The faunistic diversity of spiders (Arachnida, Araneae) of the Savanna Biome in South Africa

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Invertebrates include more than 80% of all animals, yet they are severely under-represented in studies of southern African diversity. Site biodiversity estimates that do not consider invertebrates, not only omit the greatest part of what they are attempting to measure, but also ignore major contributors to essential ecosystem processes. All available information on spider species distribution in the South African Savanna Biome was compiled. This is the largest biome in the country,occupying over one third of the surface area.A total of 1230 species represented by 381genera and 62 families are known from the biome. The last decade has seen an exponential growth in the knowledge of the group in South Africa, but there certainly are several more species that have to be discovered, and the distribution patterns of those listed are partly unknown. Information is summarized for all quarter degree squares of the biome and reveals considerable inequalities in knowledge. At a large scale the eastern region is much better surveyed than the western parts, but at smaller scales throughout the region, several areas have little information. A total of 928 spp. (75%) are free-living spiders with 571 spp. living on the soil surface, including those living in burrows (73 spp.), and 357 spp. that are associated with vegetation. The web dwellers are represented by 302 spp., with the largest number making orb-webs (123 spp.), followed by the retreat-web spiders (61 spp.) and the sheet-web spiders (39

spp.).The Salticidae is the most diverse family (159 spp.) and also has the most endemic savanna species (42 spp.), followed by Thomisidae (116 spp.). The Endemicity Index indicates that 366 species are endemic to the biome,with 322 species that are near endemics, i.e. also occurring in an adjacent biome. An abundance index (1–3) was also calculated for each species based on numbers sampled. The two indices were combined into a rarity index for each species, which gives a preliminary indication of the conservation importance of each savanna species. Information is also available on species presently protected in protected areas in the Savanna Biome and species known to playa role as predators in agro-ecosystems found within the biome.

Keywords: check list, SANSA, endemicity, mega-diverse, rarity index, protected areas, agro-ecosystems.

INTRODUCTION

Signatories of the Convention of Biological Diversity (UNEP 1992) are obligated to develop a strategic plan for the conservation and sustainable use of biodiversity. The inclusion of invertebrates in these biodiversity inventories is clearly desirable, as invertebrates include more than 80% of all animal diversity, yet they are severely under-represented in studies of southern African diversity. Site biodiversity estimates that do not consider invertebrates not only omit the greatest components of what they are attempting to measure, but also ignore groups that are very significant contributors to terrestrial ecosystem processes.

As with insects, spiders have several qualities to support human well-being and life on Earth. For example, in the face of urgent conservation issues, they can be used as valuable bio-indicators (Buchholz, 2010; Cardoso *et al.*, 2010; Clausen, 1986; Marc *et al.*, 1999; Pearce & Venier, 2006), i.e. taxa whose presence or abundance readily reflects some measure of the character of the habitat within which they are found. Most arachnid orders are known to be sensitive to pollution and alterations in habitat structure (Oxbrough *et al.*, 2005; Pearce & Venier, 2006). They are also abundant, speciose and relatively easy to collect quantitatively. Spiders are an important predatory group of terrestrial animals, and play an important role in

biological control in agro-ecosystems (Dippenaar-Schoeman, 2001), while only a few species are considered to be of medical importance to man (Dippenaar-Schoeman & Müller, 2000).

Savanna is one of the world's major biomes and covers approximately half of Africa's land surface (Scholes & Walker, 1993), occupying the extensive areas between the equatorial forests and deserts. It is characterized by a well-developed grassy layer with a prominent woody layer of trees and/or shrubs that may be evergreen and/or deciduous. Although the main vegetation types are trees and grasses, the ecology of the savanna is a complex interaction between the woody and herbaceous plants giving it a unique character (Scholes & Walker, 1993). The major delimiting factors are the effects of fire and rainfall, the latter varying from 235 to 1000 mm per year with frost 0-120 days/year (Cowling *et al*., 2004). Several surveys on spiders in the African savanna have been undertaken during the last thirty years as discussed by (Dippenaar-Schoeman & Jocqué (1997), of which the majority of published studies were carried out in South Africa.

The Savanna Biome is the largest biome in South Africa and occupies over one third of the country's surface area (Low & Rebelo, 1996; Scholes & Archer, 1997). It is especially well developed in the Northern Cape, North West, Limpopo, Mpumalanga and parts of KwaZulu-Natal and the Eastern Cape Provinces.

In 1997 the South African National Survey of Arachnida (SANSA) was launched in accordance with the country's obligations to the Convention of Biological Diversity (CBD). SANSA is providing essential information needed to address issues concerning the conservation and sustainable use of the arachnid fauna (Dippenaar-Schoeman & Haddad, 2006). It is an umbrella project that was implemented at a national level in collaboration with researchers and institutions countrywide dedicated to document and unify information on arachnids in South Africa. The information gathered is organized in a relational database (>56 000 entries) collating data from > 30 surveys involving 11 institutions. The country has a rich spider fauna with about 2 010 known species in 71 families (Dippenaar-Schoeman *et al.*, 2010), that represents ca. 4.7 % of the global spider diversity. One further objective is to provide a species-level conservation assessment of arachnids, and although spiders are absent from the majority of Red Lists, it does not mean that they are any less threatened by human activities.

As part of SANSA, 1270 localities in the Savanna Biome have been sampled since 1979. The rationale for this project is primarily to gather baseline information on diversity in an area that has been previously relatively poorly sampled. Most sampling and taxonomic research on South African arachnids, undertaken between the periods 1820-1960, was based on the fauna of the coastal provinces, as most of the practicing arachnologists were stationed there. It was only in the late seventies that more intensive sampling started in the central and northern provinces of South Africa that are dominated by savanna habitats.

The aim of this paper is to review our present knowledge of spider diversity in the Savanna Biome of South Africa. A check list of spiders found in the Savanna Biome is provided with information on their distribution in other biomes, the guild they occupy, endemicity and a rarity index. Research on species presently protected in conserved areas is discussed, as well as species that might play a role as natural control agents in agro-ecosystems in the Savanna Biome. Newly sampled genera and possible new species are indicated.

MATERIALS AND METHODS

Information from databases

Data on spider species richness for the Savanna Biome of South Africa were obtained from existing data sets for this region compiled for the first Spider Atlas of South Africa (Dippenaar-Schoeman *et al.*, 2010). The atlas was based on the SANSA database that is available in three formats: 1) information on all the preserved specimens housed in several natural history collections worldwide and published in the primary literature (15 500 records); 2) primary data of specimens housed in the National Collection of Arachnida (NCA) at the ARC-Plant Protection Research Institute (PPRI), Pretoria (45 000 records), as well as 3) a digital photographic database containing images of species recorded by the public (2 300). This digital data is available online (www.arc.agric.za quick link SANSA, Virtual Museum). Also included were grey literature, i.e. unpublished MSc and PhD theses and longer term surveys that were undertaken since the seventies in the Savanna Biome.

General behaviour recording

TABLE 1. Main guilds and their subdivisions.

WANDERERS		
GROUND WANDERERS		
	BGW	Ground dwellers living in burrows
	FGW	Free-living ground wanderers
PLANT WANDERERS		
	FPW	Free-living plant wanderers
WEB BUILDERS		
TYPES OF WEBS		
Orb-web	OWB	Web consist of a frame with mooring and bridge lines that anchors the web and radial signal threads arranged like the ribs of a umbrella converging onto the centre of the web with circular spiral threads
Funnel-web	FWB	Web made over soil surface with a funnel-shaped retreat
Gumfoot-web	GWB	Three-dimensional web consisting of a central area with or without a retreat. The upper part comprises mooring, signal and catch threads and a lower part with mooring and catch threads. The lower catch threads studded with sticky droplets are attached to the substrate
Retreat-web	RWB	Silk threads radiating from retreat used to catch prey; usually made with cribellate silk
Sheet-web	SHWB	Web which usually consists of an upper sheet with mooring, signal and catch threads.
Space-web	SPWB	Web which fill open space and are usually attached with mooring threads to different substrates.

Spiders sampled were grouped into guilds (Table 1). A guild represents a group of species that potentially compete for jointly exploited limited resources. Because most spiders live in a defined environment with limitations set by both physical conditions and biological factors, species can be grouped into guilds based on available information of their habitat preferences and predatory methods. Previously, general statements were made in placing species in guilds but with more detailed information becoming available through surveys in the biome where a wide variety of sampling methods were used, guild placement has improved considerably for

some taxa(Dippenaar-Schoeman *et al.*, 2009; Foord *et al.*, 2008; Muelelwa *et al.*, 2010; Wesołowska & Haddad, 2009). For the present study two main guilds were recognized, namely wandering spiders (W) and web builders (WB), with further subdivisions based on micro-habitat and general behaviour as observed during surveys (Table 1).

Rarity index

TABLE 2 . Index values of the distribution (level of endemicity) and abundance of each species.

Endimicity Values	
6	Endemic – known only from type locality / one locality only in the Savanna Biome
5	Known from one province only, wider than type locality
4	Known from two adjoining provinces only
3	South Africa > two provinces
2	Southern Africa (south of Zambezi and Kunene Rivers)
1	Afrotropical Region
0	Cosmopolitan or introduced

Local Abundance Value	
3	Very rare: 1-3 specimens / locality
2	Rare: 4-10 specimens / locality
1	Abundant:10-20 specimens / locality

For each species a Rarity Index based on two of the three rarity criteria as identified by Rabinowitz (1981), *viz*. population size and distribution. The latter was calculated based on current distribution, which included six categories, ranging from only known from type locality to cosmopolitan (Table 2). Estimates of population size were based on the number of individuals in the collection and were classified into three categories (Table 2). Although all of these are crude estimates that provide a basis from which to work. An index of rarity was then calculated based on the sum of the values of these two criteria and ranged from 1 (cosmopolitan, and locally abundant) to 9 (only known from type locality and possibly very rare).

RESULTS

Species diversity

A total of 23739 records from 1260 localities representing 1230 species were recorded in the South African Savanna Biome alone until end of 2010, of which 366 species are endemic to the biome. Due to the taxonomic impediment of some families (e.g. Theridiidae, Linyphiidae, Clubionidae, Lycosidae and Corinnidae), a considerable portion of the species collected cannot be accurately identified to species level or are undescribed, and the diversity indicated here represents only a portion of the actual species present. Accumulation of new species descriptions for the Savanna Biome and endemics (Fig. 1a & b) shows a marked peak between 1890 and 1910 (Peckham & Peckham, 1903; Pocock, 1896, 1897; Purcell, 1904, 1907; Simon, 1893, 1894, 1895, 1896). There was a minor peak in the 1920's (Lawrence, 1928; Tucker, 1923). In recent years (1990–2010), the rate of accumulation of new species and endemics has increased markedly (e.g. (Bosselaers & Jocqué, 2000; Griswold, 1990; Huber, 2003; Wesołowska & Haddad, 2009) and suggests that no asymptote has been reached for either species richness or endemics (Fig. 1a & b). Most of the species were described by Lawrence (166), Simon (162), Lessert (83), Purcell (82), Tucker (63), Pocock (55), Hewitt (51) and Wesołowska (44). Although increasing, the description of new species over the last 20 years does not compare to the tempo of the early 20th century. However, the number of accessions in the National Collection of Arachnida, the largest in Africa, has grown considerably over the last four years (Fig. 1c), and subsequent processing of these specimens would lead to a considerable increase in the number of new species and endemics. Knowledge of the distribution of some species is still limited, as almost 60% are known from 4 or fewer records (Fig. 2a). Almost half of all the species recorded from the Savanna Biome are endemic to South Africa (Fig. 2b).

Rarity index

The combined values of the abundance index (1-3), based on numbers sampled, and endemicity index, indicate that 104 spp. have a rarity index (RI) of nine, i.e. only known from the type locality and very rare (1-3 individuals) (Table 2), while 77 species had an index of eight and 70 an index of seven (Fig. 2b). Species with a RI of six or more have a restricted distribution and low abundance and therefore need to be assessed under IUCN requirements.

Dominant families and genera

The three families with the greatest numbers of records, i.e. Salticidae, Thomisidae and Gnaphosidae (Fig. 3a), were also the most diverse families (Fig. 3b). The Salticidae also had the most endemic species (26%, 42 spp.), followed by Zodariidae (22 spp.) and Selenopidae (19 spp.) (Fig. 3c), while Barychelidae (67%, 2 spp.), Idiopidae (55%, 12 spp.) and Zodariidae (54%, 22 spp.) were the families where at least 50% of the species were endemic to the savanna.

Salticidae: salticids are free-living spiders that build nests in which they moult, oviposit and sometimes mate or which they occupy during periods of inactivity. The nests are small, made of densely woven silk and are attached to various substrates. The eggs are deposited in this sac-like retreat. They are found in a very wide range of habitats and have been recorded in microhabitats ranging from the soil surface to various areas on plants (Wesołowska & Haddad, 2009). They are very common in the Savanna Biome and are represented by 56 genera and 157species.

Surveys in agro-ecosystems in the savanna, especially in orchards, indicate that salticids are abundant in both macadamias (72%) and avocado (30%) orchards (Dippenaar-Schoeman *et al.*, 2005; Dippenaar-Schoeman *et al.*, 2001b). Salticids have been observed preying on a variety of taxa including thrips, flies, bugs, aphids, midges, ants and mites (Carroll, 1980; Haddad *et al.*, 2004a; Haddad *et al.*, 2004b; Whitcomb & Bell, 1964). In feeding experiments conducted in Israel, salticids consumed on average 10.1 spider mites per day (Mansour *et al.*, 1995). Van den Berg *et al*. (1992) observed salticid species of the genera *Myrmarachne*, *Hyllus* and *Thyene* preying on adult citrus psyllids in South Africa. Dippenaar-Schoeman *et al.* (1999) provided an account of the prey spectrum of salticids on cotton, which included bollworms, boll weevils, robber flies and mites, with salticids not only taking prey from the foliage but searching under bracts of flowers and bolls.

Thomisidae: thomisids are free-living spiders commonly found on plants and they inhabit grass, shrubs, flowers, trees and are frequently encountered on crops. They are the second most diverse family found in the Savanna Biome and are represented by 34 genera and 116 species. However, only 13 spp. are savanna endemics. Thomisids display an interesting range of adaptations to their habitat in body shape and colour. Thomisids prey on a variety of small invertebrates (Nyffeler *et*

al., 1994a, 1994b; Plagens, 1983). Most thomisids are sit-and-wait or ambush predators, waiting for prey to move to within grasping distance (Dean *et al.*, 1982). However, MacDaniel & Sterling (1982) have shown that some species actively move about in search of prey. Thomisids are active during the day (Leigh & Hunter, 1969) and they destroy second-instar larvae of the bollworm in terminals where they wait in ambush (Whitcomb, 1967). In China they have been observed to feed on eggs and first instar larvae of bollworms (Wu *et al.*, 1969).The thomisids are widely distributed throughout the Savanna Biome as they are easily dispersed by wind.

Gnaphosidae: gnaphosids are free-living ground dwellers that make a silken sac under stones and surface debris within which they live during non-active periods. Gnaphosids are more commonly found in dry grassland and savanna regions where studies indicated that they can comprise 55% of the total ground-dwelling spider population (Van den Berg & Dippenaar-Schoeman, 1991a). A total of 24 genera and 106 species have been recorded from the Savanna Biome (Fig. 3b). Most gnaphosids are ground dwellers, with only a few living on plants where they roll leaves in a similar fashion to clubionids. However, they do not construct a definite tube. Some gnaphosids attach their egg cocoon to the substrate while others make simple cocoons in their retreats or build more complicated egg cocoons. They prey on a variety of ground-dwelling animals that include ants, termites, other insects and spiders.

Genera: The most diverse genera are *Zelotes* (25spp., Gnaphosidae), followed by *Anyphops* (31spp., Selenopidae), *Oxyopes* (23 spp., Oxyopidae), *Xerophaeus* (19 spp., Gnaphosidae), *Clubiona* (19 spp., Clubionidae), *Heliophanus* (18 spp., Salticidae), *Olios* (16 spp., Sparassidae), *Thomisus* (15 spp., Thomisidae) and *Quamtana* (15 spp., Pholcidae) (Table 3). One genus, *Vendaphaea* (Corinnidae), is endemic to the Savanna Biome.

Spiders in protected areas

Of the 1260 localities sampled, most of the larger surveys were undertaken in protected areas from northern Limpopo Province, northern KwaZulu-Natal and northern Gauteng. Both the Northern Cape and North-West Province are still undersampled. The sites with the most records were Makelali Nature Reserve (4832) (Whitmore *et al.*, 2002), Tuinplaas, Springbok Flats in Limpopo (1428) (ARC–database), Polokwane Nature Reserve (1272) (Dippenaar *et al.*, 2008),

Lajuma Research Station (1189) (Foord *et al.*, 2008), Kruger National Park (1123) (Dippenaar-Schoeman & Leroy, 2003; Robertson *et al.*, in press), Roodeplaatdam Nature Reserve (1035), (Dippenaar-Schoeman *et al.*, 1989), Mkuze Game Reserve (1020) (Dippenaar-Schoeman, 2006) and iSimangaliso Wetlands Park, Hellsgate (998) (ARC-database) and Ndumo Game Reserve (947) (Haddad *et al.*, 2006).

Taking identification to species level into consideration only, the most diverse sites were Ndumo Game Reserve (399spp.), followed by Kruger National Park (362 spp.), Tembe Elephant Park (251 spp.) (Haddad *et al.*, 2010), Makelali Nature Reserve (268 spp.), Mkuze Game Reserve (210), Lajuma Research Station (207 spp.) and Polokwane Nature Reserve (189 spp.).

Protected areas with the most Savanna endemics are Tembe Elephant Park (74 spp.), Lajuma Research Centre (51 spp.), Polokwane Nature Reserve (42 spp.) and the Kruger National Park (36 spp.). The extent of the study areas at these sites varied considerably, from as little as 450ha at Lajuma Research Station to >1000 000 ha in the Kruger National Park.

Guilds

A total of 928 spp. (75%) are free-living spiders with 571 spp. living on the soil surface, including those living in burrows (73 spp.). The plant wanderers sampled from the grass and tree layer are represented by 357 spp. The web dwellers are represented by 302 spp. with the largest number making orb-webs (123 spp.), followed by the retreat-web spiders (61 spp.) and the sheet-web spiders (39) (Table 3).

Spiders in agro-ecosystems

Predacious mites and insects have received much attention in biological control programmes of pests in Africa, while spiders appear to have been neglected. Research showed that spiders are one of the most common predator groups found in agro-ecosystems in South Africa. In some crops 70% of the predator complex is spiders. Reviews on the role of spiders in agro-ecosystems indicate an increasing interest in, and recognition of, spiders as natural control agents of insects and mites in crop systems. Spiders form part of a complex predatory

community in crops and are important in regulating pest species in both commercial and small scale farms.

A large number of species were sampled from agro-ecosystems in the Savanna Biome. The first arachnid sampling was undertaken at the ARC-Roodeplaat experimental farm to investigate the role spiders play in strawberry fields (Dippenaar-Schoeman, 1976, 1979) where 32 spp. were sampled. It was then followed by surveys of spiders in cotton fields (127 spp.) (Dippenaar-Schoeman *et al.*, 1999; Van den Berg & Dippenaar-Schoeman, 1991b; Van den Berg *et al.*, 1990) as well as Bt-cotton (54 spp.) (Mellet *et al.*, 2006). A number of surveys in orchards in the Mpumalanga Lowveld resulted in papers on spiders on citrus (197 spp.) (Dippenaar-Schoeman, 1998; Van den Berg *et al.*, 1992), macadamia (80 spp.) (Dippenaar-Schoeman *et al.*, 2001a, 2001b) and avocado (90 spp.) (Dippenaar-Schoeman *et al.*, 2005).

DISCUSSION

Although the Savanna Biome has the largest number of records of any of the South African biomes, the spiders of this vegetation type are still poorly known. The increased survey activity over the last four years has led to considerably improved knowledge, but there is a lag time involved in identifying specimens and the taxonomy of some of the groups will preclude species level identifications for some time to come. The current patterns are largely the result of where sampling was undertaken. Cardoso & Morano (2010) point to two important considerations that would provide more reliable large scale patterns of spider distributions and diversity. The first is the emergence of Cybertaxonomy, where specimen data are available online and linked to peer-reviewed publications (Platnick, 2011), enabling the organization and recombination of information (Penev *et al.*, 2009). Secondly, the emergence of standardized and optimized protocols (Cardoso, 2009; Cardoso *et al.*, 2008; Muelelwa *et al.*, 2010; Robertson *et al.*, 1999) that could allow the comparisons of the spider diversity and composition of disparate regions, independent of the individuals that did the sampling. Conservation efforts will be incumbent on more accurate data on species distributions and diversity patterns and only then would it be possible to determine the conservation status of species.

As part of the SANSA field work a standardised protocol was developed that made use of a suite of different sampling methods that could be repeated in four different habitat types in each degree square that was sampled. This included pitfall trapping, sweeping, beating, litter sifting, Winkler traps, active collecting and night collecting. Such a protocol makes provision for the use of volunteers in collecting without severely compromising the quality of data generated. Since the same protocol is used at all sampling sites, comparisons between sites in the same biome can provide a more accurate reflection of the species richness and endemism of the arachnid fauna. There are areas that still need to be properly sampled before a comprehensive analysis of biodiversity hotspots and areas of significant conservation priority can be identified.

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