Spider ecology in pistachio orchards in South Africa. MSc dissertation, University of the Free State.

HADDAD, C.R. 2004. A revision of the African spider genus *Graptartia* Simon, 1896 (Araneae: Corinnidae). *African Entomology* 12: 71–81.

HADDAD, C.R. 2005. Ecology of spiders (Arachnida: Araneae) inhabiting *Themeda triandra* Forskål grassland in semi-arid South Africa. *Navorsinge van die Nasionale Museum, Bloemfontein* 21: 25–36.

HADDAD, C.R. 2006a. A new species of *Corinnomma* (Araneae: Corinnidae) from southern and eastern Africa, with taxonomic notes on *C. olivaceum* and *C. semiglabrum*. *African Invertebrates* 47: 71–83.

HADDAD, C.R. 2006b. *Spinotrachelas*, a new genus of tracheline sac spiders from South Africa (Araneae: Corinnidae). *African Invertebrates* 47: 85–93.

HADDAD, C.R. 2010. A new species of *Poachelas* from Maputaland, South Africa (Araneae: Corinnidae), with considerable range extension for *Poachelas striatus*. *African Invertebrates* 51: 313–319.

HADDAD, C.R. 2013. A revision of the ant-like sac spider genus *Apochinomma* Pavesi, 1881 (Araneae: Corinnidae) in the Afrotropical Region. *Journal of Natural History* 47: 2493–2529.

HADDAD, C.R. & DIPPENAAR-SCHOEMAN, A.S. 2001. The effect of egg parasitism by a *Psyllaephagus* sp. (Hymenoptera: Encyrtidae) on the population size of *Peucetia striata* Karsch, 1978 (Araneae: Oxyopidae) in the Free State, South Africa. *Abstracts of the 15th International Congress of Arachnology, Badplaas*: 78.

HADDAD, C.R. & DIPPENAAR-SCHOEMAN, A.S. 2002. The influence of mound structure on the diversity of spiders (Araneae) inhabiting the abandoned mounds of the snouted harvester termite *Trinervitermes trinervoides* (Sjöstedt). *Journal of Arachnology* 30: 403–408.

HADDAD, C.R. & DIPPENAAR-SCHOEMAN, A.S. 2005. Epigeic spiders (Arachnida: Araneae) in Nama Karoo grassland in the Northern Cape Province. *Navorsinge van die Nasionale Museum, Bloemfontein* 21: 1–10.

HADDAD, C.R. & DIPPENAAR-SCHOEMAN, A.S. 2006a. Epigeic spiders (Araneae) in pistachio orchards in South Africa. *African Plant Protection* 12: 12–22.

HADDAD, C.R. & DIPPENAAR-SCHOEMAN, A.S. 2006b. Spiders (Arachnida: Araneae) inhabiting abandoned mounds of the snouted harvester termite *Trinervitermes trinervoides* (Sjöstedt) (Isoptera: Termitidae: Nasutitermitinae) in the Free State, with notes on their biology. *Navorsinge van die Nasionale Museum, Bloemfontein* 22: 1–15.

HADDAD, C.R. & DIPPENAAR-SCHOEMAN, A.S. 2009. A checklist of the non-acarine arachnids (Chelicerata: Arachnida) of the De Hoop Nature Reserve, Western Cape Province, South Africa. *Koedoe* 51 (149): 1–9.

HADDAD, C.R. & DIPPENAAR-SCHOEMAN, A.S. 2015. Diversity of non-acarine arachnids of the Ophathe Game Reserve, South Africa: testing a rapid sampling protocol. *Koedoe* 57 (1255): 1–15.

HADDAD, C.R. & LOUW, S.VDM. 2006. Phenology, ethology and fecundity of *Heliophanus pistaciae* Wesołowska (Araneae: Salticidae), an agrobiont jumping spider in South African pistachio orchards. *African Plant Protection* 12: 1–11.

HADDAD, C.R. & LYLE, R. 2008. Three new genera of tracheline sac spiders from southern Africa (Araneae: Corinnidae). *African Invertebrates* 49: 37–76.

HADDAD, C.R. & WESOŁOWSKA, W. 2006. Notes on taxonomy and biology of two *Stenaelurillus* species from southern Africa (Araneae: Salticidae). *Annales Zoologici* (Warszawa) 56: 575–586.

HADDAD, C.R. & WESOŁOWSKA, W. 2011. New species and new records of jumping spiders from central South Africa (Araneae: Salticidae). *African Invertebrates* 52: 51–134.

Haddad, C.R. & Wesołowska, W. 2013. Additions to the jumping spider fauna of South Africa (Araneae: Salticidae). *Genus* 24: 459–501.

Haddad, C.R. & Louw, S.vdM. 2012. A redescription of *Merenius alberti* Lessert, 1923 (Araneae: Corinnidae), with remarks on colour polymorphism and its relationship to ant models. *African Invertebrates* 53: 571–591.

Haddad, C.R., Louw, S.vdM. & Dippenaar-Schoeman, A.S. 2004a. Spiders (Araneae) in ground covers of pistachio orchards in South Africa. *African Plant Protection* 10: 97–107.

Haddad, C.R., Louw, S.vdM. & Dippenaar-Schoeman, A.S. 2004b. An assessment of the biological control potential of *Heliophanus pistaciae* (Araneae: Salticidae) on *Nysius natalensis* (Hemiptera: Lygaeidae), a pest of pistachio nuts. *Biological Control* 31: 83–90.

Haddad, C.R., Dippenaar-Schoeman, A.S. & Pekár, S. 2005. Arboreal spiders (Arachnida: Araneae) in pistachio orchards in South Africa. *African Plant Protection* 11: 32–41.

Haddad, C.R., Dippenaar-Schoeman, A.S. & Wesołowska, W. 2006. A checklist of the non-acarine arachnids (Chelicerata: Arachnida) of the Ndumo Game Reserve, Maputaland, South Africa. *Koedoe* 49: 1–22.

Haddad, C.R., Louw, S.vdM. & Pekár, S. 2008. Commercial pistachio orchards maintain lower density and diversity of spiders (Araneae): a study from South Africa. *African Plant Protection* 14: 24–36.

Haddad, C.R., Honiball, A.S., Dippenaar-Schoeman, A.S., Slotow, R. & Van Rensburg, B.J. 2010. Spiders (Arachnida: Araneae) as indicators of elephant-induced habitat changes in the Maputaland Centre of Endemism, South Africa. *African Journal of Ecology* 48: 446–460.

Haddad, C.R., Dippenaar-Schoeman, A.S., Foord, S.H., Lotz, L.N. & Lyle, R. 2013. The faunistic diversity of spiders (Arachnida: Araneae) of the Grassland Biome in South Africa. *Transactions of the Royal Society of South Africa* 68: 97–122.

Haddad, C.R., Foord, S.H., Fourie, R. & Dippenaar-Schoeman, A.S. (in press). Effects of a fast-burning spring fire on the ground-dwelling spider assemblages (Arachnida: Araneae) in a central South African grassland habitat. *African Zoology.*

Halleen, F. & Dippenaar-Schoeman, A.S. 2013. Spiders in vineyards. *SANSA Newsletter* 19: 10.

Hamer, M. 2012. An assessment of zoological research collections in South Africa. *South African Journal of Science* 108 (1090): 1–11.

Hann, S.W. 1990. Evidence for the displacement of an endemic New Zealand spider, *Latrodectus katipo* Powell by the South African species *Steatoda capensis* Hann (Araneae: Theridiidae). *New Zealand Journal of Zoology* 17: 295–307.

Harington, J.S. 1951. A new leptonetid spider, *Cangoderces lewisi*, n. gen., n. sp., from the Cango Caves, Oudtshoorn. *Annals of the Natal Museum* 12: 81–90.

Hebert, P.D.N., Cywinska, A., Ball, S.L. & De Waard, J.R. 2003. Biological identifications through DNA barcodes. *Proceedings of the Royal Society of London B* 270: 313–321.

Heidger, C. 1988. Ecology of spiders inhabiting abandoned mammal burrows in South African savanna. *Oecologia* 76: 303–306.

Heino, J. & Soininen, J. 2007. Are higher taxa adequate surrogates for species-level assemblage patterns and species richness in stream organisms?. *Biological Conservation* 137: 78–89.

Henschel, J.R., Schneider, J.M. & Meikle, T. 1996. Does group-living or aggregation of the spiders *Stegodyphus* affect parasitism by the wasp *Pseudopompilus*? *Bulletin of the British Arachnological Society* 10: 138–140.

Holm, E. & Dippenaar-Schoeman, A.S. 2010. *Goggo Guide: the Arthropods of southern Africa*. Pretoria, Lapa.

Horn, J.L. 2004. The invertebrates of indigenous forests in Limpopo Province, South Africa: diversity, biogeography and conservation. Unpublished MSc thesis, University of KwaZulu-Natal.

Hostetler, M., Allen, W. & Meurk, C. 2011. Conserving urban biodiversity? Creating green infrastructure is only the first step. *Landscape and Urban Planning* 100: 369–371.

Jäger, P. 2014. *Olios sjostedti* Lessert, 1921 (Araneae: Sparassidae): first description of the female and first records from South Africa and Botswana. *African Invertebrates* 55: 201–208.

Jansen, R., Makaka, L., Little, I.T. & Dippenaar-Schoeman, A.S. 2013. Response of ground-dwelling spider assemblages (Arachnida, Araneae) to montane grassland management practices in South Africa. *Insect Conservation and Diversity* 6: 572–589.

Jocqué, R. 1990. A revision of the Afrotropical genus *Diores* (Araneae, Zodariidae). *Annales du Musée Royal de l'Afrique Centrale* 260: 1–81.

Jocqué, R. 1991. A generic revision of the spider family Zodariidae (Araneae). *Bulletin of the American Museum of Natural History* 201: 1–160.

Jocqué, R. & Dippenaar-Schoeman, A.S. 1992. Two new termite-eating *Diores* species (Araneae, Zodariidae) and some unique observations on unique prey immobilization. *Journal of Natural History* 26: 1405–1412.

Jocqué, R., Alderweireldt, M. & Dippenaar-Schoeman, A.S. 2013. Biodiversity: An African perspective. In Penney, D. (Ed.), *Spider Research in the 21st Century.* Manchester, Siri Scientific Press. pp. 18–57.

Johannesen, J., Lubin, Y., Smith, D.R., Bilde, T. & Schneider, J.M. 2007. The age and evolution of sociality in *Stegodyphus* spiders: a molecular phylogenetic perspective. *Proceedings of the Royal Society of London B* 274: 231–237.

Johannesen, J., Moritz, R.F.A., Simunek, H., Seibt, U. & Wickler, W. 2009a. Species cohesion despite extreme inbreeding in a social spider. *Journal of Evolutionary Biology* 22: 1137–1142.

Johannesen, J., Wickler, W., Seibt, U. & Moritz, R.F.A. 2009b. Population history in social spiders repeated: colony structure and lineage evolution in *Stegodyphus mimosarum* (Eresidae). *Molecular Ecology* 18: 2812–2818.

Jonsson, M., Bell, D., Hjältén, J., Rooke, T. & Scogings, P.F. 2010. Do mammalian herbivores influence invertebrate communities via changes in the vegetation? Results from a preliminary survey in Kruger National Park, South Africa. *African Journal of Range & Forage Science* 27: 39–44.

Josling, N.A. & Lotz, L.N. 2014. Spiders of the Kalkfontein Dam Nature Reserve. *Abstracts of the 11th Colloquium of the African Arachnological Society, Amanzi Private Game Reserve, South Africa*: 14.

Kaiser, W., Avenant, N. & Haddad, C.R. 2009. Assessing the ecological integrity of a grassland ecosystem: refining the SAGraSS method. *African Journal of Ecology* 47: 308–317.

Kassimatis, E. 2008. Surveys of the National Botanical Gardens: Pretoria National Botanical Garden. *SANSA Newsletter* 6: 5.

Keiser, C.N., Modlmeier, A.P., Singh, N., Jones, D.K. & Pruitt, J.N. 2014a. Exploring how a shift in the physical environment shapes individual and group behavior across two social contexts. *Ethology* 120: 825–833.

Keiser, C.N., Jones, D.K., Modlmeier, A.P. & Pruitt, J.N. 2014b. Exploring the effects of individual traits and within-colony variation on task differentiation and collective behavior in an arid social spider. *Behavioral Ecology and Sociobiology* 68: 839–850.

Kelly, J. & Dippenaar-Schoeman, A.S. 2014. What do flower crab spiders really prey on?. *Plant Protection News* 98: 6.

Kelly, J., Mathebula, S. & Dippenaar-Schoeman A.S. 2014. Species for Africa – a rich biodiversity of insects and spiders collected from one trap in an urban area in Pretoria. *Abstracts of the 11th Colloquium of the African Arachnological Society, Amanzi Private Game Reserve, South Africa*: 16.

Kerley, G.I.H. 1989. Diet of small mammals from the Karoo, South Africa. *South African Journal of Wildlife Research* 19: 67–72.

Kobelt, M. & Nentwig, W. 2008. Alien spider introductions to Europe supported by global trade. *Diversity and Distributions* 14: 273–280.

Kopij, G. 2000. Diet of swifts (Apodidae) and swallows (Hirundinidae) during the breeding season in South African grassland. *Acta Ornithologica* 35: 203–206.

Kotze, D.J. & Samways, M.J. 1999. Support for the multi-taxa approach in biodiversity assessment, as shown by epigaeic invertebrates in an Afromontane forest archipelago. *Journal of Insect Conservation* 3: 125–143.

Kotze, D.J. & Samways, M.J. 2001. No general edge effects for invertebrates at Afromontane forest/grassland ecotones. *Biodiversity and Conservation* 10: 443–466.

Kraus, O. & Kraus, M. 1988. The genus *Stegodyphus* (Arachnida, Araneae). Sibling species, species groups, and parallel origins of social living. *Verhandlungen naturwissenschaften vereins Hamburg (NF)* 30: 151–254.

Krüger, K. & Dippenaar-Schoeman, A.S. 2000. Integrated pest management of insect and mite pests on tomatoes. Unpublished report, Tomato Producers Organisation, ARC-PPRI.

Kuntner, M., Haddad, C.R., Aljančič, G. & Blejec, A. 2008. Ecology and web allometry of the arboricolous nephilid orb-weaving spider *Clitaetra irenae* in Maputaland. *Journal of Arachnology* 36: 583–594.

Lamoral, B.H. 1968. On the ecology and habitat adaptations of two intertidal spiders *Desis formidabilis* (O.P. Cambridge) and *Amaurobioides africanus* Hewitt, at "The Island" (Kommetjie, Cape Peninsula), with notes on the occurrence of two other spiders. *Annals of the Natal Museum* 20: 151–193.

Laskowski, K. & Pruitt, J.N. 2014. Evidence of social niche construction: persistent and repeated social interactions generate stronger personalities in a social spider. *Proceedings of the Royal Society of London B* 281: 1–7.

Lawes, M.J., Kotze, D.J., Bourquin, S.L. & Morris, C. 2005. Epigaeic invertebrates as potential ecological indicators of Afromontane forest condition in South Africa. *Biotropica* 37: 109–118.

Lawrence, R.F. 1953. *The Biology of the Cryptic Fauna of Forests, with Special Reference to the Indigenous Forests of South Africa*. Cape Town.

Lawrence, R.F., Croeser, P.M.C. & Dippenaar-Schoeman, A.S. 1980. Spiders of Maputaland with notes on associated Arthropods. In Bruton, M.N. & Cooper, K.H. (Eds), *Studies of the Ecology of Maputaland.* Durban, Rhodes University and the Natal Branch of the Wildlife Society of Southern Africa. pp. 146–163.

Leroy, A. 2008. Surveys of the National Botanical Gardens: Lowveld National Botanical Garden. *SANSA Newsletter* 6: 6.

Leroy, A. & Jocqué, R. 1993. A note on the stitching habit of *Chariobas* sp. (Araneae, Zodariidae). *Journal of African Zoology* 107: 189–190.

Leroy, A. & Leroy, J. 2000. *Spiderwatch in Southern Africa*. Cape Town, Struik.

Leroy, A. & Leroy, J. 2005. Notes on the natural history of a trapdoor spider *Ancylotrypa* Simon (Araneae, Cyrtaucheniidae) that constructs a spherical burrow plug. *Journal of Arachnology* 33: 558–562.

Leroy, J., Jocqué, R. & Leroy, A. 1998. On the behaviour of the African bolas-spider *Cladomelea akermani* Hewitt (Araneae, Araneidae, Cyrtarachninae), with description of the male. *Annals of the Natal Museum* 39: 1–9.

Lewis, A.S. & Dippenaar-Schoeman, A.S. 2011. A revision of the spider genus, *Sylligma* Simon, 1895 (Araneae: Thomisidae) from the Afrotropical Region. *African Entomology* 19: 119–132.

Little, I.T., Hockey, P.A.R. & Jansen, R. 2013. A burning issue: Fire overrides grazing as a disturbance driver for South African grassland bird and arthropod assemblage structure and diversity. *Biological Conservation* 158: 258–270.

Líznarová, E., Sentenská, L., Garcia, F.L., Pekár, S. & Viera, C. 2013. Local trophic specialisation in a cosmopolitan spider (Araneae). *Zoology* 116: 20–26.

Lotz, L.N. 2002. A revision of the Afrotropical genus *Cheiramiona* (Araneae: Miturgidae: Eutichurinae). *Annales Musee Royal de l'Afrique Centrale (série Zoologie)* 290: 39–86.

Lotz, L.N. 2006. Afrotropical Archaeidae: 3. The female of *Eriauchenius cornutus* and new species of *Afrarchaea* (Arachnida: Araneae) from South Africa. *Navorsinge van die Nasionale Museum, Bloemfontein* 22: 113–127.

Lotz, L.N. 2009. Harvestmen (Arachnida: Opiliones) in Southern Africa – an annotated catalogue with notes on distribution. *Navorsinge van die Nasionale Museum, Bloemfontein* 25: 1–46.

Lotz, L.N. 2015. New species of the Afrotropical spider genus *Cheiramiona* Lotz & Dippenaar-Schoeman (Araneae: Eutichuridae). *Zootaxa* 3981: 71–94.

Lotz, L.N., Seaman, M.T. & Kok, D.J. 1991. Surface active spiders (Araneae) of a site in semi-arid central South Africa. *Navorsinge van die Nasionale Museum, Bloemfontein* 7: 529–540.

Lovell, S., Hamer, M., Slotow, R. & Herbert, D. 2007. Assessment of congruency across invertebrate taxa and taxonomic levels to identify potential surrogates. *Biological Conservation* 139: 113–125.

Lovell, S., Hamer, M., Slotow, R. & Herbert, D. 2009. An assessment of the use of volunteers for terrestrial invertebrate biodiversity surveys. *Biodiversity and Conservation* 18: 3295–3307.

Lovell, S.J., Hamer, M.L., Slotow, R.H. & Herbert, D. 2010. Assessment of sampling approaches for a multi-taxa invertebrate survey in a South African savanna-mosaic ecosystem. *Austral Ecology* 35: 357–370.

Low, A.B. & Rebelo, A.G. 1996. *Vegetation of South Africa, Lesotho and Swaziland*. Pretoria, Department of Environmental Affairs and Tourism.

Lubin, Y. & Bilde, T. 2007. The evolution of sociality in spiders. *Advances in the Study of Behavior* 37: 83–145.

Lubin, Y., Birkhofer, K., Berger-Tal, R. & Bilde, T. 2009. Limited male dispersal in a social spider with extreme inbreeding. *Biological Journal of the Linnean Society* 97: 227–234.

Lubin, Y. & Crouch, T. 2003. Trial by fire: social spider colony demographics in periodically burned grassland. *African Zoology* 38: 145–151.

Lyle, R. 2011a. Arachnids join the Toyota Enviro Outreach. *SANSA Newsletter* 15: 4.

Lyle, R. 2011b. The male of *Fuchiba tortilis* Haddad & Lyle, 2008 and three new species of *Spinotrachelas* Haddad, 2006 from South Africa. *Annals of the Ditsong National Museum of Natural History* 1: 123–131.

Lyle, R. & Dippenaar-Schoeman, A.S. 2013. Sampling in the Diamond Route Reserves. *SANSA Newsletter* 18: 10.

Lyle, R. & Dippenaar-Schoeman, A.S. 2014. SANSA bio-blitz surveys 2. SANSA spider survey at the Ezemvelo Nature Reserve, Gauteng. *SANSA Newsletter* 20: 11–99.

Lyons, C.-L. 2009. Evaluating restoration success of alluvial diamond-mined sites in South Africa using invertebrate community indicators. Unpublished MSc thesis, University of Cape Town.

McGeoch, M.A., Sithole, H., Samways, M.J., Simaika, J.P., Pryke, J.S., Picker, M., Yus, C., Armstrong, A.J., Dippenaar-Schoeman, A.S., Engelbrecht, I.A., Braschler, B. & Hamer, M. 2011. Conservation and monitoring of invertebrates in terrestrial protected areas. *Koedoe* 52 (1000): 1–13.

McKinney, M.L. 2002. Urbanization, biodiversity, and conservation. *BioScience* 52: 883–890.

Magoba, R.N. & Samways, M.J. 2012. Comparative footprint of alien, agricultural and restored vegetation on surface-active arthropods. *Biological Invasions* 14: 165–177.

Majer, M., Svenning, J.-C. & Bilde, T. 2013. Habitat productivity constrains the distribution of social spiders across continents – case study of the genus *Stegodyphus*. *Frontiers in Zoology* 10 (9): 1–10.

Mansell, M. & Dippenaar-Schoeman, A.S. 2007. Spiders in vineyards. *SANSA Newsletter* 3: 12.

Marais, P. 2010. Barcoding South African arachnids. *SANSA Newsletter* 11: 2–3.

Marais, P. 2013. iIimbovane Outreach Project. *SANSA Newsletter* 18: 9.

Marais, P., Van den Berg, A.M. & Dippenaar-Schoeman, A.S. 2008. Effects of genetically modified Bt-maize on spider (Arachnida: Araneae) populations in the Delmas district, Mpumalanga, South Africa. Abstracts of the 9*th* Colloquium of the African Arachnological Society, Lajuma Mountain Retreat, South Africa: 23.

Marais, P., Dippenaar-Schoeman, A.S., Lyle, R., Anderson, C. & Mathebula, S. 2013. Catalog of the spider types deposited in the National Collection of Arachnida of the Agricultural Research Council, Pretoria (Arthropoda: Arachnida: Araneae). *ARC-Plant Protection Research Institute, Technical Communication* 2013 (1): 1–25.

Masner, L. 1968. A new scelionid wasp from the intertidal zone of South Africa (Hymenoptera: Scelionidae). *Annals of the Natal Museum* 20: 195–198.

Measey, G.J., Rebelo, A.D., Herrel, A., Vanhooydonck, B. & Tolley, K.A. 2011. Diet, morphology and performance in two chameleon morphs: do harder bites equate with harder prey?. *Journal of Zoology* 285: 247–255.

Mellet, M.A. 2005. Cotton cultivation practices with special reference to the effect of Bt-cotton on Arthropoda populations. Unpublished MSc thesis, University of Pretoria.

Mellet, M.A., Schoeman, A.S. & Dippenaar-Schoeman, A.S. 2006. The effect of Bt-cotton cultivation on spider populations in Marble Hall, South Africa. *African Plant Protection* 12: 40–50.

Mgobozi, P.M., Somers, M.J. & Dippenaar-Schoeman, A.S. 2008. Spider responses to alien plant invasion: the effect of short- and long-term *Chromolaena odorata* invasion and alien clearing. *Journal of Applied Ecology* 45: 1189–1197.

Midega, C.A.O. 2005. Impact of a habitat management system and Bt-maize on stemborer natural enemies and biodiversity of arthropods and soil fauna in Kenya and South Africa. Unpublished PhD dissertation, Kenyatta University.

Midega, C.A.O., Khan, Z.R., Van den Berg, J., Ogol, C.K.P.O., Dippenaar-Schoeman, A.S., Pickett, J.A. & Wadhams, L.J. 2008. Response of ground dwelling arthropods to a 'push-pull' system and Bt-maize: spiders as an indicator group. *Journal of Applied Entomology* 132: 248–254.

Midgley, J.M. 2012. Quantifying the structure of epigaeic invertebrate communities along an altitudinal gradient on the Great Escarpment, South Africa. Unpublished PhD thesis, Rhodes University.

Miller, J.A., Carmichael, A., Ramirez, M.J., Haddad, C.R., Řezáč, M., Johannesen, J., Kral, J., Wang, X.P., Spagna, J.C. & Griswold, C.E. 2010a. Phylogeny of entelegyne Spiders: affinities of the family Penestomidae (NEW RANK), generic phylogeny of Eresidae, and asymmetric rates of change in spinning organ evolution (Araneae, Araneoidea, Entelegynae). *Molecular Phylogenetics and Evolution* 55: 786–804.

Miller, J.A., Griswold, C.E. & Haddad, C.R. 2010b. Taxonomic revision of the spider family Penestomidae (Araneae, Entelegynae). *Zootaxa* 2534: 1–36.

Miller, J.A., Griswold, C.E., Scharff, N., Řezáč, M., Szűts, T. & Marhabaie, M. 2012. The velvet spiders: an atlas of the Eresidae (Arachnida, Araneae). *ZooKeys* 195: 1–144.

Modiba, M.A., Dippenaar, S.M. & Dippenaar-Schoeman, A.S. 2005. A checklist of spiders from Sovenga Hill, an inselberg in the Savanna Biome, Limpopo Province, South Africa (Arachnida: Araneae). *Koedoe* 48: 109–115.

Modlmeier, A.P., Laskowski, K.L., DeMarco, A.E., Coleman, A., Zhao, K., Brittingham, H.A., McDermott, D.R. & Pruitt, J.N. 2014. Persistent social interactions beget more pronounced personalities in a desert-dwelling social spider. *Biology Letters* 10: DOI: 10.1098/rsbl.2014.0419.

Moran, V.C. & Southwood, T.R.E. 1982. The guild composition of arthropod communities in trees. *Journal of Animal Ecology* 51: 289–306.

Mucina, L. & Rutherford, M.C. 2006. *The Vegetation of South Africa, Lesotho and Swaziland*. Pretoria, South African National Biodiversity Institute.

Muelelwa, M.I., Foord, S.H., Dippenaar-Schoeman, A.S. & Stam, E.M. 2010. Towards a standardized and optimized protocol for rapid assessments: spider species richness and assemblage composition in two savanna vegetation types. *African Zoology* 45: 273–290.

Mukherjee, A., Wilske, B., Navarro, R.A., Dippenaar-Schoeman, A.S. & Underhill, L.G. 2010. Association of spiders and lichen on Robben Island, South Africa: a case report. *Journal of Threatened Taxa* 2: 815–819.

Munyai, T.C. & Foord, S.H. 2012. Ants on a mountain: spatial, environmental and habitat associations along an altitudinal transect in a centre of endemism. *Journal of Insect Conservation* 16: 677–695.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., Da Fonseca, G.A.B. & Kent, J. 2000. Biodiversity hotspots for conservation priorities. *Nature* 403: 853–858.

Nagy, K.A., Huey, R.B. & Bennett, A.F. 1984. Field energetics and foraging mode of Kalahari lacertid lizards. *Ecology* 65: 588–596.

Nchai, M.C. 2008. The impact of land use on invertebrate assemblages in the Succulent Karoo, South Africa. Unpublished MSc thesis, University of Stellenbosch.

Neethling, J.A. & Haddad, C.R. 2013. Arboreal spider assemblages associated with four tree species in the Grassland Biome of central South Africa (Arachnida: Araneae). *Transactions of the Royal Society of South Africa* 68: 123–131.

Nel, E., Kelly, J. & Dippenaar-Schoeman, A.S. 2014. Notes on the biology of the wasp, *Chalybion spinolae* (Hymenoptera: Sphecidae), an obligatory predator of *Latrodectus* (Araneae: Theridiidae) spiders in South Africa. *Journal of Natural History* 48: 1585–1593.

Nentwig, W. & Kobelt, M. 2010. Spiders (Araneae). In Roques, A. *et al*. (Eds), *Alien Terrestrial Arthropods of Europe*. *BioRisk* 4: 131–147.

New, T.R. 1999. Untangling the web: spiders and the challenges of invertebrate conservation. *Journal of Insect Conservation* 3: 251–256.

Nicolai, V. 1989. Thermal properties and fauna on the bark of trees in two different African ecosystems. *Oecologia* 80: 421–430.

Owen, C.A., Coetzee, J.A. & Van Noort, S. 2014. Distributional range of the South African maritime spider-egg parasitoid wasp, *Echthrodesis lamorali* (Hymenoptera: Platygastridae: Scelioninae). *African Invertebrates* 55: 323–332.

Parr, C.L., Robertson, H.G., Biggs, H.C. & Chown, S.L. 2004. Response of African savanna ants to long-term fire regimes. *Journal of Applied Ecology* 41: 630–642.

Pekár, S. & Haddad, C.R. 2011. Trophic strategy of ant-eating *Mexcala elegans* (Araneae: Salticidae): looking for evidence of evolution of prey-specialization. *Journal of Arachnology* 39: 133–138.

Petráková, L., Líznarová, E., Pekár, S., Haddad, C.R., Sentenská, L. & Symondson, W.O.C. (2015). Discovery of a monophagous true predator, a specialist termite-eating spider (Araneae: Ammoxenidae). *Scientific Reports* 5, Article number: 14013.

Picker, M. & Griffiths, C. (Eds) 2011. *Alien & Invasive Animals: A South African perspective*. Cape Town, Struik Nature.

Picker, M.D. & Samways, M.J. 1996. Faunal diversity and endemicity of the Cape Peninsula, South Africa – a first assessment. *Biodiversity and Conservation* 5: 591–606.

Podjed, D. & Muršič, R. 2008. Dialectical relations between professionals and volunteers in a biodiversity monitoring organization. *Biodiversity and Conservation* 17: 3471–3483.

Power, R.J. 2014. The arachnofauna of the North West Province: a literature survey. Unpublished report, Department of Economic Development, Environment, Conservation & Tourism, North West Provincial Government, Mahikeng.

Prendini, L. 2005. Scorpion diversity and distribution in southern Africa: pattern and process. In Huber, B.A., Sinclair, B.J. & Lampe, K.-H. (Eds), *African Biodiversity: Molecules, Organisms, Ecosystems*. *Proceedings of the 5th International Symposium on Tropical Biology, Museum Alexander Koenig, Bonn*. New York, Springer Verlag. pp. 25–68.

Prendini, L., Weygoldt, P. & Wheeler, W.C. 2005. Systematics of the *Damon variegatus* group of African whip spiders (Chelicerata: Amblypygi): evidence from behaviour, morphology and DNA. *Organisms, Diversity and Evolution* 5: 203–236.

PRYKE, J.S. & SAMWAYS, M.J. 2008. Conservation of invertebrate biodiversity on a mountain in a global biodiversity hotspot, Cape Floral Region. *Biodiversity and Conservation* 17: 3027–3043.

PRYKE, J.S. & SAMWAYS, M.J. 2009. Recovery of invertebrate diversity in a rehabilitated city landscape mosaic in the heart of a biodiversity hotspot. *Landscape and Urban Planning* 93: 54–62.

PRYKE, J.S. & SAMWAYS, M.J. 2010. Significant variables for the conservation of mountain invertebrates. *Journal of Insect Conservation* 14: 247–256.

PRYKE, J.S. & SAMWAYS, M.J. 2012a. Importance of using many taxa and having adequate controls for monitoring impacts of fire for arthropod conservation. *Journal of Insect Conservation* 16: 177–185.

PRYKE, J.S. & SAMWAYS, M.J. 2012b. Conservation management of complex natural forest and plantation edge effects. *Landscape Ecology* 27: 73–85.

PRYKE, J.S. & SAMWAYS, M.J. 2012c. Ecological networks act as extensions of protected areas for arthropod biodiversity conservation. *Journal of Applied Ecology* 49: 591–600.

RADFORD, A.N. 2008. Age-related changes in nestling diet of the cooperatively breeding green woodhoopoe. *Ethology* 114: 907–915.

RAMÍREZ, M.J. 2014. The morphology and phylogeny of Dionychan spiders (Araneae: Araneomorphae). *Bulletin of the American Museum of Natural History* 390: 1–374.

REBELO, T.G., FREITAG, S., CHENEY, C. & MCGEOCH, M.A. 2011. Prioritising species of special concern for monitoring in Table Mountain National Park: The challenge of a species rich, threatened ecosystem. *Koedoe* 53 (1019): 1–14.

REDBORG, K.E. 1998. Biology of the Mantispidae. *Annual Review of Entomology* 43: 175–194.

REYERS, B. & MCGEOCH, M.A. 2007. A biodiversity monitoring framework for South Africa: progress and directions. *South African Journal of Science* 103: 295–300.

REYNOLDS, B.N. 2014. The effects of long-term burning regimes on savanna spider assemblages. Unpublished MSc thesis, University of Pretoria.

RIVERS-MOORE, N.A. & SAMWAYS, M.J. 1996. Game and cattle trampling, and impacts of human dwellings on arthropods at a game park boundary. *Biodiversity and Conservation* 5: 1545–1556.

ROBERTSON, M.P., CUMMING, G.S. & ERASMUS, B.F.N. 2010. Getting the most out of atlas data. *Diversity and Distributions* 16: 363–375.

ROBERTSON, M.P., HARRIS, K.R., COETZEE, J.A., FOXCROFT, L.C., DIPPENAAR-SCHOEMAN, A.S. & VAN RENSBURG, B.J. 2011. Assessing local scale impacts of *Opuntia stricta* (Cactaceae) invasion on beetle and spider diversity in Kruger National Park, South Africa. *African Zoology* 46: 205–223.

ROETS, F. & PRYKE, J.S. 2013. The rehabilitation value of a small culturally significant island based on the arthropod natural capital. *Journal of Insect Conservation* 17: 53–65.

ROFF, J. & DIPPENAAR-SCHOEMAN, A.S. 2005. Description of a new species of *Cladomelea* bolas-spider from South Africa, with notes on its behaviour (Araneae: Araneidae). *African Invertebrates* 45: 1–6.

ROFF, J. & HADDAD, C.R. 2015. *Pasilobus dippenaarae* sp. n. (Araneae: Araneidae), a new species of bird-dropping spider from South Africa, with a key to the Afrotropical species. *African Invertebrates* 56: 445–454.

RUCH, J., HEINRICH, L., BILDE, T. & SCHNEIDER, J.M. 2009a. Relatedness facilitates cooperation in the subsocial spider, *Stegodyphus tentoriicola*. *BMC Evolutionary Biology* 9 (257): 1–7.

RUCH, J., HEINRICH, L., BILDE, T. & SCHNEIDER, J.M. 2009b. The evolution of social inbreeding mating systems in spiders: limited male mating dispersal and lack of pre-copulatory inbreeding avoidance in a subsocial predecessor. *Biological Journal of the Linnean Society* 98: 851–859.

RUCH, J., HEINRICH, L., BILDE, T. & SCHNEIDER, J.M. 2012. Site selection and foraging in the eresid spider *Stegodyphus tentoriicola*. *Journal of Insect Behaviour* 25: 1–11.

SASA, A. 2011. Arthropods associated with commercial Proteaceae in the Western Cape Province, South Africa. Unpublished MSc thesis, University of Stellenbosch.

SCHEFFERS, B.R., JOPPA, L.N., PIMM, S.L. & LAURANCE, W.F. 2012. What we know and don't know about Earth's missing biodiversity. *Trends in Ecology & Evolution* 27: 501–510.

SCHLINGER, E.I. 1987. The biology of Acroceridae (Diptera): True endoparasitoids of spiders. In Nentwig, W. (Ed.), *Ecophysiology of Spiders*. Berlin, Springer-Verlag. pp. 319–327.

SCHOEMAN, C. 2014. Beta diversity and turnover of groups in the Vhembe Biosphere Reserve. *SANSA Newsletter* 21: 4.

SCHÖNHOFER, A.L. 2008. On harvestmen from the Soutpansberg, South Africa, with description of a new species of *Monomontia* (Arachnida: Opiliones). *African Invertebrates* 49: 109–126.

SCOBLE, M. 2010. Rationale and value of natural history collections digitisation. *Biodiversity Informatics* 7: 77–80.

SEIBT, U. & WICKLER, W. 1988a. Interspecific tolerance in social *Stegodyphus* spiders (Eresidae, Araneae). *Journal of Arachnology* 16: 35–39.

SEIBT, U. & WICKLER, W. 1988b. Bionomics and social structure of 'Family Spiders' of the genus *Stegodyphus*, with special reference to the African species *S. dumicola* and *S. mimosarum* (Araneida, Eresidae). *Verhandlungen naturwissenschaftlicher Verein in Hamburg* 30: 255–303.

SEIBT, U. & WICKLER, W. 1990. The protective function of the compact silk nest of social *Stegodyphus* spiders (Araneae, Eresidae). *Oecologia* 82: 317–321.

SESHOTHELA, S.L. & DIPPENAAR-SCHOEMAN, A.S. 2011. New termite eating spiders from the Cederberg Wilderness Area (Araneae: Ammoxenidae). *Abstract of the 10th African Arachnological Colloquium in the Newsletter of the African Arachnological Society* 24: 20.

SEYMOUR, C.L. & DEAN, W.R.J. 1999. Effects of heavy grazing on invertebrate assemblages in the Succulent Karoo, South Africa. *Journal of Arid Environments* 43: 267–286.

SHARRATT, N.J., PICKER, M.D. & SAMWAYS, M.J. 2000. The invertebrate fauna of the sandstone caves of the Cape Peninsula (South Africa): patterns of endemism and conservation priorities. *Biodiversity and Conservation* 9: 107–143.

SMITH, G.F., STEENKAMP, Y., KLOPPER, R.R., SIEBERT, S.J. & ARNOLD, T.H. 2003. The price of collecting life. *Nature* 422: 375–376.

SMITH MEYER, M.K.P. 1996. *Mite Pests and their Predators on Cultivated Plants in Southern Africa, Vegetables and Berries*. Plant Protection Research Institute Handbook No. 6. Pretoria, Agricultural Research Council.

SNYMAN, L.P., OHL, M., MANSELL, M.W. & SCHOLTZ, C.H. 2012. A revision and key to the genera of Afrotropical Mantispidae (Neuropterida, Neuroptera), with the description of a new genus. *ZooKeys* 184: 67–93.

STEENKAMP, E. 2014. A comparative study of spider diversity from Robben Island to sites along the west coast in search of restoration targets. *SANSA Newsletter* 21: 9.

TOTI, D.S., COYLE, F.A. & MILLER, J.A. 2000. A structured inventory of Appalachian grass bald and heath bald spider assemblages and a test of species richness estimator performance. *Journal of Arachnology* 28: 329–345.

TRUTER, J., VAN HAMBURG, H. & VAN DEN BERG, J. 2014. Comparative diversity of arthropods on Bt Maize and Non-Bt Maize in two different cropping systems in South Africa. *Environmental Entomology* 43: 197–208.

TUCKER, R.W.E. 1917. On some South African Aviculariidae (Arachnida). Families Migidae, Ctenizidae, Diplotheleae and Dipluridae. *Annals of the South African Museum* 17: 79–138.

TUCKER, R.W.E. 1920a. Spiders of Kirstenbosch. *Journal of the Botanical Society of South Africa* 6: 21–24.

TUCKER, R.W.E. 1920b. Contributions to the South African Arachnid Fauna. II. On some new South African spiders of the families Barychelidae, Dipluridae, Eresidae, Zodariidae, Heracliidae, Urocteidae, Clubionidae. *Annals of the South African Museum* 17: 439–488.

TUCKER, R.W.E. 1923. The Drassidae of South Africa. *Annals of the South African Museum* 19: 251–437.

TURNER, A.A. (Ed.) 2012. *Western Cape Province State of Biodiversity 2012*. Stellenbosch, CapeNature Scientific Services.

UYS, C., HAMER, M. & SLOTOW, R. 2006. Effect of burn area on invertebrate recolonization in grasslands in the Drakensberg, South Africa. *African Zoology* 41: 51–65.

UYS, C., HAMER, M. & SLOTOW, R. 2010. Step process for selecting and testing surrogates and indicators of Afrotemperate forest invertebrate diversity. *PLoS ONE* 5 (e9100): 1–10.

UYS, C.J. 2012. The impact of pine plantations and alien invertebrates on native forest and fynbos invertebrate communities in Table Mountain National Park. Unpublished PhD thesis, University of Cape Town.

VALERIO, A.A., AUSTIN, A.D., MASNER, L. & JOHNSON, N.F. 2013. Systematics of Old World *Odontacolus* Kieffer *s.l.* (Hymenoptera, Platygastridae *s.l.*): parasitoids of spider eggs. *ZooKeys* 314: 1–151.

VAN DAM, G. & ROBERTS, A. 1917. Notes on nests of some trapdoor spiders and the nest of *Calommata transvaalicus* Hewitt. *Annals of the Transvaal Museum* 5: 218–233.

VAN DEN BERG, A.M. 1989. An investigation into the effects two commonly used pesticides on spider mite predator population in cotton with reference to spiders. Unpublished M.Sc. dissertation, Rand Afrikaanse Universiteit.

VAN DEN BERG, A.M. & DIPPENAAR-SCHOEMAN, A.S. 1988. Spider communities in a pine plantation at Sabie, eastern Transvaal: a preliminary survey. *Phytophylactica* 20: 293–296.

VAN DEN BERG, A.M. & DIPPENAAR-SCHOEMAN, A.S. 1991a. Spiders, predacious insects and mites on South African cotton. *Phytophylactica* 23: 85–86.

VAN DEN BERG, A. & DIPPENAAR-SCHOEMAN, A.S. 1991b. Ground-living spiders from an area where the harvester termite *Hodotermes mossambicus* occurs in South Africa. *Phytophylactica* 23: 247–253.

VAN DEN BERG, A., DIPPENAAR-SCHOEMAN, A.S., VAN JAARSVELDT, M.J. & VAN DER WALT E. 2002. Red-billed quelea control on the Springbok Flats: impact on the Arachnida fauna (Araneae). Abstracts of the 7*th* Colloquium of the African Arachnological Society, *Durban, South Africa*.

VAN DEN BERG, M.A., DEACON, V.E., FOURIE, C.J. & ANDERSON, S.H. 1987. Predators of the citrus psylla, *Trioza erytreae* (Hemiptera: Triozidae), in the Lowveld and Rustenburg areas of Transvaal. *Phytophylactica* 19: 285–289.

VAN DEN BERG, M.A., DIPPENAAR-SCHOEMAN, A.S., DEACON, V.E. & ANDERSON, S.H. 1992. Interaction between citrus psylla, *Trioza erytreae* (Hem. Triozidae), and spiders in an unsprayed citrus orchard in the Transvaal Lowveld. *Entomophaga* 37: 599–608.

VAN DER MERWE, M. 1994. A comparative survey of cursorial spider communities in indigenous Afromontane forests and in pine plantations. Unpublished MSc thesis, University of Pretoria.

VAN DER MERWE, M., DIPPENAAR-SCHOEMAN, A.S. & SCHOLTZ, C.H. 1996. Diversity of ground-living spiders at Ngome State Forest, KwaZulu-Natal: a comparative survey in indigenous forest and pine plantations. *African Journal of Ecology* 34: 342–350.

VAN HELSDINGEN, P.J. 2011. Spiders in a hostile world (Arachnoidea, Araneae). *Arachnologische Mitteilungen* 40: 55–64.

VAN NIEKERK, P. & DIPPENAAR-SCHOEMAN, A.S. 2013. A revision of the crab spider genus *Heriaeus* Simon, 1875 (Araneae: Thomisidae) in the Afrotropical Region. *African Invertebrates* 54: 447–476.

VAN NOORT, S. 2009. The maritime platygastrid *Echthrodesis lamorali* Masner. *Skaphion* 3 (40): 1–3.

VAN NOORT, S. 2011. Caught in the act – *Echthrodesis* laying eggs. *Skaphion* 5 (26–28): 1–2.

VAN NOORT, S., MASNER, L., POPOVICI, O., VALERIO, A.A., TAEKUL, C., JOHNSON, N., MURPHY, N.P. & AUSTIN, A.D. 2014. Systematics and biology of the aberrant intertidal parasitoid wasp *Echthrodesis lamorali* Masner (Hymenoptera: Platygastridae s.l.): a parasitoid of spider eggs. *Invertebrate Systematics* 28: 1–16.

VAN WILGEN, B.W., DAVIES, S.J. & RICHARDSON, D.M. 2014. Invasion science for society: a decade of contributions from the Centre for Invasion Biology. *South African Journal of Science* 110 (a0074): 1–12.

VASCONCELLOS-NETO, J., ROMERO, G.Q., SANTOS, A.J. & DIPPENAAR-SCHOEMAN, A.S. 2007. Associations of spiders of the genus *Peucetia* (Oxyopidae) with plants bearing glandular hairs. *Biotropica* 39: 221–226.

VELDTMAN, A. 2012. Arthropods. In Turner, A.A. (Ed.), *Western Cape Province State of Biodiversity 2012*. Stellenbosch, CapeNature Scientific Services.

VISSER, D., WRIGHT, M.G., VAN DEN BERG, A. & GILIOMEE, J. 1999. Species richness of arachnids associated with Protea (Proteaceae) in the Cape fynbos. *African Journal of Ecology* 37: 334–343.

VOSS, S.C., MAIN, B.Y. & DADOUR, I.R. 2007. Habitat preferences of the urban wall spider *Oecobius navus* (Araneae, Oecobiidae). *Australian Journal of Entomology* 46: 261–268.

WARD, P.I. & ENDERS, M.M. 1985. Conflict and cooperation in the group feeding of the social spider *Stegodyphus mimosarum*. *Behaviour* 94: 167–182.

WEBB, P. & DIPPENAAR-SCHOEMAN, A.S. 2014. A photographic survey of the arachnids of Irene. Abstracts of the 11*th* Colloquium of the African Arachnological Society, Amanzi Private Game Reserve, South Africa: 29.

WESOŁOWSKA, W. 2009. A revision of the spider genus *Mexcala* Peckham et Peckham, 1902 (Araneae: Salticidae). *Genus* 20: 149–186.

WESOLOWSKA, W. & CUMMING, M.S. 1999. The first termitivorous jumping spider (Araneae: Salticidae). *Bulletin of the British Arachnological Society* 11: 204–208.

WESOŁOWSKA, W. & HADDAD, C.R. 2002. A new termitivorous jumping spider from South Africa (Araneae Salticidae). *Tropical Zoology* 15: 197–207.

WESOŁOWSKA, W. & HADDAD, C.R. 2009. Jumping spiders (Araneae: Salticidae) of the Ndumo Game Reserve, Maputaland, South Africa. *African Invertebrates* 50: 13–103.

WESOŁOWSKA, W. & HADDAD, C.R. 2013. New data on the jumping spiders of South Africa (Araneae: Salticidae). *African Invertebrates* 54: 177–240.

WESOLOWSKA, W. & SZEREMETA, M. 2001. A revision of the ant like salticid genera *Enoplomischus* Giltay, 1931, *Kima* Peckham & Peckham, 1902 and *Leptorchestes* Thorell, 1870 (Araneae, Salticidae). *Insect Systematics & Evolution* 32: 217–240.

WESOŁOWSKA, W., AZARKINA, G.N. & RUSSELL-SMITH, A. 2014. Euophryine jumping spiders of the Afrotropical Region—new taxa and a checklist (Araneae: Salticidae: Euophryinae). *Zootaxa* 3789: 1–72.

WHEELER, Q.D., KNAPP, S., STEVENSON, D.W., STEVENSON, J., BLUM, S.D., BOOM, B.M., BORISY, G.G., BUIZER, J.L., DE CARVALHO, M.R., CIBRIAN, A., DONOGHUE, M.J., DOYLE, V., GERSON, E.M., GRAHAM, C.H., GRAVES, P., GRAVES, S.J., GURALNICK, R.P., HAMILTON, A.L., HANKEN, J., LAW, W., LIPSCOMB, D.L., LOVEJOY, T.E., MILLER, H., MILLER, J.S., NAEEM, S., NOVACEK, M.J., PAGE, L.M., PLATNICK, N.I., PORTER-MORGAN, H., RAVEN, P. H., SOLIS, M.A., VALDECASAS, A.G., VAN DER LEEUW, S., VASCO, A., VERMEULEN, N., VOGEL, J., WALLS, R.L., WILSON, E.O. & WOOLLEY, J.B. 2012. Mapping the biosphere: exploring species to understand the origin, organization and sustainability of biodiversity. *Systematics and Biodiversity* 10: 1–20.

WHITEHOUSE, M.E.A. & LUBIN, Y. 2005. The function of societies and the evolution of group living: spider societies as a test case. *Biological Reviews* 80: 347–361.

WHITMORE, C. 2000. Biodiversity of spiders (Araneae) in a savanna ecosystem and the processes that influence their distribution. Unpublished MSc thesis, University of Natal.

WHITMORE, C., SLOTOW, R., CROUCH, T.E. & DIPPENAAR-SCHOEMAN, A.S. 2001. Checklist of spiders (Araneae) from savanna ecosystem, Northern Province, South Africa: including a new family record. *Durban Museum Novitates* 26: 10–19.

WHITMORE, C., SLOTOW, R., CROUCH, T.E. & DIPPENAAR-SCHOEMAN, A.S. 2002a. Diversity of spiders (Araneae) in a savanna reserve, Northern Province, South Africa. *Journal of Arachnology* 30: 344–356.

WHITMORE, C., CROUCH, T.E. & SLOTOW, R.H. 2002b. Conservation of biodiversity in urban environments: invertebrates on structurally enhanced road islands. *African Entomology* 10: 113–126.

WICKLER, W. & SEIBT, U. 1986. Aerial dispersal by ballooning in adult *Stegodyphus mimosarum. Naturwissenschaften* 73: 628–629.

WIECZOREK, J., BLOOM, D., GURALNICK, R., BLUM, S., DÖRING, M., GIOVANNI, R., ROBERTSON, T. & VIEGLAIS, D. 2012. Darwin Core: An evolving community-developed biodiversity data standard. *PLoS ONE* 7 (e29715): 1–8.

WIESE, L. & DIPPENAAR-SCHOEMAN, A.S. 2014. Spider diversity of the Addo Elephant National Park. Abstracts of the 11*th* Colloquium of the African Arachnological Society, Amanzi Private Game Reserve, South Africa: 31.

WILBY, R.L. & PERRY, G.L.W. 2006. Climate change, biodiversity and the urban environment: a critical review based on London, UK. *Progress in Physical Geography* 30: 73–98.

WILLIAMS, P., FAITH, D., MANNE, L., SECHREST, W. & PRESTON, C. 2007. Complimentarity analysis: Mapping the performance of surrogates for biodiversity. *Biological Conservation* 128: 253–264.

WILSON, D.S. & CLARK, A.B. 1977. Above ground predator defence in the harvester termite, *Hodotermes mossambicus* (Hagen). *Journal of the Entomological Society of Southern Africa* 40: 271–282.

WORLD SPIDER CATALOG 2014. World Spider Catalog. Natural History Museum Bern, version 15.5. http://wsc.nmbe.ch (accessed 2 December 2014).

YESSON, C., BREWER, P.W., SUTTON, T., CAITHNESS, N., PAHWA, J.S., BURGESS, M., GRAY, W.A., WHITE, R.J., JONES, A.C., BISBY, F.A. & CULHAM, A. 2007. How global is the Global Biodiversity Information Facility? *PLoS ONE* 2 (#e1124): 1–10.