DIVERSITY AND GUILD STRUCTURE OF SPIDERS IN THE SELECTED SACRED GROVES OF NORTHERN KERALA

Thesis submitted in partial fulfilment of the requirements for the Degree of

DOCTOR OF PHILOSOPHY IN ZOOLOGY

Under the Faculty of Science

University of Calicut

by

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MARCH 2021

DECLARATION

I, SUMESH N.V., hereby declare that the work embodied in the thesis "**DIVERSITY AND GUILD STRUCTURE OF SPIDERS IN THE SELECTED SACRED GROVES OF NORTHERN KERALA**" submitted to the University of Calicut in partial fulfilment of the requirements for the Degree of Doctor of Philosophy in Zoology is a bonafide record of the research work carried out by me under the supervision of Dr. Sudhikumar A.V, Assistant Professor, Department of Zoology, Christ College (Autonomous), Irinjalakuda. No part of the thesis has formed the basis for the award of any degree, diploma or other similar titles of any university.

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This is to certify that **Mr. SUMESH N.V.** has completed the research work for the full period prescribed under the Ph.D. ordinance of the University of Calicut. This thesis "**DIVERSITY AND GUILD STRUCTURE OF SPIDERS IN THE SELECTED SACRED GROVES OF NORTHERN KERALA**" embodies the results of his investigations conducted during the period at which he worked as a research scholar. I recommend the thesis to be submitted for the evaluation for the award of the degree of Doctor of Philosophy in Zoology of the University of Calicut.

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Dedicated to my father

“If you want to live and thrive, let the spider run alive”

Acronyms and Abbreviations

AIC	Akaike Information Criterion
ANOVA	Analysis of Variance
BIC	Bayesian Information Criterion
CBD	Conservation of Biological Diversity
CDM	Clean Development Mechanism
CBNRM	Community Based Natural Resource Management
E(sn)	Expected Number of Species
IndVal	Indicator Value
iNEXT	Interpolation and Extrapolation for Species Diversity
LCL	Lower Confidence Level
LogLik	Log Likelihood Function
MAB	Man and Biosphere Programme
MLE	Maximum Likelihood Estimation
NDBR	Nanda Devi Biosphere Reserve
nMDS	Non-metric Multidimensional scaling
PERMANOVA	Permutational Analysis of Variance
sd	Standard Deviation
se	Standard Error
SG’S	Sacred groves
UCL	Upper Confidence Level
UNESCO	United Nations Educational and Scientific and Cultural Organization
WSC	World Spider Catalogue
WWF	World Wildlife Fund

Habitat types

EVN	Evergreen
MDS	Moist-deciduous
MGE	Mangroves
MYA	Myristica
SEN	Semi-evergreen

Study area

CK	Chama Kavu
ED	Edayilekadu Kavu
KK	Kammadom Kavu
KO	Konganichal Kavu
KS	Koyithatta Sree Dharmasastha Kavu
ME	Sree Malliyodan Kavu
MK	Madayi Kavu
MP	Mannam Purathu Kavu
NE	Neeliaar Kottam
PA	Payyamkulam Kavu
PK	Palathara Kunji Kavu
PO	Poongottu Kavu
PP	Puthiya Parambathu Kavu
PS	Periyanganam Sree Dharmasastha Kavu
TK	Thazhe Kavu

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ABSTRACT

Sacred groves are important gene pools and the first major effort of the society to recognize and conserve biodiversity. Moreover, by preserving rich biodiversity, they help in soil and water conservation. At present sacred groves are on the path of gradual decline owing to various socio-economic factors. Like other groves of Kerala, sacred groves of North Malabar region are also facing the threat of extinction from increasing anthropogenic activities. The study on the diversity and guild structure of spiders in the selected sacred groves of Northern Kerala was conducted during February 2016 to January 2018. The sampling methods such as line transect, hand picking, beating, aerial sampling, litter collection and visual search were used for spider sampling from 15 sacred groves of Kannur and Kasargod districts. The collected specimens were preserved and identified up to species or genus level using available literature. A total of 257 species of spiders belonging to 136 genera and 28 families were identified from the study area. Family Araneidae, were found as the most dominant followed by Salticidae, Theridiidae and Thomisidae. Five families were observed as least dominant in the study area. There was a significant difference in diversity, abundance and richness between habitats and seasons. The species accumulation curve reached in a plateau represents that the sampling effort was almost complete and majority of specimens collected from the study area. Species rank abundance distributions for habitats were best explained by Zipf-Mandelbrot models, as indicated by AIC. The rarefaction curves showed clear differences in rarefied species richness within habitats and seasons. Local diversity differs among the two sampled localities. At the habitat level, the different facets of biodiversity followed a clear pattern, where spiders of sacred groves of Kannur have higher abundance, species richness and diversity than Kasargod. Spiders collected from the different habitats of sacred groves were sorted into eight guilds based on their foraging behaviour in the field.

Keywords: Araneo fauna, Diversity, India, Line transect, Sacred grove

CHAPTER 1
INTRODUCTION

CHAPTER-1

INTRODUCTION

1.1. Introduction

India is a mega diverse country known for its plethoric biodiversity and remarkable endemicity. Knowledge about the biodiversity indicates that, the spiders are one of the most diverse groups of organisms existing across the globe. India has around 60 of the 120 spider families and 1,842of the 48,389 species known worldwide (Caleb & Sankaran, 2021). More number of species undoubtedly await discovery with estimates of global spider species diversity being around 80,000 species. Though the spiders are one of the most ubiquitous and diverse group of organisms in India, their study has always remained largely neglected. They have, however, largely been ignored because of the human tendency to favour some organisms over others.

Spiders are an ancient animal group going back to the Carboniferous era, over 350 million years. The fossils of true spiders have been found in Carboniferous rocks dating back to 318 to 299 million years ago, and are very similar to the most primitive and extant sub-order Mesotheleae. The main groups of modern spiders, Mygalomorphae and Araneomorphae, first appeared in the Triassic period, before 200 million years ago. Spiders belong to the Phylum Arthropoda, under the Class Arachnida and the Order Araneae. It is believed that the name Arachnida is originated from from the Greek maid name “Arachne”. Spiders are air-breathing arthropods that have eight legs and chelicerae with fangs that inject venom. They are the largest order of Arachnida and rank seventh in total species diversity among all other orders of organisms. Spiders are abundant and are widely spread in almost all ecosystems and constitute one of the most important components of the global biodiversity by forming one of the most ubiquitous groups of predaceous organisms in the animal kingdom (Riechert & Lockley, 1984). Spiders are one of the most diverse predatory order with female dominance. Spiders can be categorized into weavers and non-weavers (Tikader, 1987). Their life span is about one year but few live for 10 or 25 years (Smith, 1971; Vijayalakshmi & Preston, 1993).

Spiders have served as evolutionary models for studying complex mating, web spinning behaviours, key innovation, adaptive radiation hypothesis, and have been an inspiration for important theories like sexual selection by female choice. Anatomically, spiders differ from other arthropods in that the usual body segments are fused into two tagmata, the cephalothorax and abdomen and joined by a small cylindrical pedicel. In all except the most primitive group, the Mesothelae, spiders have the most centralized nervous systems of all arthropods, as all their ganglia are fused into one mass in the cephalothorax. Unlike most arthropods, spiders have no extensor muscles in their limbs and instead extend them by hydraulic pressure. Their abdomens bear appendages that have been modified into spinnerets that extrude silk from up to six types of glands. Spider webs vary widely in size, shape and the amount of sticky thread used. It now appears that the spiral orb web may be one of the earliest forms, and spiders that produce tangled cobwebs are more abundant and diverse than orb-web spiders. Spider like arachnids with silk producing spigots appeared in the Devonian period about 386 million years ago, but these animals apparently lacked spinnerets.

Spiders use a wide range of strategies to capture prey: trapping it in sticky webs, mimicking the prey to avoid detection, or running it down. Most detect prey mainly by sensing vibrations, but the active hunters have acute vision and hunters of the genus *Portia* show signs of intelligence in their choice of tactics and ability to develop new ones. Spider's guts are too narrow to take solids, and they liquefy their food by flooding it with digestive enzymes. They also grind food with the bases of their pedipalps, as arachnids do not have the mandibles that crustaceans and insects have.

Male spiders identify themselves by a variety of complex courtship rituals to avoid being eaten by the females. Males of most species survive for a few mating, mainly due to their short life spans. Females weave silken egg cases, each of which may contain hundreds of eggs. Females of many species care for their young, for example by carrying them around or by sharing food with them. A minority of species are social, building communal webs that may house anywhere from a few to 50,000 individuals. Social behaviour ranges from precarious toleration, as in the widow spiders, to co-operative hunting and food sharing. While the venom of a few species is dangerous to humans, scientists are now doing research on the use of spider venom in medicine and as non-polluting pesticides. As a result of their wide range of behaviours, spiders have become common icon in art and mythology symbolizing various combinations of patience, cruelty and creative powers.

Spiders possess the characteristics of predators that can contribute to density-independent limitation of prey, including self-damping, high levels of polyphagy, and life cycles that are asynchronous to those of prey species (Riechert & Bishop, 1990). An herbivorous species, *Bagheera kiplingi*, was described in 2008, but the all other known species are predators, mostly preying on insects and on other spiders (cannibalistic). A few species also take up birds and lizards as their prey. Spider silk also an important to bird species for nest building (Uetz, 1991); 24 of 42 families of passerine birds are depends on silk from spiders for nest construction (Hansel, 1993).

Being highly diverse and abundant predators, spiders are important regulators of terrestrial arthropod populations (Riechert & Bishop, 1990; Coddington & Levi, 1991; Moran et al., 1996) and may prove to be useful indicators of the overall species richness and health of terrestrial communities (Noss, 1990). As with insects, spiders have several qualities to support human well-being and life on earth hence the conservation of the same is an urgent requirement. They can be used as a valuable bio-indicator, whose presence or abundance readily reflects some measure of the character of the habitat in which they are found. Furthermore, their predatory habits, short lifecycles, varied dispersal systems and sensitivity to change in vegetation structure make spiders good ecological indicators and biological pest controller. Like, most terrestrial invertebrates, spiders are affected by habitat alteration such as deforestation, agriculture, grazing and urbanization (Well et al., 1983). Clear cutting of forest reduces spider abundance and changes spider community composition drastically. Environmental protection and life supporting systems are closely conncted with biodiversity conservation.

Spiders have a very significant role to play in ecology by being exclusively predatory and thereby maintaining an ecological equilibrium. Many spiders feed on noxious insects like houseflies and mosquitoes which are vectors of human diseases. A large number of spiders are found in agricultural fields and thus play an important role in controlling the population of many agricultural pests. Some families, like orb weavers, do this through passive hunting with their signature webs. Others, like wolf spiders, do this through active hunting. Spiders also kill other arachnids and spiders - even those of the same species - which help keep their own numbers in check. Jocque (1981a & b) showed that size in spiders is dependent on the quality of the habitat. The predatory behaviour of spiders make them an important component in biodiversity. Spider is used as a model organism for research in biology, behaviour and communication.

Various regions are home to many species of spiders. Not only are they able to thrive in the climate, they are also able to find plenty of food resources for them to enjoy. They are known as terrestrial as they almost always live on land. They may be found in trees, on plants, and even living in the blades of grass in our yard. Spiders are quite versatile and they do well in all types of habitat. They do have to find shelter though when the cooler temperatures settle in. Otherwise their body temperature can change too much and they will die. This is why there are times of the year when we may see them plenty and others that you don't see them around at all. Spiders are ectothermal species, i.e., the internal temperature depends on heat transferred from the external environment; and they are also poikilothermic, i.e., body temperature varies, but can be regulated behaviourally. All metabolic activities depend on temperature. There is an extreme dependence of metabolic rate on temperature in poikilothermic animals, increasing exponentially with temperature.

Spider surveys may provide an effective means for measuring the impact of habitat degradation or land use change on biodiversity. Baseline studies involving spiders as biological indicators have been conducted in different places. Allred (1969) and Allred & Gertsch (1976) documented spider diversity in Arizona and Utah after new power plant installations and in Nevada at the Nevada Nuclear Test Site. Skerl (1999) also expressed the need for spider species lists for use in conservation decision making. Churchill (1997) briefly reviewed the potential of spiders as ecological indicators in Australia. Clausen (1986) described the role of spiders as assessing the biodiversity as monitoring tools. Kremen et al. (1993a) suggested the use of spiders in conservation planning and Mciver et al. (1990) defined litter spiders as bio- indicator of recovery after clear cutting in a western coniferous forest. Gibson et al. (1992) discussed the changes in spider assemblages in relation to succession and grazing management. Wise (1993) highlighted the importance of spiders in ecological webs.

The knowledge on diversity and distribution of spiders in India is sparse as compared to other regions of the world. Indian spiders have been studied earlier by several European workers and later by Indian Arachnologists. A review of literature reveals that Stoliczka (1869); Karsch (1873); Simon (1887a & b); Thorell (1895) & Pocock (1900) were the pioneer workers of Indian spiders. The first detailed account of Indian spiders was provided by Pocock (1900) which lists 216 spider species under 17 families. The abundance of spiders is summarized by Gertsch (1949) as: "Spiders are among the dominant predators of any terrestrial community. When the fauna of the soil and its plant cover is analyzed, they come to light in vast numbers, in such convincing abundance that it is evident that play a significant part in the life of every habitat". Recent studies investigated the importance of spiders as ecological indicators. Terrestrial arthropods, of which spiders are amongst, have long been monitored for early warning signs of environmental change. In contrast to vertebrate indicator species, the physiology of many arthropods exhibits a greater susceptibility to environmental change, and thus greater detectability.

1.2. Sacred groves

A sacred grove or sacred natural sites are any group of trees which are culturally and religiously unavoidable.

The ancient generation worshipped and protected this sacred forests and trees by giving them a special emphasis. The practice of assigning a patch of forest as the abode of Gods or Goddesses is common and several tree species as sacred trees belong to the religion based conservation ethos of ancient people all over the world. It is considered as a community based repository of biological diversity. The sacred groves resemble a well-developed forest ecosystem and show a high degree of species richness depending on the extent of preservation of the grove. Some groves are also represented as hot spots of biodiversity. According to Aumeeruddy (1994), in the Kerinci valley of Sumatra, sacred village forests fulfill a range of functions - economic, religious, social and environmental.

According to Hughes & Chandran (1998), sacred groves are defined as “segments of landscape containing vegetation, life forms and geographical features, delimited and protected by human societies under the belief that to keep them in a relatively undisturbed state is expression of an important relationship of humans with divine or with nature”. In short sacred groves are the relic forest segments preserved in the name of religion and culture. These groves are mostly associated with temples and are also culturally important.

Sacred groves are well known for preserving local biodiversity. A good number of studies have reported the presence of unique floral and faunal assemblages along with rare and endemic members. The congenial microclimate, availability of food, nutrients, and shelter are the major factors for making the groves habitable for a wide range of organisms which are not easily available in other areas.

Sacred groves feature in various cultures throughout the world. They mythological landscape and cult practice of Celtic, Baltic, Germanic, Ancient Greek, Near Eastern, Roman, and Slavic polytheism, and were also used in India, Japan, and West Africa. The practice of assigning a patch of forest as the abode of Gods or Goddesses is not new. The societies of Greece, Roman, Asia and Africa had long preserved sections of the natural environment as sacred groves to Gods and Goddesses (Khiewtam & Ramakrishnan, 1989).

In India sacred groves are found in a wide range of ecological situations from estuaries to mountain localities. Gadgil & Vartak (1976) recorded the important regions with sacred groves in India are the North Eastern Himalaya (Khasi-Garo hills), Western Ghats, Aravalli hills of Rajasthan and Sarguja, Chandes and Bastar area in central India. According to Malhotra et al. (2007) estimation of the number of sacred groves in India is yet to be completed. He pooled together all the data and recorded around 22,968 sacred groves in India. The total area recorded is 68,633 hectares for 9,196 sacred groves. In Tamil Nadu, it is about 1262 sacred groves (T.N Forest Dept., 2011). Based on this incomplete data, it is impossible to come up with a reasonable estimation, but experts like Pushpangadan et al. (1998), Ramakrishnan et al (1998), Ramakrishnan (2001), Sinha & Maikhuri (1998) recorded that actual number is likely 1,00,000 to 1,50,000 in India.

Sacred groves are known colloquially in different names at differentstates. '*Deoris'* or *'Deovaris'* in Maharashtra, '*Dev'* in Madhya Pradesh, *'Oran'* in Rajasthan '*Devarakadu', 'Sidharavana', 'Pavithravana'* in Karnataka, *'Kavu',* *'Sarpa Kavu', 'Naga Kavu'* in Kerala and Tamil Nadu, *'Kottam', 'Mundya', 'Vallikkettu'* in North Kerala. Sacred groves in India may be owned by a family, clan, or a trust body, and are in some cases managed by a temple committee made up of clan elders.

There are three categories of sacred groves are present in India:

1. Traditional sacred groves - it is the place where the village deity resides, who is represented by an elementary symbol.

2. Groves around the burial or cremation grounds.

3. Temple grove - here a grove is created around a temple and conserved.

First major effort of the societal initiative to recognize and conserve biodiversity because they are valuable germplasm collections. They harbour numerous rare, endangered, and endemic plants and animals. They have been preserving many rare and endemic wild plant species, which potentially benefit mankind in medicine, agriculture, and industry as a source of natural products for drugs, food, fuel and fiber. In general, they act as nursery and store house of many plants used in Ayurveda, tribal and folk medicines. Besides preserving a rich biodiversity, they also help in soil and water conservation. They are home of local flora and fauna and are the seat of secrets of herbs, medicines, myth and magic. It is a unique tradition of preserving trees, tanks and groves associated with temples or deities (Amirthalingam, 1998). This practice is predominantly linked to Hindu Gods and Goddesses (Chandran & Hughes, 1997); there are references to even Muslims and Buddhists practicing this tradition (Apffel-Marglin & Parajuli, 2000). Several groves had stone seats as symbolic to the divine, while the Hindu Gods were mostly pre-brahminic (Chandran & Hughes, 1997).

The overall concepts of the sacred groves are traditional values, religious beliefs, taboos and socio-cultural practices. However, it is also one of the *in situ* conservation methods of plant diversity. In this advanced era the traditional values and socio-cultural practices have been weakened among the people mainly within the young generation. The importance of groves also declined due to various factors and it resulted in the disappearance of sacred groves in villages.

Kerala is one of the states in India, where the sacred groves are widely distributed from the West Coast to the Eastern high lands. The first authentic report on the sacred groves appeared in the Census report of Travancore had done by Lt. Ward and Lt. Corner reported the presence of 15,000 sacred groves in Travancore (1827). In the due course, sacred groves received greater research attention from anthropological as well as biological conservation point of view. Rajendraprasad (1995) had been documented 2000 sacred groves in Kerala that are distinct and unique in biological diversity. According to Prasad & Mohanan (1995), it is estimated about 500 hectares of forest area is under sacred grove, contributing 0.05% of the total forest area of the state. Induchoodan (1996) revealed the presence of only 761 sacred groves. Basha (1998) documented there are 362 sacred groves in Kerala. The total extent of the sacred groves in Kerala is about 440ha.

This primitive tribal culture of Pre-Dravidian era is mostly distributed along with the plains and lower elevations from the sea level to 450 m altitude near human settlements and away from the forest. Kollam, Pathanamthitta, Alapuzha Districts in south and Kannur, Kasargod and Kozhikode Districts in north have been described as the ‘hot spots’ of sacred groves in Kerala. Even though the groves are more or less disturbed and reduced in size many of them are still rich in biodiversity. The vegetation in the groves is highly varied like mangroves, fresh water myristica swamps or either tropical forest types namely ever green, semi-evergreen and moist deciduous.

The sacred groves in Kerala are locally known as Sasthan Kavu or Ayyappan Kavu, Amman Kavu or Bhagavathi Kavu, Vanadevatha and Cheerumba or Cheema depending upon the ownership and the deities to whom these groves are dedicated. The worship of divine mother existed very strongly in India than any other country. The Kavu are of two kinds -some are in the midst of human habitation. These Kavu have serpent (*Sarpa Kavu*) or Durga *(Durga Kavu*) as deities. The Ayyappan Kavu, on the other hand, exist in the mountain ranges engulfed in forests (Nayar, 1987). The rituals and rites performed in sacred groves vary with region, caste and patron deity of the groves. *“Theyyam*” and associated rituals (*pooja*) are typically performed in the sacred groves of Northern Kerala. The ‘*Theyyam’ or ‘Theyyattam’* is a popular ritual dance of north Kerala, particularly now found in *‘Kavus’* and *‘Kazhakams’* of the traditional Kolethunadu, ie, in the present Kannur and Kasargod Districts.

Sacred groves are the refuge of certain plant species preserved on religious grounds which can satisfy the aesthetic, scientific, cultural, and recreational needs of mankind (Bhakat, 1990). In the words of Dr. M. S. Swaminathan, “the sacred groves, unlike a botanical garden, where a wide range of trees and plants are collected and cultivated for the purpose of our education and enjoyment, the sacred groves are one method of expressing the gratitude of human families to the trees which sustain and support life under a given agro- ecological condition” (Kandari et al., 2014). Sacred groves are maintained intact for generations to support relic vegetation and are often among the best places to study endemism (Balasubramanyan & Induchoodan, 1996). Sacred groves are specific areas imbued with powers beyond those of humans; they are home to mighty spirits that can take or give life; they originate from a range of roots, and include: sites linked to specific events; sites surrounding temples; burial grounds housing the spirits of ancestors; the home of protective spirits; the home of deities from which priests derive their healing powers; homes to a powerful animal or plant species; forest area that surround natural sacred features such as rivers, rocks, caves and bottomless water holes; and site of initiation of ritual (Gadgil & Vartak, 1981).

They are, therefore, of central importance as far as ecological conservation and policy regarding conservation and management of forest at state and national levels are concerned. The factors like holiness and religious importance play a crucial role in encouraging sustainable utilization and conservation of both flora and fauna. The scientific, economic, social and spiritual values implicit in them will have to be made explicit. The new land reforms in Kerala and the religious beliefs and taboos of younger generations are major threat in protecting and conserving these sacred groves.

Regardless of whether the responsibility of managing the sacred grove is under one or few families or is fully assigned to a statutory agency for temple and sacred grove management, it has been a fact that many stakeholders have an interest and role to play for ensuring effective management of systems. However, due to the changing socio-economic conditions and land use systems many sacred groves are now threatened and altered both in terms of size, vegetation structure and species composition. In Kerala, based on management systems, sacred groves can be categorized into three types. The sacred groves are maintained by the statutory agencies for temple management (Devaswom Board), group of families and individual families.

1.3. Ecological importance

Among arthropods, spiders have gained wide acceptance as indicators of environmental quality; as such, their abundance, species richness and community structure are useful indicators of the biodiversity of the biocoenosis as a whole (Willett, 2001). The species richness of spiders have been correlated with latitude and mean annual temperature (Finch et al., 2008; Whitehouse et al., 2009), with habitat complexity and maximum regional temperature (Jiménez-Valverde & Lobo, 2007) as well as with altitudinal gradients (Chatzaki et al., 2005; Bowden & Buddle, 2010). Spiders respond quickly to brusque changes in habitat heterogeneity (Rubio et al., 2008), and as a consequence of the narrow spatial scale in which spiders divide these biotic and abiotic changes, they become an appropriate species to evaluate patterns in diversity at a regional scale. As follows, a decrease in similarity between spider assemblages was recorded as climatic and geographic distance increased (Carvalho et al., 2011), although the response to the latter was weak in some cases (Jiménez-Valverde et al., 2010).

Sacred groves provide various ecosystem services to the local communities and by providing water for organisms living in and around the groves. Their immediate surroundings are cool and also produce plenty of oxygen into the environment. Main vegetation types of sacred groves are evergreen, semi-evergreen, moist deciduous and mangrove forests. Vegetation retains water, and releases it slowly during dry periods. This adds humidity to the air and cools it (Malhotra et al., 2001). Similarly, vegetation holds nutrients, and the root systems keep nutrients in the soil from leaching away. It also reduces the salt content of wells in coastal areas to a greater extend. Sacred groves provide living space for species of insects and birds that control crop pests or act as pollinators for crops. They may also serve as seed banks and nurseries for species of trees and plants of commercial or cultural importance, such as fruit trees and medicines, acting as a source for re-forestation and propagation (Malhotra et al., 2001).

Sacred groves enrich the soil through its rich litter and the nutrients generated as a result of litter decomposition. In the context of the dwindling of evergreen forests at an alarming rate in the Western Ghats, preservation and management are unavoidable, as each “Kavu” is a treasure house of many rare/endangered species, germplasm collection of all the plants in an area and an abode of rare/endemic medicinal and economically important plants.

Sacred groves are nature’s laboratories for evolution of wild species and repositories of significant genetic and ecosystem diversity. It has been preserved as sustainable resources, ensuring basic capital intact and considered valuable gene pool and the first major efforts to recognize and conserve biodiversity. Gadgil & Vartak (1975) observed in many parts of India, sacred groves represent surviving examples of climax community. They received greater attention from anthropological as well as biological conservation point of view. The soils of sacred groves show high porosity and low bulk density compared to the soils of the vicinity. The thick litter cover and channels created by soil macro fauna together enhances water retention, root system development, gaseous exchange and heat conductance.

The forest patches showed different degrees of degradation. However, due to the changing socio-economic conditions and land use systems many sacred groves are now threatened and altered both in terms of size, vegetation structure and species composition.

1.4. Relevance

Conservation of biodiversity is the idea behind the Kavu. Biodiversity values and high conservation priorities in sacred groves increasing the potential as a tool and model for conservation studies. Sacred groves have served as an important reservoir of biodiversity, preserving unique species of plants, insects and animals.

Among the plants that grow in the sacred groves of North Kerala, at least 50 are endemic to Western Ghats and folk practitioners utilize most of them as raw drug source (Unnikrishnan,1990). The sacred groves are the reservoir of the rural community by augmenting irrigation and fertility to soil. Sacred groves helped in reducing water runoff and in maintaining soil moisture. Now a days about 75% of Kavu are facing the threat of extinction. It is high time to recognize that Kavu's are the 'lungs and reservoirs' of a locality. Thus the conservation of sacred groves is one of the most important measures to protect our both flora and fauna especially the predatory spiders. The developed countries, who viewed our Kavu sarcastically earlier, are now the savior and advisors for the preservation of these natural treasures. Let us have the strength and ability for the awareness of preserving our divine jungles from the encroachment of concrete jungles.

Most arachnid orders are known to be sensitive to pollution and alteration in habitat structure. Taxonomic studies of different spider species from protected areas and agro ecosystems were investigated by many researchers. Spiders also have an added advantage to being conspicuous and amenable to techniques of observation that are relatively cheap, easily deployable and replicable, making them a group suitable for statistical comparisons and monitoring of habitats. Furthermore, their predatory habits, short lifecycles, varied dispersal systems and sensitivity to change in vegetation structure make spiders good ecological indicators.

As taxonomic group spiders are good candidates for bio indication because they form a species rich group, inhabiting all kinds of terrestrial ecosystems. Additionally, each species has its own, well documented, specific demands regarding humidity, temperature, and litter and vegetation structure. This means that slight change in habitat quality potentially cause significant changes in the composition of spider assemblage. The availability of background information on characteristics of spiders enables us to predict changes that can be adverted by management actions their quick and fairly constant response towards (anthropogenic) stress and changes in the environment together with their easily standardized sampling, spiders meet the criteria of ecological indicators. Hence spiders can be used as ecological indicators to assess the condition of environment, to produce an early warning signal of changes in the environment.

Indian society is an unbelievable mixture of different cultures and traditions. Each society has its own life style. Many of these societies or cultures have traditionally developed strategies of conserving and managing nature and the natural resource. The sacred groves are not mere physical entities. They reflect the value system of communities. The dynamics of the sacred groves can be related to the changes taking place in the socio cultural realms of the society. Ethno-botanists and anthropologists are debating the role of sacred groves as conservation mechanism of the communities. Sacred groves are a biological heritage and a system that has helped to preserve the representative genetic resources existing in the surrounding regions for generations.

In this study, emphasis was to specify the diversity of spiders and abundance of spiders in 15 selected sacred groves of Kasargod and Kannur Districts of Kerala. The following 15 sacred groves were selected for the study: Edayilekadu Kavu (SG101), Kammadom Kavu (SG102), Koyithatta Sree Dharmasastha Kavu (SG103), Mannampurathu Kavu (SG104), Sree Malliyodan Kavu (SG105), Payyamkulam Kavu (SG106), Periyanganam Sree Dharmasastha Kavu (SG107), Puthiyaparambathu Kavu (SG108), Chama Kavu (SG201), Konganichal Kavu (SG202), Madayi Kavu (SG203), Neeliarkottam (SG204), Palathara Kunji Kavu (SG205), Poongottu Kavu (SG206) and Thazhe Kavu (SG207). Generally, taxonomic studies on spiders and invertebrates of sacred groves are few and limited. No specific extensive studies on spider faunal diversity in the region were done and published. It is the first approach in this region to study the spider fauna and thus providing baseline information. Data thus collected may facilitate future in initiatives of biodiversity databases of these species in this region.

1.5. Objectives of the study

1. Conduct a survey of spiders in sacred groves of northern Kerala.
2. Estimate the abundance, species diversity, species richness of spider population in sacred groves.
3. Study the regional diversity of spiders in various sacred groves.
4. Study the guild structure of spiders in sacred groves.

1.6. Organization of the thesis

The Thesis is organized into six chapters-

Chapter I – Introduction:

This chapter deals with general introduction, sacred groves, ecological importance, relevance, objectives of the study and organization of the research report.

Chapter II – Review of related literature:

This chapter includes the review of literature relevant to the present study and is summarized as sacred groves and its importance, conservation in sacred groves, ecological importance of sacred groves, global and local diversity of spiders, studies of spiders in India, spiders in sacred groves and spiders as bio indicators.

Chapter III – Materials and Methods: This chapter deals with the methodology acquire for the execution of the present study.

Chapter IV – Results: This chapter accounts for the findings of the present study.

Chapter V – Discussion: This chapter assesses the outcomes of the present study.

Chapter VI – Summary and Conclusion:

This chapter deals with the summary of findings and conclusion

References

Publications

Plates

CHAPTER 2
REVIEW OF LITERATURE

CHAPTER-2

REVIEW OF LITERATURE

"A substantive, thorough, sophisticated literature review is a pre-condition for doing substantive, thorough, sophisticated research" (Boote & Beilee, 2005). The intention of any literature review is to summarize and synthesize the arguments and ideas of existing knowledge in a particular field without adding any new contributions. Being built on the existing knowledge they assist the researcher to even turn the wheels of the topic of the research.

The importance of literature review in research can be condensed in to an analytical feature to enable the multifold reach of its implication. It increases the value to the authenticity of the research in many ways. Interpretation of ideas in the light of updated developments and helps in consistency and relevancy; filling the research gaps; indicating the significance of the study in a particular area of research; points out the area of further research; justify the research and helps to setting up research question; sets up a theoretical frame work; helps to adopt appropriate methodology for research; identify the relationship of works in context and its contribution to the topic and to other works.

A sacred grove is any group of trees that are of special religious importance to a particular culture. Sacred groves feature in various cultures throughout the world. They are important ecological centers to study the potential vegetation. Some of the important studies regarding sacred groves have been reviewed here.

2.1. Sacred groves and its importance

Many traditional conservation practices of different indigenous communities of the world contributed to the protection and conservation of biodiversity. Dedicating small forest patches to the local deities and worshiping them is a good example of traditional practice of different indigenous communities of the world. Such forest patches are called “sacred groves”. Sacred groves are the tracts of virgin forest that were left untouched by the local inhabitants, harbour rich biodiversity, and are protected by the local people due to their cultural and religious beliefs and taboos that the deities reside in them (Khan et al., 2008). The existence of sacred groves has been reported in many parts of Asia, Africa, Europe, Australia and America (Khan et al., 2008; Hughs & Chandran, 1998; Gadgil & Vartak, 1976). The document of Man and Biosphere programme (MAB, 1995) has detailed the sacred groves present in Ghana, Senegal and Sumatra. Various sacred sites associated with rich vegetation in Bangladesh were reported by Hussain (1998). Several small size sacred groves were reported from Nepal (Ingles, 1994). In Maldives, medicinal plants with traditional importance are considered by the local people as sacred (Hussain, 1998). These pristine forests are thousand years older than that of ancient human settlements. Gadgil & Vartak (1975) have traced the historical link of the sacred groves to the pre- agricultural hunting and gathering stage of societies. Studies on sacred groves have taken place all over the world. Protection of rare species in various groves of Ghana and Nigeria was reported by Dacher (1997). A study on the persistence and loss of cultural values of Tiriki sacred groves in Hamisi District, Kenya was conducted by Kassilly & Tsingalia (2009). This study revealed that the traditional believes and cultural values of the Tiriki people alone are no longer adequate in securing a future for the sacred groves in Hamisi District.

Communally protected sacred groves are found all over India. They have religious connotation for protecting the community. These were areas where hunting and logging are prohibited. If logging is done then it has to be done with sustainability in mind and substitution. However, collection of honey and deadwood is allowed. These groves are sometimes associated with temples/shrines/monasteries or with burial grounds. Sacred groves like the Alpine Meadows protects natural habitat on religious grounds. Khumbongmayum et al. (2004) described 15 sacred plants species present in different sacred groves of Manipur. Sunitha & Rao (1999) studied the characteristics and distribution of flora of the sacred groves of Andhra Pradesh. A study on the status of important sacred groves in Himalayan region revealed that economic forces are strongly influencing the traditional communities to exploit rather than the community-oriented protection of these groves (Saxena et al.,1998). The sacred groves traditionally managed by the village communities along the forest belts of South India are gradually disappearing. Chandrakanth et al. (2004) analysed the revolution on community-based resource management and also the impact of socio-economic factors which led to the gradual disintegration of the Sacred groves. Sukumaran et al. (2008) studied the rare and endemic plants in the sacred groves of Kanyakumari District in Tamil Nadu.

Being a biotype in a rural landscape, the sacred groves carry out several ecological functions, which directly or indirectly help in the maintenance of ecosystems health of all interacting landscape units (Pushpangadan et al., 1998). Sacred groves with their complex array of interaction influence the flora and fauna of the region as well as microclimate of the locality. Contributions of sacred groves to a village landscape in managing hydrological balance and availing the carbon credits under the Clean Development Mechanism (CDM) of Kyoto protocol have also been recognized by many workers. Sacred groves are maintained intact for generations to support relic vegetations and are often among the best places to study endemism (Induchoodan & Balasubramanyan, 1991).

Pioneer works of sacred grove by Ward & Conner (1827) reported existence of about 15,000 sacred groves in Travancore. Later studies of Ramachandran & Mohanan (1991) identified 239 sacred groves in Kerala. Induchoodan (1988) recorded 364 important sacred groves in Kerala with plant diversity of 722 species. A number of studies have been conducted on the floristic diversity of sacred groves throughout the Western Ghats (Gadgil & Vartak, 1975; 1976; 1981; Chandran & Gadgil, 1993a & b; Unnikrishnan, 1995). A detailed survey of sacred grove in Kozhikode District shows that there are 65 sacred groves and listed 83 Naga Kottas in the District (Unnikrishnan, 1995). Sacred village forests perform a range of functions-economic, religious, social and environmental. Examination of the contribution of the sacred forests to biodiversity conservation offers perspective on the sacred forests as a model for environmental protection (Camera, 1994). Thus the role of natural sacred sites, principally sacred groves, is attracting increasing interest in international organizations and conservation organizations such as UNESCO, the WWF and has important relevance for the implementation of article 8j of the Conservation of Biological Diversity (CBD) act which stresses more on the use of traditional wisdom and practices for conservation and sustainable use of biological diversity.

2.2. Conservation in sacred groves

Sacred groves act as an important place for biodiversity conservation. Several threatened plants, medicinal plants and animals are well conserved in sacred groves. Subrahmanya & Ravindran (2012a & b) made a study on endemic and rare medicinal plants of sacred grove of North Malabar. Rajendraprasad et al. (2000) made a study on the vegetational characterisation and litter dynamics of sacred groves of Kerala. Chandrashekhara & Sankar (1998a) conducted a study on ecology and management of sacred groves in Kerala includes a study of the influence of different management systems at Sri Bhagavathi Kavu at Iringole, Sri Shankukulangara Bhagavathi Kavu at Sree Narayanapuram and Sarpa Kavu at Ollur.

Several ecological investigations have been completed in sacred groves of Meghalaya (Khiewtam, 1986; Khan et al., 1987; Barik et al., 1992; Rao, 1992; Khiewtam & Ramakrishnan, 1989, 1993; Barik et al., 1996a & b; Rao et al., 1997; Tiwari et al., 1998a & b; Tiwari et al., 1999; Tripathi et al., 2002; Pandey et al., 2003; Upadhyaya et al., 2003; Mishra et al., 2004). The regeneration status of several important species was studied in sacred groves of Karnataka (Boraiah et al., 2001; 2003; Kumar & Swamy, 2003), Meghalaya (Khan et al., 1986; Barik et al., 1992; Rao et al., 1990, 1997) and Manipur (Khumbongmayum, 2004; Khumbongmayum et al., 2005b, 2006). Basha (1998) has given an account on the distribution and conservation values of sacred groves in Kerala. In Kerala, based on management systems, sacred groves can be categorized into three groups namely those managed by individual families, by groups of families and by the statutory agencies for temple management (Devaswom Board). They were studied for their tree species composition and vegetation structure. The vegetation of the sacred groves has certain distinctive ecological characteristics. The sacred groves of Kerala have discrete tiers of trees, shrubs and herbs, climbers and stranglers, epiphytes, parasites and many wild relatives of cultivated plants (Rajendraprasad, 1995). Broadly, the vegetation of these groves has been classified into two category viz.

evergreen type and the moist deciduous type (Basha, 1998). Khumbongmayum (2004) has prepared a comprehensive ecological study of the four sacred groves of Manipur and compared the biological spectrum of the groves to the normal spectrum of phanerogamic flora of the world. Biological spectrum of sacred groves of Kerala also closely resembles the normal spectrum in the percentage of therophytes (Pushpangadan et al., 1998). Ecological and sociocultural aspects of biodiversity conservation in sacred groves of Bonai forest division, Odisha were reported by Mohapatra et al. (2017).

An ecological study on sacred groves of Malabar discloses the major physico chemical aspects of sacred grove soils and floral diversity in seven selected sacred groves of Northern Kerala (Anupama, 2009). Sacred grove can serve as an effective model for decentralized community based natural resource management if they have proper economic incentives and legal backing regarding the property right issues (Ishani & Burch, 2009). In Kozhikode District, there are 188 sacred groves well preserved and rich in biodiversity (Sreeja & Unni, 2008). Murugan et al. (2007) made a study on socio cultural perspectives to the sacred groves and serpentine worship in Palakkad District, Kerala. A total of 25 threatened plant species have been recorded from the coastal sacred groves of Thrissur District (Sujanapal et al., 2006). Bhakat & Pandit (2003) documented the socio religious and ecological aspects of Chilkigarh sacred groves. It revealed the importance of this area in terms of ecology and human welfare. The study pointed out major strategies for the effective long-term conservation and healthier management of the grove. Irula community protects the sacred groves of Coimbatore forest division. Factors like the deity and related religious believes, ownership and plant diversity of the grove were studied by Balasubramanyan & Rajasekaran (1996). The status of sacred groves in

Kerala was examined by Pushpangathan et al. (1998). They focused mainly on distribution, vegetation structure, dynamics, ecological functions, rituals, worship and celebrations. Critical review of the traditional nature worship practices which led to the national and regional goals of conservation was done by Saxena & Maikhuri (1998). Shankar (1997) suggested measures for the restoration of sacred groves. These include determination of site, clearing thorny shrubs and fencing, different patterns of picking, soil working, selection of species, planting process, watering, saucing and after care of restored site.

According to Khurana (1998a & b) the factors for fast deterioration of sacred groves are changing values, increase in population, development pressure and apathy on the part of the government departments, many of which did not give the concept due merit. If steps are not taken to stop their decline, these microcosmos will disappear from the face of earth, leaving it deprived of valuable species of flora and fauna. Both Union and State governments should provide high priority to identifying and managing these sources of genetic wealth and act fast.

2.3. Ecological importance of sacred groves

Several ecological studies have been carried out in these sacred forest patches. Floristic composition of sacred groves in different parts of India has been studied by a number of researchers viz., Karnataka (Vasanth et al., 2001), Kerala (Chandrashekara & Sankar, 1998b), Pondicherry (Kadamba, 1998; Kadamba et al., 2000; Ramanujam & Kadamba, 2001; Ramanujam & Kumar, 2003), West Bengal (Basu, 2000), Meghalaya (Tiwari et al., 1998b, 1999; Tripathi et al., 2002; Jamir, 2002; Jamir & Pandey, 2002; Law, 2002; Upadhaya, 2011) and Manipur (Khumbongmayum, 2004). Many studies have also been conducted in anthropological and ecological dimensions of sacred groves in India (Malhorta et al., 2001). Sunitha & Rao (1999) studied the characteristics and distribution of flora of the sacred groves of Andhra Pradesh.

Sinha & Maikhuri (1998) reported several sacred groves from Garhwal Himalaya. Visalakshi (1995) made studies on the biodiversity of dry evergreen forest in two sacred groves in East Coast of Tamil Nadu. Freeman (1994) and Kalam (1996) had done cursory studies on the socio historical aspects of sacred groves. Chandran & Gadgil (1993a & b) reported faunistic diversity in one of the sacred groves in Uttara Karnataka. Induchoodan & Balasubrahmanyan (1991) made a survey of endemic plants of three sacred groves. Several ecological investigations have been made in sacred groves of Meghalaya (Khan et al., 1987, 1997). In 1975, Gadgil & Vartak studied the floristic and ethnobotanical aspects of sacred groves of Maharashtra. Vartak & Gadgil (1981) studied the sacred groves along the Western Ghats from Maharashtra and Goa. In India, the earliest documented work on sacred groves is that of Brandis (1897). Basha (1998) has given an account on the distribution and conservation values of sacred groves in Kerala. Rajendraprasad et al. (1995) studied the floristic aspects of sacred grove in Kerala and reported that there are about 2000 reasonably well-preserved sacred groves in Kerala. A detailed eco- folklore study of sacred grove of North Kerala has been done by Unnikrishnan (1995) who listed 62 sacred groves in Kasargod and 57 sacred groves in Kannur District. A preliminary study of sacred groves of Kerala was done by Ramachandran & Mohanan (1991) and identified 239 sacred groves. A new species of leguminous climber *Kunstleria keralensis* has been reported from one of the sacred groves of Kerala (Mohanan & Nair, 1981).

The unique ecological systems like Kavu and associated ponds are integrated with the life and culture of Keralites (Kutty, 2001). Socio cultural and bioecological dimensions of 31 selected sacred groves from North Kerala had done by Chandrasekara et al. (2002). Legal status, management system and importance of sacred groves in maintaining the rural ecosystem integrity and biodiversity conservation were also studied.

Ecological survey of Anjanuvale sacred grove from Junnar area of Pune District Maharashtra state, India was conducted by Phansalkar & Kulkarni, (2014). An analysis on the concept of ecological and biodiversity conservation systems in sacred groves of Pachmarhi Biosphere Reserve of India was done by Kala (2011a & b). Kanak Durga sacred grove of West Bengal, although fairly protected, is facing mild threats due to minor micro habitat changes for developmental works, grazing and exotic weed invasion (Bhakat, 2009). A web interfaced multimedia database in sacred groves of India have developed by Gaikwad et al. (2004) in order to build up a comprehensive information resource documenting the biodiversity status of sacred groves.

2.4. Global and local diversity of spiders

Arachnids are an important but generally poorly studied group of class Arthropoda. Despite the lack of interest in spiders, many information on spider fauna are available which provide an outline of the diversity of spiders in various regions.

Spiders (Araneae) represent a diverse and functionally important group of arthropods. The distribution, abundance and diversity of spiders has drawn attention of naturalists in different parts of the world since the 18^{th} century. There are approximately 48,974 spider species that have been described worldwide belonging to 4,195 genera and 128 families (WSC, 2021) and are estimated to comprise 60,000-1,70,000 species (Coddington & Levi, 1991). Of these, 2299 spider species belonging to 552 genera and 67 families are reported from South East Asia. Of these 552 genera, 49 are monotypic represented by single species and 65 genera which are endemic to one or more South Asian countries and about 1830 species are endemic to South Asia (Siliwal & Molur, 2007). Comprehensive research on the diversity of araneofauna of many countries has been conducted by many workers. Namkung (2003) conducted a study on the spiders of Korea. Recently many works on South East Asian spiders have been published which also contributed significantly to understanding our spider wealth. Tikader (1987) described the spider fauna of Indo-Pakistan sub-continent. Biswas (1987) described the spiders of odisha. Lehtinen (1967) prepared a comparative and phylogenetic system of classification of cribellate spiders. Baseline studies involving spiders as biological indicators have been conducted in different places. Allred (1969) and Allred & Gertsch (1976) documented spider diversity in Arizona and Utah after new power plant installations and in Nevada Nuclear Test Site.

The number of spider species known from India have risen steadily from 1067 species (Tikader, 1987), 1442 species (Siliwal et al., 2005), 1520 species (Sebastian & Peter, 2009) to 1686 species (Keswani et al., 2012). Presently, 1852 species under 477 genera in 61 families are known (Caleb & Sankaran, 2021). This list has been updated in accordance with the latest version of the World Spider Catalog 2021.

Of the 1,852 species, 1,002 are endemic to Indian mainland, 71 species are endemic to Andaman and Nicobar Islands and one species is endemic to

Lakshadweep (Siliwal et al., 2005). The families represented by the highest number of genera and species in India are Salticidae (66 genera; 192 species) followed by Thomisidae (38 genera; 164 species) (Uniyal & Hore, 2008). Even though spiders are extremely abundant throughout the country, our knowledge of the Indian spiders is scanty. A general description of spiders from all over the world has been provided by Preston-mafham & Preston-mafham (1984). Latreille (1804), Koch (1836), Cambridge (1885, 1892 & 1897) and Simon (1887a & b) prepared the early taxonomic records on spiders. Petrunkevitch (1933) provided an inquiry into natural classification of spiders based on study of their internal anatomy. Impact of catalogues prepared by Bonnet (1945) remained in the taxonomic work of spiders over a couple of centuries. Comparative and phylogenetic system of classification of spiders was proposed by Lehtinen (1967) .

The book by Vijayalakshmi & Preston (1993) provides a good introduction to the study of spiders for amateurs. Kremen et al. (1993b) suggested that indicator properties of species assemblages used for natural areas monitoring. Wise (1993) highlighted the importance of spiders in ecological webs. Gibson et al. (1992) discussed the changes in spider assemblages in relation to succession and grazing management. Studies of Hamamura (1969), Gavarra & Raros (1973), Sasaba et al. (1973), Samal & Misra (1975), Kobayashi (1977), Chiu (1979), Holt et al. (1987) and Tanaka (1989) clearly described the role of spiders as predators in reducing insect pests in rice fields. Mciver et al. (1990) defined litter spiders as bio- indicator of recovery after clear cutting in a western coniferous forest.

The most comprehensive description yet on Indian spiders is by Tikader (1987). This handbook does not provide the region information in which the spider species listed is found but has listed 1066 species under 43 families. Each of the families namely, Lycosidae, Salticidae, Gnaphosidae, Thomisidae and Araneidae are the predominant and constitutes about ten percent or more of the spider fauna recorded by Tikader (1987). Spiders are abundant in terrestrial ecosystems and abundant in both natural and agricultural habitats (Turnbull, 1973; Nyfeller & Benz, 1987). Clausen (1986) described the role of spiders as assessing the biodiversity as monitoring tools. Spiders form one of the widely distributed groups of predaceous organisms in the animal kingdom (Riechert & Lockley, 1984). Spiders, by virtue of their small size, are able to exploit very small and specific features within the environment. Spiders are known to occupy nearly every terrestrial habitat. Species diversity and diversity of web types followed the overall seasonal pattern of spider abundance (Lubin, 1978). Robinson et al. (1974) showed that the abundance of web-building spiders in forest-edge and secondary-growth habitats in New Guinea did indeed vary seasonally; though the patterns of variation were different in different species, adopted visual search sampling methods in their study to sample the spider fauna from quadrates selected at random of selected study sites and described the advantage of visual censusing as that the spiders in the study area remain undisturbed and can be censused repeatedly.

However, many reviews have been collected in the international context which gave a supportive idea, during the present study. For eg. Thorell (1895) published a descriptive catalogue of over two hundred species of Burmese spiders including 150 new species, Malaysian spiders by Workman (1896), spiders from Taiwan and Hokkaido by Saito (1934), spiders of Great Britain by Locket & Millidge (1951), spiders of Taiwan by Lee (1966), spiders of' Tokyo by Shinkai (1969), spiders of Australia by Mascord (1970), spiders of China by Feng (1990), spiders of Korea by Kim (1991), Kim & Namkung (1992) and Namkung et al.(2002), spiders of Madagascar by Ono (1993) and spiders of Bangladesh by Biswas & Begum (2004); Biswas & Raychaudhuri (1998a &b, 2004).

2.5. Studies of spiders in India

Spiders are extremely abundant throughout the country, but our knowledge of the Indian spiders is meagre. Studies on Indian spiders have been done earlier by several European workers and later by Indian arachnologists. Two of the earliest contributions on Indian spiders were made by Stoliczka (1869) and Karsch (1873). Simon (1887a & b,1889a & b,1892, 1894,1895, 1897a & b and 1903) recorded many species from the Himalayan region and Islands of the east side of India. Blackwell (1867), Karsch (1873), Simon (1887a & b), Thorell (1895) and Pocock (1900 a & b) were the pioneer workers on Indian arachnology. They described many species from oriental realm. Cambridge (1869a & b) and Karsch (1873) worked in the Indian, Sri Lankan and Minicoy islands. Tikader (1980a & b, 1982a, b & c), Tikader & Malhotra (1980) described spiders from India. Tikader (1980b) compiled a book on crab spiders of India which comprised 115 species of 25 genera belongs to 2 subfamilies with 23 new species. A review on the main morphological features of crab spiders is provided in this work.

Beginning in 1960 for about five decades Tikader's works occupied a prominent portion of Arachnology in India. These works gave the firm foundation of Arachnology in India and inspired several other workers into this field. His works contributed significantly in enriching our knowledge about the spiders of India. Some of the Tikader's works which became important assets for Indian Arachnologists are the following: Spider fauna of Maharashtra (1963a), South Indian crab-spiders (1963b), Spider fauna of Sikkim (1970a), Spider fauna of India I

(1970b) and part II (1970c), Key to Indian spiders (1976a,b & c), Spider fauna of Andaman and Nicobar Islands (1977), Thomisidae, Fauna of India (Araneae) (1980a), Lycosidae, Fauna India (Araneae) (1980b), Spider fauna of Calcutta (1981), Gnaphosidae, Fauna of India (Araneae) (1982b), Araneidae, Fauna of India (Araneae) (1982a), Hand Book on Indian spiders (1987). These works are good field manuals for both professionals and amateurs. Spider surveys may provide an effective means for measuring the impact of habitat degradation or land use change on biodiversity.

Bhattacharya (1935-1941) conducted a few studies on ant-like spiders and also on giant crab spiders. In the 20th century studies on Indian spiders were documented by Narayan (1915); Sherriffs (1919); Gravely (1921); Reimoser (1934) and Dayal (1935). Narayan (1915) gave interesting accounts of many ant-like spiders of the family Salticidae in India. The first detailed account of Indian spiders was provided by Pocock (1900a) which lists 216 spider species under17 families. The knowledge on diversity and distribution of spiders in India is sparse as compared to other regions of the world.

Tikader & Biswas (1981) studied 15 families, 47 genera and 99 species from Calcutta and surrounding areas with illustrations and descriptions. Pocock (1895, 1899a & b, 1900a & b) recorded two hundred species from India, Burma, and Ceylon in his work 'Fauna of British India, Araneae' (1900a). His book provided the first list of spiders, along with enumeration and new descriptions in British India based on spider specimens at the British Museum, London. He also reported on Oriental Mygalomorphs (1895, 1899a, and 1900b), new species of Indian arachnids (1899b &1901) and spiders of Laksha dweep (1904) provides with the one of earliest information from these regions. Sheriffs (1919,1927,1928 & 1929) described numerous interesting species from southern India. Gravely studied mygalomorph spiders (1915, 1921 & 1935) and provided more information on Indian spiders. The first comprehensive list of Indian spiders with 1067 species belonging to 249 genera in 43 families was published by Tikader (1987). Contributions made by Sinha (1951a & b, 1952) on Lycosidae and Araneidae are also important. Tikader & Malhotra (1980), Tikader & Biswas (1981). Spider fauna of Bengal, Gujarat and Andhra Pradesh were studied respectively by Biswas & Biswas (1992) Patel (1973, 1975a & b), Patel & Vyas (2001), Patel & Reddy (1989) and Reddy & Patel (1991-93). Tikader (1960, 1963a & b, 1970a, b & c, 1976a, b & c, 1977, 1980a & b, 1981, 1982a, b & c,1987) described many species from the families crab spider, elongated crab spiders, wolf spiders, orb web spiders and ground spiders from all over India. Gajbe (1983, 1987, 1988, 1989, 1991, 1992, 1993, 1995a, b & c, 1999) has prepared a checklist of 186 species of spiders in 69 genera under 24 families and described many new species of spiders from Madhya Pradesh and Chattisgarh region. A brief account on spiders is also provided by Vijayalakshmi & Preston (1993) in the book titled 'Spiders: An Introduction'. Spiders of protected areas in India have received very little attention. The main work has been conducted by Gajbe (1995a) in Indravati Tiger Reserve and recorded 13 species. Rane & Singh (1977) recorded five species and Gajbe (1995b) 14 species from Kanha Tiger Reserve, Madhya Pradesh.

Biswas & Biswas (2004) contributed significantly to spider diversity by rendering comprehensive lists of new recorded spider species from Manipur and West Bengal. Dhali et al. (2011) reported 34 species of spiders belonging to 27 genera and 12 families from Corbett National Park. Biswas & Biswas (2010) reported 127 species of spiders belonging to 49 genera under 17 families from Uttarakhand state.

Ekka & Kujur (2015) studied the spider fauna of Indra Vihar Park, Raigarh, Chhattisgarh. A total 163 samples were collected, the result reveals presence of 63 species representing 38 genera under 10 families, and 2 species were unidentified. Among all these 10 families, predominant diversity was examined in the family Araneidae followed by Gnaphosidae, Thomisidae, Lycosidae and Oxyopidae. Rithe (2012) studied the spider diversity from relocated area of Melghat Tiger Reserve, from which total of 254 species belonging to 113 genera and 27 families were recorded from Koha, Kund and Bori meadows and concluded that the relocation of three villages has had a positive biological impact on habitat recovery. Centre for Indian Knowledge System, Chennai has also conducted ecological studies of spiders in a cotton agro ecosystem of Guindy National Park. Chetia & Kalita (2012) studied diversity and distribution of spiders from Gibbon Wild life Sanctuary, Assam. Quasin & Uniyal (2010) made a preliminary investigation of diversity in the Kedarnath Wild life Sanctuary-UP, India. Kumar & Shiva Kumar (2006) revealed the spider fauna of paddy fields in Gujarat and Tamil Nadu. Smith (2004) recently described a new species of *Poecilotheria* from Southern India. Gajbe (2004) published several studies on spiders from Madhya Pradesh. Molur et al. (2004) published studies on *Macracantha arcuata* and about the common names of South Asian Theraphosid spiders. Patel & Vyas (2001) described 56 species of spiders belonging to 36 genera in 18 families from Hingolgarh Nature Education Sanctuary, Gujarat. Patel & Patel (1973) reported some new species of spiders from family clubionidae from Gujarat. Sadana (1995) conducted several studies on salticids of North India. Gayathrirani (1985) studied the behaviour of orb- weaving spider *Cyrtophora*. Tikader & Biswas (1981) studied 15 families, 47 genera and 99 species from Calcutta and surrounding areas with illustrations and descriptions. Two of the earliest contributions on Indian spiders were made by Stoliczka (1869) & Karsch (1873).

Adarsh & Nameer (2015) conducted a study on spiders of Kerala Agricultural University Campus, Thrissur, Kerala. Sudhikumar et al. (2015) conducted a preliminary study on spider fauna in Mannavan shola forest, Kerala. A total of 72 species belonging to 57 genera of 20 families were collected. Jose et al. (2018) conducted a study on spider diversity in Kavvayi river basin, Kerala. Jobi (2018) recorded 147 species belonging to 92 genera of 26 families from Pathiramanal island in the Vembanadu lake, Kerala. Pradeep (2018) reported 70 species belonging to 48 genera of 20 families of ground dwelling spiders from Kerala region of Western Ghats.

Simon (1887b) described many species from the Himalayan region and Andaman and Nicobar. Hore (2009) studied the diversity of spiders from Terai Conservation area and recorded a total of 186 species belonging to 77 genera and 27 families. Quasin (2011) studied diversity of spiders in Nanda Devi Biosphere Reserve, and a total of 244 species belonging to 108 genus and 33 families were recorded during the entire sampling period. Using the abundance-based estimator Chao1, the predicted richness for the three sites (Lata Kharak), (Malari) and (Bhyundar Valley). This indicated that the inventory was complete at the regional scale (91%). Family composition varied considerably in relation to the altitudinal gradient. Habitat covariates viz., pH, litter dept, humidity, temperature were found to be important predictors for spider assemblages.

The first attempt of molecular taxonomy of spiders from India was done by Tyagi et al. (2019). This study revealed a total of 101 morphospecies from 72 genera belonging to 21 families with five endemic species and 3 holotypes. They generated and analysed 489 barcodes, from these they obtained 85 novel barcodes of 22 morphospecies which were contributed to the global data base. Singh et al. (2020) provided an updated checklist of yellow sac spiders (cheiracanthiidae) of Indian states and Union territories. The checklist of this widely distributed yellow sac spiders represented 38 species coming under 2 genera in India.

2.6. Sacred groves in India

In India, Gadgil &Vartak (1975) are the pioneers of scientific study in the field of sacred groves. They have studied floristic and ethno-botanical aspects of sacred groves of Maharashtra and North Karnataka. Detailed information on the location, area, associated deities were available for 233 sacred groves from the District of Maharashtra by Gadgil &Vatrak (1981). Presence of groves in different parts of the country was recorded by Amrithalingam (1998), Bor (1942), Buch (1987), Induchoodan (1988), Mehere-Homji (1987), Nipounage (1988), Rodger (1994), Subramanayan & Sasidharan (1988), Sharma & Kulkarni (1980), Shankar (1997), Tiwari et al. (1998a & b), Rao (2002) Vartak & Kumbhojkar (1984), Vartak et al. (1986) & WWF of A.P. (1996). A monograph about sacred groves in India was written by Malhotra et al. (2007). In this, they narrated about an overview of sacred groves in India including ecological and biological dimensions along threats and opportunities.

Biodiversity of sacred groves are made by Bhaskar et al. (2000), Chandran et al. (1998), Deb et al. (1997), Godbole et al. (1998), Jha et al. (1998), Kulkarni et al. (1993), Parthasarathy & Sethi (1997), Tetali & Gunale (1990), Tiwari et al. (1999). The study related to religious and socio-cultural aspects of sacred groves were done by Bhasin (1999), Chandrakanth & Nagraj (1997), Sinha & Mai Khuri (1998), Singh et al. (1998) & Swamy et al. (1998).

Many workers in India studied the association of biodiversity conservation with magico-religious beliefs and taboos. A few such works are like Gadgil & Vatak (1973, 1976), Dash & Chauhan (2002), Vartak (1996), Gadgil &Vartak (1981), Godbole (1996), Roy Burman (1991) and Hajra (1987).

According to Nipounage et al. (1988) folklores about sacred groves have resulted in the continued preservation of patches of forests enriched with natural flora, as well as cultural trends. They listed 84 sacred groves and deities which are protected on religious grounds. The status of biodiversity in Maulong Syiem sacred grove of Meghalaya was studied by Tripathy et al. (2002). Floristic studies on sacred groves from Sinhagad hills in Pune District at Maharashtra had done by Nipounage et al. (1993). This study demonstrates economic and scientific utility of the sacred groves.

Gokhale et al. (1998) studied the history and current status of sacred groves in several states of India. This recommends a sharp decrease in the coverage of sacred lands and associated water bodies of the country. Malhotra (1998) provided us an overview of the various anthropological dimensions of sacred groves in India. A study was conducted on the diversity of sacred groves of 7 villages of West Bengal and 220 villages in Orissa by Malhotra et al. (1998). A comparative study on the social importance of the sacred groves of Mahadeo Kolis and the Kunbis of Maharashtra were done by Roy Burman (1996). Untawale et al. (1998) described some sacred groves with mangrove vegetation of Gujarat and Maharashtra. A floristic study on sacred forests of Agastheeshwram was conducted by Sukumaran &

Jeeva (2008). About 40% of the total species recorded from this study were rare and endangered.

Sacred sites of Bangladesh are associated with rich vegetation (Hussain, 1998). Some Hindu minorities of Bangladesh visits every year for worship in Dubla Island sacred grove in Sundarbans (Islam et al., 1998). The rural inhabitants of Afghanistan create and conserve sacred groves as part of their historical and geographical tradition (Mohamed, 1998). The collective efforts of rural folks of Ghana to protect sacred groves influenced positively their socio-economic and cultural lives (Michaloud & Durry, 1998).

Sacred groves are the best modals of biodiversity conservation. Many of plants and animals that are threatened in the wild are well conserved in several sacred groves. It has been observed that plants with medicinal values that are rare in the forest are abundant in the sacred groves (Juginu et al., 2016). It serves as an effective model for decentralized community based natural resource management if they have proper economic incentives and legal backing regarding the property right issues (Ishani & Burch, 2009). In Kozhikode District, there are 188 sacred groves well preserved and rich in biodiversity (Sreeja & Unni, 2018). Murugan et al. (2007) made a study on socio cultural perspectives to the sacred groves and serpentine worship in Palakkad District, Kerala. Nativity, endemism and rarity of the plant in Indian Himalaya region had done by Samant & Pant (2003). Diversity, distribution pattern and traditional knowledge of sacred plants identified and documented by Samant & Pant (2003). Vegetation diversity and evenness of Shirkai Sacred Grove in Maharashtra was conducted by Kulkarni & Shindikar (2005). Floral and bird diversity of sacred groves at Dapoli, Ratnagiri District at Maharashtra conducted by Ulman et al. (2009).

From a recent study done in a sacred grove in Kollam District of Kerala by Shailajakumari et al. (2020) rediscovered a threatened endangered tree species named *Madhuca diplostemon* after 184 years from its first collection. *Globa andersonii* is another species of plant belonging to family Zingiberaceae was also redicoverd from both Himalayan regions and sacred groves of Kerala by Thachat et al. (2020). This emphasis the crucial role of sacred groves in preserving an intact flora and associated fauna.

2.7. Spiders in sacred groves

Spiders are considered as generalist predators and have the world’s most abundant taxon-insect as their main food (Maloney et al., 2003). They can be found in approximately all terrestrial habitats in nature. Actually, they can be found in most anthropogenic habitats too. Most spider species occur as high- density populations in diverse communities. With all these properties, they have been hailed as an ideal group for studying meta community dynamics (Schmidt et al., 2008).

In India, works on the diversity of spiders in protected areas have also taken place. Diversity of spiders in Nanda Devi Biosphere Reserve is an example (Quasin, 2011). The protected area network in the Indian Himalayan region consists of seven biosphere reserves including Nanda Devi Biosphere Reserve (NDBR), 31 National Parks and 111 Wildlife Sanctuaries. A total of 244 species belonging to 108 genus and 33 families were collected during this study.

Documenting and understanding spider assemblages in tropical forests in the present context of rapid loss is an important task (Kapoor, 2006). Sacred groves are supposed to be relics of ancient vegetation and remnants of larger forest tracts (Chandran et al., 1998) and they have been shown to hold rare and endemic species of plants (Jayarajan, 2004; Sukumaran & Jeeva, 2008; Sukumaran & Raj, 2007; Bhagawat et al., 2005a; Khumbongmayum et al., 2005a & b ; Punde, 2007; Tambat et al., 2005; Page et al., 2010), birds (Bhagawat et al., 2005b; Jayarajan, 2004; Jyothy & Nameer, 2015), mammals (Jayarajan, 2004) and butterflies (Barua, 2007; Gaude & Janarthanam, 2015). But spider fauna recording attempt was very rare in sacred groves.

According to ancient Tamil civilization trees are represented as god they worshipped trees for their well-being and existence. By this practice they can avoid the impact of evil spirit and can acquire the grace of Goddesses Amman (Raman & Palavaryan, 1997). Visalakshi (1995) conducted a study of biodiversity in dry evergreen forests of two sacred groves in the coastal region of Tamil Nadu.

Ramachandran (1993) reported about 240 sacred groves in Kerala. They hold many rare and endangered plants which are in need of urgent protection. Study of Srinivasan et al. (1998) revealed the presence of 7 species of lizards belong to 4 families in three sacred groves of Kerala. A total of 38 species of endangered and endemic plants were described by Vartak (1983) from 12 selected sacred groves of the Western Ghats. According to Krishna (2002) the rural and tribal people actively participated in the conservation of sacred groves and they considered this as a sacred duty. Studies conducted by Ramachandran & Mohanan (1991) described 65 sacred groves from Alappuzha District of Kerala and they recorded Iringole Kavu as the largest Kavu in Kerala with an area of 20.234 ha.

According to Andrew (1998) sacred groves have been preserved purely by the virtue of the ancient Indian traditions and religious practices. They have ecological and economic significance due to the presence of rare and endangered species. A faunistic survey of Jayarajan (2004) recorded 8 species of spiders along with other organisms from the sacred groves of Northern Kerala. Sivaperuman (1998) conducted a study in Kerala during 1997-1998 over a period of 4 months in 3 sacred groves. This study was recorded only 14 species with visual search method. A correlation between size of the sacred grove and spider species richness was expected but not found. Sivaperuman et al (2002) conducted a study on spider diversity and their webs in selected sacred groves of Kerala. Sivaperuman (2008) done a conservation study of spiders in sacred groves. Another study was conducted in the South Western Maharashtra (Patil, 2011). Seven sacred groves were surveyed once each for spiders among potential indicator taxa. The enlisting of spiders of groves of Rathnagiri, Maharashtra was done by Patil (2016). He recorded 377 species belonging to 39 families from 102 groves of Rathnagiri. A preliminary investigation on spider fauna from two selected habitats of Thrissur District, Kerala was done by Sumesh & Sudhikumar (2018), who recorded a total of 50 species of spiders belonging to 22 genera under 14 families from sacred grove and scrub jungle. Roy et al. (2012) recorded 5 species of spiders from sacred trees of Sherampore, Hoogly, West Bengal. De & Palita (2018) recorded 81 species of spiders from six sacred groves of Odisha.

2.8. Spiders as bio indicators

Samways et al. (2010) have defined a bioindicator as a species that (i) readily reflects the abiotic and biotic state of an environment, (ii) represents the impact of environmental change on a habitat, community or ecosystem, or (iii) is indicative of the diversity of a subset of taxa, or of whole diversity, within an area. One of the main challenges to conservation of biodiversity is our often-poor knowledge of species rich groups of organisms and areas of the world. With the limited resources, it is essential to collect information with efficient approaches. Bioindicators can be grouped in to environmental indicators, ecological indicators or biodiversity indicators (McGeoch, 2013). The bioindicator response is generally measured in terms of species abundance and distribution.

Many arthropod groups are considered hopeful bioindicators because of their high species richness, large biomass, the significance and diversity of their functional roles, and their responsiveness to environmental change (Samways et al., 2010). Kremen (1992) had much earlier suggested that terrestrial arthropods could be used for virtually any monitoring programme, so long as the goals are well distinct. Bisevae & Major (2002) concluded that certain invertebrates were much superior and cost effective bioindicators than vertebrates. Hore & Uniyal (2008) studied that spiders are used for monitoring habitat conditions.

Community Based Natural Resource Management (CBNRM) seems as a feasible approach to management of sacred groves (Bhagwat & Rutte, 2006). CBNRM programs envisage development of specific indicators to monitor the progress towards goals and objectives (Gruber, 2011). Similar indicators can be devised for monitoring ecosystem health or conservation status (Patil, 2016).

Very often species or other taxa are used as indicators of changes in natural habitats. In 1970s and 1980s, single species were typically used to indicate contamination levels. But Kremen's (1992) discussed that, the approach changed to species assemblages and ordination. Later on Dufrene & Legendre (1997) proposed IndVal measure to indicator potential species in an assemblage. It was and still is very famous method to identify indicator species. But, evidently better measures like *phi coefficient of association* are being proposed (Tichy & Chytri, 2006). Spiders, too, are considered useful indicators of environmental conditions and they are gaining importance even in Indian context (Uniyal et al., 2011). In fact, they were found to be the finest indicators among as diverse groups as beetles, Hemiptera, ants, springtails, birds and other terrestrial vertebrates (Majer et al., 2007). Kapoor (2006) interestingly reviewed the properties of spiders to be good ecological indicators as them being conspicuous; amenable to relatively cheap, predators with short life cycle; easily deployable and replicable methods of sampling; equipped with varied dispersal systems; and having sensitivity to change in vegetation structure (Patil, 2016).

Habitat features and landscape parameters determine in the environment of a sacred grove. Habitat features, in turn, are in a state of flux. They are influenced by management interventions and disturbances. Sacred groves are ideally areas with minimum management and interference. But all conservationists and researchers have expressed concern over the violation of this 'minimum'rule (Gadgil & Vartak, 1975). Spider guilds specific to micro-habitats like ground, bark and foliage did also show strong association levels with potential to indicate changes in these micro-habitats (Pinzon & Spence, 2010)

Page et al. (2010) have, however, advised against using only one life form (trees in their case) as indicators of effects of fragmentation in sacred groves. But it is nonetheless practical to explore indicators across life forms separately and then combine them into efficient monitoring protocols. That is why one of the popular approaches to short-cut the inventories are using higher taxa surrogates. Genus was found to be promising surrogate for spider species richness in Mediterranean forests (Cardoso et al., 2004). This also helps in overcoming the taxonomic conflict (Coddington et al., 1991). Even within spider assemblages of Hungarian agricultural fields and pastures, rare species were found to respond particularly well to smaller ecological changes (Batary et al., 2008; Samu & Szinetar, 2002).

CHAPTER 3
MATERIALS AND METHODS

CHAPTER-3

MATERIALS AND METHODS

In any kind of research, methodologies occupy a very important position as it describes the sequential steps of techniques and procedures adopted to solve a problem under investigation. Methodology lays out in the way in which formal research is to be carried out and outlines the detailed descriptions of procedures and research variables. It helps the researcher to explore the varied strands of the study and adequately measure them so as to satisfy the requirement. The methodology accepted for the present study is summarized below.

3.1. Study area

Kerala (8°17' 30" N/12°47'40" N & 074°27'47" E/077°37'12" E), is a narrow coastal strip on the south-western part of India and also known as the land of coconuts. It is located in the tropical region of Indian Peninsula, bordered by the Arabian Sea on the west and the Western Ghats on the east, extending to an area of about 38,852 km^2, which accounts for about 1.18% of the total geographical area of the country.

The state has distinctive altitudinal variations from 5 m in the west to 2695 m in the east while the state itself varies between 11-121 km width and has a coast of length 590 km (Pavithran et al., 2014). The state of Kerala is divided into14 Districts and based on geographic, cultural and historic similarities, these 14 Districts are categorized into three groups - Southern Kerala (Alappuzha, Kollam, Kottayam, Pathanamthitta and Thiruvananthapuram), Central Kerala (Ernakulam, Idukki, Palakkad and Thrissur) and Northern Kerala (Kannur, Kasaragod, Kozhikode, Malappuram and Wayanad).

A total of 15 sacred groves were selected for the present study. They were located in Kasargod and Kannur Districts of Northern Kerala. Kannur is one of the 14 Districts along the west coast in the state of Kerala. It is located between is 11°52´8.04´´ North latitude and 075° 21´19.66´´ East longitude and an area of 2,966 km^2. Kannur District is bounded by Kasargod District to the north, Kozhikode District to the south, Mahé District to the southwest and Wayanad District to the southeast. To the east the District is bounded by the Western Ghats, which forms the border with the state of Karnataka (Kodagu District). The Arabian Sea lies to the west. Paithalmala is the highest point in the Kannur District (1,372m). Enclosed within the southern part of the District is the Mahé District of the Union Territory of Puducherry. The District was established in 1957. Kannur is the sixth-most urbanised District in Kerala. Kasargod District is one of the 14 Districts in the southern Indian state of Kerala. It is located between is 12°30´0´´ North latitude and 075° 0´0´´ East longitude and an area of 1,992 km^2. The District is bordered to the south by Kerala's Kannur District, and to the southeast and north by Karnataka's Districts of Kodagu and Dakshina Kannada respectively. To the east, the District is bordered by the Western Ghats, while along the west; it is bordered by the Laccadive Sea.

Physiognomy of vegetation and floristic composition of the sacred grove are similar to the low-level evergreen forest. The vegetation in uninterrupted groves is rich and comprises several layers of trees mixed with herbs, shrubs and lianas. The soil is rich in humus and covered with thick litter. Macro fungi are abundant, so also the ferns. Whenever there is a water body, algae and water plants grow gregariously.

Climatic and edaphic changes due to anthropogenic and animal interferences lead to the floristic variations in sacred groves (Anupama, 2009). Generally, vegetation of the sacred groves divided into evergreen, semi-evergreen, evergreen with fresh water Myristica swamp, freshwater Myristica swamp, moist deciduous and mangroves. The different plant groups like trees, climbers, stragglers, woody climbers, epiphytes constitute the flora. Plants include Angiosperms, Gymnosperms, Pteridophytes, Bryophytes and Lichens. Top canopy is represented by major shrubs species like *Artocarpus hirsutus*, *Vateria indica*, *Hopea* sp., *Artocarpus heterophyllus* (plavu), *Alstonia scholaris* (ezhilampala), *Tabernaemontana alternifolia* (koonampala), *Corypha umbraculifera* (Kodappana), *Caryota urens* (choondapana), *Calycopteris floribunda* (pullani), *Canthium angustifolium*, flowering plants such as *Chassalia curviflora* (vellakurinji), *Barleria prionitis* (manjakanakambaram) and *Sarcostigma kleinii* (odappazham). Dominant climbers include *Cyclea pellata* (padathali), *Piper nigrum* (kurumulaku), *Plumbago zeylanica* (vellakoduveli) and *Pothos scadens* (paruvakodi). Medicinal plants like *Canthium parviflorum*, *Zizyphus oenoplia* and *Holoptelea integrifolia* are found here. The threatened flora like *Ampelocissus indica*, and *Tabernaemontana alternifolia* and members belonging to Eriocaulaceae family, *Drosera* sp., *Polycarpaea* sp., and *Utricularia* sp. are found here. Thekkumbadu Thazhe Kavu is a coastal sacred grove which contains mangrove as the main flora. It is the one and only the sacred grove with mangrove vegetation in Kerala. It is a small island on the bank of Valapattanam river and this grove is situated in a salt marsh. Three sides of the grove contain salty river water and one side with paddy field. The mangrove vegetation found here are particularly belonging to Rhizophoraceae. The mangrove also exists as fringing vegetation distributed along the sides of paddy field. In this area 11 true mangroves species belongs to 6 families and 19 mangrove associates and other Angiosperms are found. Among these *Kandelia candel* and *Sonneratia alba* are very rare. *Rhizophora mucronata* is the most dominant species. *Excoecaria agallocha, Avicennia marina, Avicennia officinalis*, *Rhizophora apiculata* and *Bruguiera cylindrica* are present. The endemic species like *Holigarna arnottiana* and vulnerable species like *Gloriosa superba* are found here. The typical tree vegetation is dominated by *Syzygium zeylanicum* and *Memecylon randerianum*.

The meteorological data of the study area during the study period is furnished in Table 1. Average annual rainfall is 779.94 mm in 2016-2017 and 970.51 in 2017-2018. May and October are the wet months while November to April is relatively dry. Relative humidity is always greater than 75%. Range of the temperature is between18.43°C and 32.99°C.

Different parameters like rainfall data, temperature, relative humidity and location details recorded using various methods. Sampling area sites are recorded by using global positioning system (GPSmap76CSx). Temperature and relative humidity were recorded by using Hygrometer (Mextech M288 CTHW digital thermo hygrometer with indoor/outdoor temperature). Rainfall data sets for the representative area over the study region is derived from the High-resolution Gridded rainfall Data sets of India Meteorological Department (IMD- Pai et al., 2014).

Table 1. The meteorological data of the study area during the study period.

Meteorological variables	Seasons	2016-2017	2017-2018
Rainfall (mm)	Pre-monsoon	212.8	215.9
	Monsoon	2073.33	2438.77
	Post-monsoon	53.7	256.87
Maximum temperature (^{0}C)	Pre-monsoon	32.99	32.43
	Monsoon	27.43	27.71
	Post-monsoon	30.52	29.69
Minimum temperature (^{0}C)	Pre-monsoon	21.53	20.86
	Monsoon	20.64	21.08
	Post-monsoon	18.43	18.94
Relative humidity (%)	Pre-monsoon	79.45	79.27
	Monsoon	88.03	87.5
	Post-monsoon	78.15	77.27

3.2. Study time

The study was made during the period of 2015 to 2020. Study area identification, selection and pilot study were done in 2015 to 2016. Spider sampling was carried out from 2016 February till 2018 January. Data analysis and further taxonomical identification were done in 2018 to 2020. The following 15 sacred groves were selected for the study: Edayilekadu Kavu (SG101), Kammadom Kavu (SG102), Koyithatta Sree Dharmasastha Kavu (SG103), Mannam Purathu Kavu (SG104), Sree Malliyodan Kavu (SG105), Payyamkulam Kavu (SG106), Periyanganam Sree Dharmasastha Kavu (SG107), Puthiya Parambathu Kavu (SG108), Chama Kavu (SG201), Konganichal Kavu (SG202), Madayi Kavu (SG203), Neeliaar Kottam (SG204), Palathara Kunji Kavu (SG205), Poongottu Kavu (SG206) and Thazhe Kavu (SG207) (Plate 1 & Plate 2). The details of study area are given in the Table 2 & Figure 1.

Plate 1

Photographs of Sacred Groves in Kasargod District

(A)

(B)

(C)

(D)

(E)

(F)

(G)

(H)

(A). Edayilakadu Kavu (SG101), (B). Kammadom Kavu (SG102), (C). Koyithatta Sree Dharmasastha Kavu (SG103), (D). Mannam Purathu Kavu (SG104), (E). Sree Malliyodan Kavu (SG105), (F). Payyamkulam Kavu (SG106), (G). Periyanganam Sree Dharmasastha Kavu (SG107) and (H). Puthiya Parambathu Kavu (SG108).

Plate 2

Photographs of Sacred Groves in Kannur District

(A)

(B)

(C)

(D)

(E)

(F)

(G)

(A). Chama Kavu (SG201), (B). Konganichal Kavu (SG202), (C). Madayi Kavu (SG203), (D). Neeliaar Kottam (SG204), (E). Palathara Kunji Kavu (SG205), (F). Poongottu Kavu (SG206) and (G). Thazhe Kavu (SG207).

Table 2. Details of sites covered for spider inventory in sacred groves of Kasargod and Kannur Districts.

Sl. No	Name of sacred groves	Code	Location	Co-ordinates	Area of sacred grove (ha)	Vegetation	Diety	District
1	EDAYLAKADU	SG101	Thrikkarippoor	12˚08'10.72'' N 75˚09'23.88'' E	6.40	Evergreen type	Bhagavathy nagam	KASARGOD
2	KAMMADOM KAVU	SG102	West elery	12˚18'41.0''N 75˚18'55.8'' E	24.00	Evergreen with fresh water myristica swamp	Thayyi Paradevatha	KASARGOD
3	KOYITHATTA SREE DHARMA SASTHA KAVU	SG103	Koyithatta	12˚17'11.4'' N 075˚14'53.88'' E	3.00	Evergreen type	Sasthavu	KASARGOD
4	MANNAM PURATHUKAVU	SG104	Neeleswaram	12˚15'27.6'' N 75˚07'59.4'' E	2.83	Semi ever green type	Thaipardhevath a Nagam	KASARGOD
5	SREE MALLIYODAN KAVU	SG105	Konnakkad	12˚22'1.24'' N 75˚19'22.8'' E	3.00	Semi ever green type	Malliyodan devasthanam	KASARGOD
6	PAYYAMKULAM KAVU	SG106	Kinaur,Karintha lam	12˚17'41.7' N 75˚12'18.96'' E	5.00	Evergreen type	Poomala bhagavthy	KASARGOD
7	PERIYANGANAM SREE DHARMA SASTHA KAVU	SG107	Periyanganm	12˚18'36.0'' N 75˚15'52.56'' E	2.00	Semi ever green type	Sasthavu	KASARGOD

Table 2. (Contd) Details of sites covered for spider inventory in sacred groves of Kasargod and Kannur Districts.

8	PUTHIYA PARAMBATHUKAVU	SG108	Puthukky, Neeleswaram	12°15’34.56’’ N 75°07’41.16.’’ E	3.00	Semi ever green type	Bhagavathy	KASARGOD
9	CHAMA KAVU	SG201	Vellur, Payyannur	12°09’07.03’’ N 75°12’35.5’’ E	3.640	Evergreen type	Thayyi Paradevatha	KANNUR
10	KONGANICHAL KAVU	SG202	Thulluvadakkam, Alappadambu	12°8’36.41’’ N 75°14’18.76’’ E	3.320	Evergreen type	Narambil Bhagavathy	KANNUR
11	MADAYI KAVU	SG203	Eripuram, madayi	12°02’05.5’’ N 75°21’50.0’’ E	6.06	Moist deciduous	Thayyi Paradevatha	KANNUR
12	NEELIAR KOTTAM	SG204	Morazha, Anthoor	11°56’03.8’’ N 75°21’50.0’’ E	8.7	Evergreen type	Neeliamma	KANNUR
13	PALATHARA KAVU	SG205	Karivellur	12°10’07.0’’ N 75°12’07.9’’ E	1.00	Evergreen type	Bhagavathy	KANNUR
14	POONGOTTU KAVU	SG206	Mattannur, Poongottu	11°55’14.7’’ N 75°36’58.9’’ E	14.60	Fresh water myristica swamp	Sasthavu	KANNUR
15	THAZHE KAVU	SG207	Thekkumbadam, Mattul	11°57’59.3’’ N 75°17’50.9’’ E	7.52	Mangrove	Bhagavathy	KANNUR

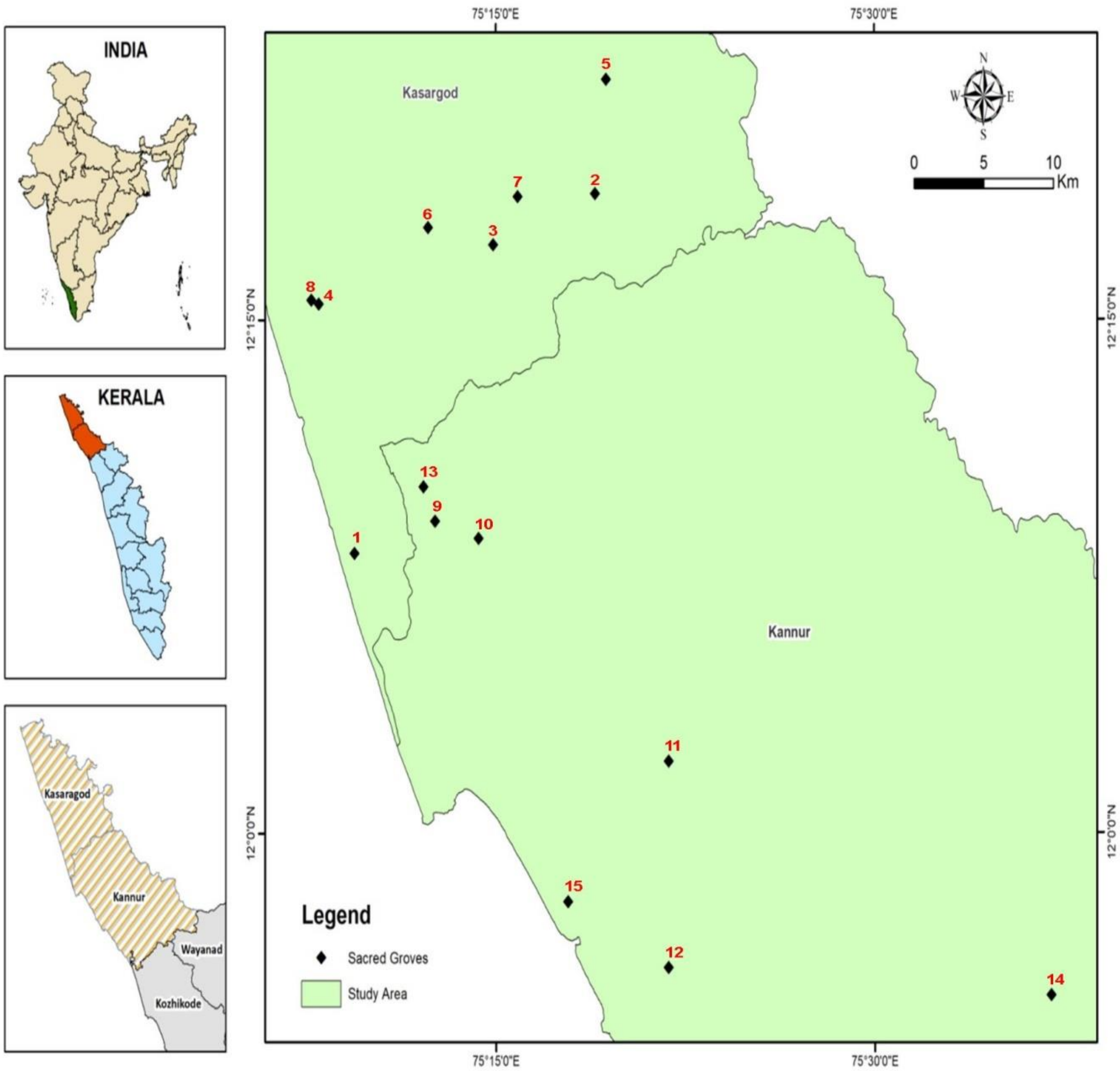


Figure 1. Map showing the study area. Edayilekadu Kavu (01), Kammadom Kavu (02), Koyithatta Sree Dharmasastha Kavu (03), Mannam Purathu Kavu (04), Sree Malliyodan Kavu (05), Payyamkulam Kavu (06), Periyanganam Sree Dharmasastha Kavu (07), Puthiya Parambathu Kavu (08), Chama Kavu (09), Konganichal Kavu (10), Madayi Kavu (11), Neeliaar Kottam (12), Palathara Kunji Kavu (13), Poongottu Kavu (14) and Thazhe Kavu (15).

3.3. Sampling

A sample is always used to obtain information about populations and provide needed information quickly. It is always used to assess the quality and accuracy. Sampling is an indispensable part of population ecology. It provides a foundation for the research programme, furnishing data on density, dispersion, age structure, reproduction and migration (Pedigo & Buntin, 1994). Various sampling methods are now available for collecting spiders from their own habitat. The following standard sampling methods were used.

Spider sampling was carried out from 2016 February till 2018 January. The study periods were divided into Pre-monsoon (February-May), Monsoon (June-September) and Post-monsoon (October-January) seasons and samples collected from each season. Spiders were collected in the morning from 7.00 am to 10.00 am and evening from 4.00 pm to 7.00 pm. Line transect method (Lubin, 1978) were adopted in this study. A total of 30 fixed transects (100 m in length, the transects were l m wide and 2 m high, extending up from the surface of the leaf litter) were established across the 15 sacred groves. Spiders were collected along 100 m transect length of two transects per habitat. Each transect was sampled for 1 hour, thus adding up to 1-2 hours for a study area. A total of 90 samples were collected during the study period from the study area. To avoid the edge effect transects were fixed 25 m inside from the boundary.

3.4. Sampling Techniques

As spiders exploit a wide variety of niches, sampling was done in order to collect representative samples from selected habitat. For example, hand picking, beating method, aerial sampling, litter collection and visual search method (Plate 3) that can record spiders across these strata as well as web-builders and bark-dwellers etc. These methods in addition have variable sampling efficiencies and need to be carefully chosen based on the sampling exercise (Sorenson et al., 2002). Study site was examined thoroughly for the possible spiders**.** Other time constrained semi-quantitative collection methods were employed (Coddington et al., 1996) to maximize capture.

3.4.1. Hand picking: One of the best methods to collect spiders. The specimens can also be carefully picked by hand, with the help of a soft paint brush the specimen can be gently hit into a collecting vial.

3.4.2. Beating method: The beating method is suited to collect the spiders from sturdier vegetation, such as trees and shrubs. To begin, place a beating tray (this is usually an inverted umbrella or sheet) beneath the tree or shrub. Next firmly tap the plant with a stick. Check the tray or umbrella after beating to collect any spiders that may have fallen before they get away.

3.4.3. Aerial sampling: Aerial sampling of spiders done by searching leaves, trunks, and spaces in between, from knee height up to maximum overhead arm's reach and transferring them into collection bottles. Smaller spiders collect by leading them into tubes containing alcohol with the help of a brush dipped in alcohol. Spiders found on the webs caught in the jar by holding it open beneath them and by tapping these spiders into it with the lid.

3.4.4. Litter collection: It involves the collection of spider samples from ground to knee level. This method of sampling is used to collect spiders, which were found to be visible in the ground, litter, in broken logs, rocks etc.

Plate 3

Methods of spider sampling used in the study area

(A)

(B)

(C)

(D)

(A). Hand picking, (B). Beating method, (C). Aerial sampling, (D). Litter collection.

3.4.5. Visual search method: in this method spiders were spotted on the flowers, folded leaves, under the leaflets, ground, shrubs, and on the bark. Spiders were easily collected by driving them into a sample container.

3.4.6. Preservation: All the specimens were kept in separate vials and all vials of a sample were kept separately in sample bags with proper labeling and other notes of taxonomic importance. After sampling was over, the collected specimens were brought to the laboratory. They were sorted and an effort was made to identify in live specimen using reference books like (Sebastian & Peter, 2009). Those who could be identified with certainty were recorded and kept away releasing back. The individuals difficult to identify were checked if they were adult. If they were juveniles, they were attempted to identify up to at least family or genus and were recorded. The adults were immediately killed using alcohol and were examined under the microscope. The killed specimens were preserved in 70% ethyl alcohol. Some adults of each species or morphospecies were preserved as voucher specimen with proper cataloguing. They were subjected to detailed taxonomic examination for identification. They were identified with the help of standard taxonomic keys, expert advice and standard literatures. They will be retained for future reference and will be deposited in Museum of Centre for Animal Taxonomy and Ecology, Department of Zoology, Christ College, Irinjalakuda. The field collection data also used to calculate the species richness, species diversity and relative abundance of dominant spiders present in different locations and seasons.

3.4.7. Identification: Specimens collected were transported to the laboratory. Comparatively large specimens were photographed in the field itself before collection with the help of special digital camera and lens (Canon EOS 5D digital

SLR and Canon 180 mm macro lens). Preserved specimens were examined under a stereo zoom microscope (Leica-M205C) in the laboratory for taxonomic identification. Spiders were identified up to species level with the help of available keys and literature (Sebastian & Peter, 2009). Identification and classification was also done on the basis of morphometric characters of various body parts. Whenever necessary and congruent with availability of time and other resources, the genitalia of male and female spiders were dissected and cleared using 10% KOH. As per the standard protocol for confirming identities of spiders, these cleared genitalia were compared with illustrations and descriptions available in the literature. In several cases expert advice was sought from scientists working on a particular family or genus (Patil, 2016). Most of the literature for this purpose was sourced from World Spider Catalog (WSC,2021) which has an almost complete global repository of taxonomic literature on spiders. Similarly, Aranea of India (Caleb & Sankaran, 2021) etc were found immense help.

3.5. Diversity indices

The diversity of the different sacred groves is described as Hill numbers or effective number of species or species equivalents. They are increasingly used to characterize the phylogenetic, taxonomic or functional diversity of an assemblage. However, empirical estimates of Hill numbers, including species richness, tend to be an increasing function of sampling effort and thus tend to increase with sample completeness. Integrated curves based on sampling theory that smoothly link rarefaction (interpolation) and prediction (extrapolation) standardize samples on the basis of sample size or sample completeness and facilitate the comparison of biodiversity data (Chao et al., 2014). Hill numbers are a mathematically unified family of diversity that incorporate relative abundance and species richness and overcome many of the shortcomings of the commonly used diversity indices like Shannon entropy and Simpson index (Chao et al., 2014). It is possible to characterize the species diversity of an assemblage using the first three Hill numbers, where q = 0 is the species richness, q =1 is the exponential of Shannon's entropy (Shannon diversity), and q =2 is the inverse of Simpson's concentration index (Simpson index). The diversity indices, Shannon and Simpson, were converted into effective number of species (Jost, 2006), which is the number of equally abundant species necessary to produce the observed value of diversity. Effective number of species may be called a good diversity measure, they possess a uniform set of mathematical properties that accurately capture the diversity concept and facilitates the interpretation of results (Jost, 2006). Analysis was carried out using Vegan package 2.5-7 (Oksanen et al., 2020). The changes in average abundance and Alpha diversity of spiders among areas (Shannon-Weiner, Simpson diversity and Richness) were compared using one-way ANOVA and Tukey Honest Significant Differences test. The abundance-based data were analysed with R packages such as (R Core team, 2020) SpadeR package version 0.1.1 (Species Prediction and Diversity Estimation, Chao & Chiu, 2016) and iNEXT package 2.0.9 (Hsieh et al., 2016 & Chao et al., 2014) also give the 95% confidence intervals to define the sampling variation, constructed using 200 bootstrap replications (Chao, 1987; Chao & Chiu, 2016). The relative abundance based Morisita-Horn dissimilarity index (q=1) was used to find the overall and the pairwise dissimilarities of the five habitats, using the SpadeR package (Chao & Chiu, 2016).

Rarefaction is inevitable that differences in sample size will exist between both the historic and present surveys and between the yearly surveys, even if the sampling protocol is followed exactly. Except under certain conditions it is meaningless to compare the diversity or measure the turnover of different-sized collections. Therefore, scaled all samples to the size of smallest sample, a procedure called rarefaction. Rarefaction is a method used to calculate $E(Sn)$, the expected number of species in a sample of n individuals selected at random from a collection containing N individuals of S species (Heck et al., 1975). From the list of individuals in all but the smallest of the samples, a number equal to the number of individuals in the smallest sample was randomly selected. This generates a new species list and associated abundance distribution.

A rank abundance curve or Whittaker plot is a chart used by ecologists to display relative species abundance, a component of biodiversity. It can also be used to visualize species richness and species evenness. It overcomes the shortcomings of biodiversity indices that cannot display the relative role different variables played in their calculation. The curve is a 2D chart with relative abundance on the Y-axis and the abundance rank on the X-axis. X-axis: the abundance rank. The most abundant species is given rank 1; the second most abundant is 2 and so on. Y-axis: the relative abundance. Usually measured on a log scale, this is a measure of a species abundance (e.g., the number of individuals) relative to the abundance of other species. The rank abundance curve visually depicts both species richness and species evenness. Species richness can be viewed as the number of different species on the chart i.e., how many species were ranked. Species evenness is reflected in the slope of the line that fits the graph (assuming a linear, i.e. logarithmic series, relationship).

A steep gradient indicates low evenness as the high-ranking species have much higher abundances than the low-ranking species. A shallow gradient indicates high evenness as the abundances of different species are similar. Relative species abundance is a component of biodiversity and refers to how common or rare a species is relative to other species in a defined location or community. Relative abundance is the percent composition of an organism of a particular kind relative to the total number of organisms in the area. Relative species abundances tend to conform to specific patterns that are among the best-known and most-studied patterns in macro ecology. In fact, *AIC or BIC* when comparing models fitted by maximum likelihood to the same data, the smaller the AIC or BIC, the better the fit. The theory of AIC requires that the log-likelihood has been maximized: whereas AIC can be computed for models not fitted by maximum likelihood, their AIC values should not be compared. Examples of models not 'fitted to the same data' are where the response is transformed (accelerated-life models are fitted to log-times) and where contingency tables have been used to summarize data. These are generic functions (with S4 generics defined in package stats4): however, methods should be defined for the log-likelihood function logLik rather than these functions: the action of their default methods is to call logLik on all the supplied objects and assemble the results. Note that in several common cases logLik does not return the value at the MLE. The log-likelihood and hence the AIC/BIC is only defined up to an additive constant. Different constants have conventionally been used for different purposes and so extract AIC and AIC may give different values (and do for models of class "lm"). Particular care is needed when comparing fits of different classes (with, for example, a comparison of a Poisson and gamma GLM being meaningless since one has a discrete response, the other continuous).

The variation among the different groups / different habitats was analysed using the PERMANOVA test (Anderson et al., 2011), done using Adonis function of vegan with 999 permutations and was visualised using nMDS plot. This was done using a dissimilarity matrix derived from Horn index using the vegdist() function of the vegan package. The abundance data was double root transformed to normalise the distribution. To check if the differences were brought about by the dispersions of the sample sites, homogeneity of multivariate dispersions was done. Regional diversity analysis was done by using a non-parametrical test called Wilcoxon rank sum test. Most of the boxplots were prepared using R package ggplot2 (Wikham, H 2016).

3.6. Guild structure studies

Guild classification is based on daily activity pattern at family level which includes ecological characteristics relating to foraging manner, pattern of web, prey species, microhabitat utilisation. Output of the analysis was prepared into graphical form. The spider guild classification was composed habitat wise, according to the families collected during the study period. Ecological characteristics of each family helps in the designation of spider guilds (Young & Edwards, 1990) and Spiders collected from the sacred groves with different habitats were sorted into the different guilds based on their foraging behaviour in the field (Uetz et al., 1999). The guild classification in the present study is based on the results of Cardoso et al., 2011.

Fifteen sacred groves were chosen in different regions of the Kannur and Kasargod Districts to provide a reasonable synopsis of spider diversity. Sampling followed the semi-quantitative design with different effort per method at each site. In this kind of sampling, each sample represented one method applied for 1 or 2 h of continuous and active collection (i.e., including time required to transfer the specimens to a vial, without interruptions). Semi-quantitative sampling as functional for this work, it enhances maximum richness with minimum effort but still permitting comparability of study sites by using a standard set of methods, effort per method and time of day.

In this work information on foraging strategy was used. Data for each family was collected from a number of sources and used the general characteristics of families, acknowledging that exceptions in many cases are inevitable at such a large taxonomic and geographic scale. In a few families in which relatively large numbers of species clearly have evolved distinct lifestyles. Separate the families into sub-families and classified each accordingly. These sub-families are hereafter treated as families. When families were largely unknown, used the characteristics of a particular species in the family for which the behavior was known. Microsoft Excel 2007 and 2013 were used for calculation and graphical representation for the Total guild structure, Spider species richness and Spider abundance among guilds across five habitat types.

For further evaluation of the structure of sacred grove spider assemblages and their ecological function and present an analysis of the guild structure of the fauna of sacred groves of Northern Kerala, although give emphasis to the lack of knowledge on natural history and behaviour for many of the species. The knowledge of natural history and ecology of spiders is essential for an understanding of the role of spiders in natural and agroecosystems (Sunderland & Greenstone, 1999), but these information are especially inadequate from tropical assemblages. This database will in the future facilitate species identification of sacred grove spider collections, allow comparison of morphospecies and serve as an important background for biodiversity evaluation in natural and anthropogenic habitats and helps in recognition of species distribution and loss.

CHAPTER 4
RESULTS

CHAPTER-4

RESULTS

4.1. INVENTORY OF SPIDERS IN SACRED GROVES

4.1.1. Spider diversity in sacred groves

Rich spider diversity has been documented in the present study with 257 species including morphospecies. This is close to 14% of the known Araneomorph spider species from India (Caleb & Sankaran, 2021). These 257 species belong to 28 families and 136 genera which respectively comes to 46% and 29% of Araneomorph families known from 1ndia (Caleb & Sankaran, 2021)). Figure 2 displays taxonomic diversity in terms of genus and species richness in the 28 spider families recorded in the study. It was observed that family Araneidae was dominant in terms of taxonomic richness (19 genera, 50 species), as well as in terms of number of individuals captured through systematic sampling. The second dominant family was Salticidae (35 genera, 43 species). It was closely followed by Theridiidae (17 genera, 29 species). A list of species (including morphospecies) recorded in this study represented in Table 3.

Table 3. Representation of genera and species in different spider families of the entire spider assemblage recorded in the study area.

FAMILY	No. of Genera	No. of Species
ANYPHAENIDAE	1	1
ARANEIDAE	19	50
CHEIRACANTHIIDAE	1	5
CLUBIONIDAE	2	11
CORINNIDAE	2	6
CTENIDAE	1	1
GNAPHOSIDAE	3	3
HERSILIIDAE	1	2
LINYPHIIDAE	2	2
LYCOSIDAE	4	12
MIMETIDAE	1	2
MITURGIDAE	1	1
OECOBIIDAE	1	1
OONOPIDAE	2	2
OXYOPIDAE	4	17
PALPIMANIDAE	2	2
PHILODROMIDAE	3	5
PHOLCIDAE	5	7
PISAURIDAE	1	2
SALTICIDAE	35	43
SCYTODIDAE	1	2
SPARASSIDAE	4	7
TETRAGNATHIDAE	5	15
THERIDIIDAE	17	29
THOMISIDAE	13	20
TRACHELIDAE	1	2
ULOBORIDAE	3	6
ZODARIIDAE	1	1
	136	**257**

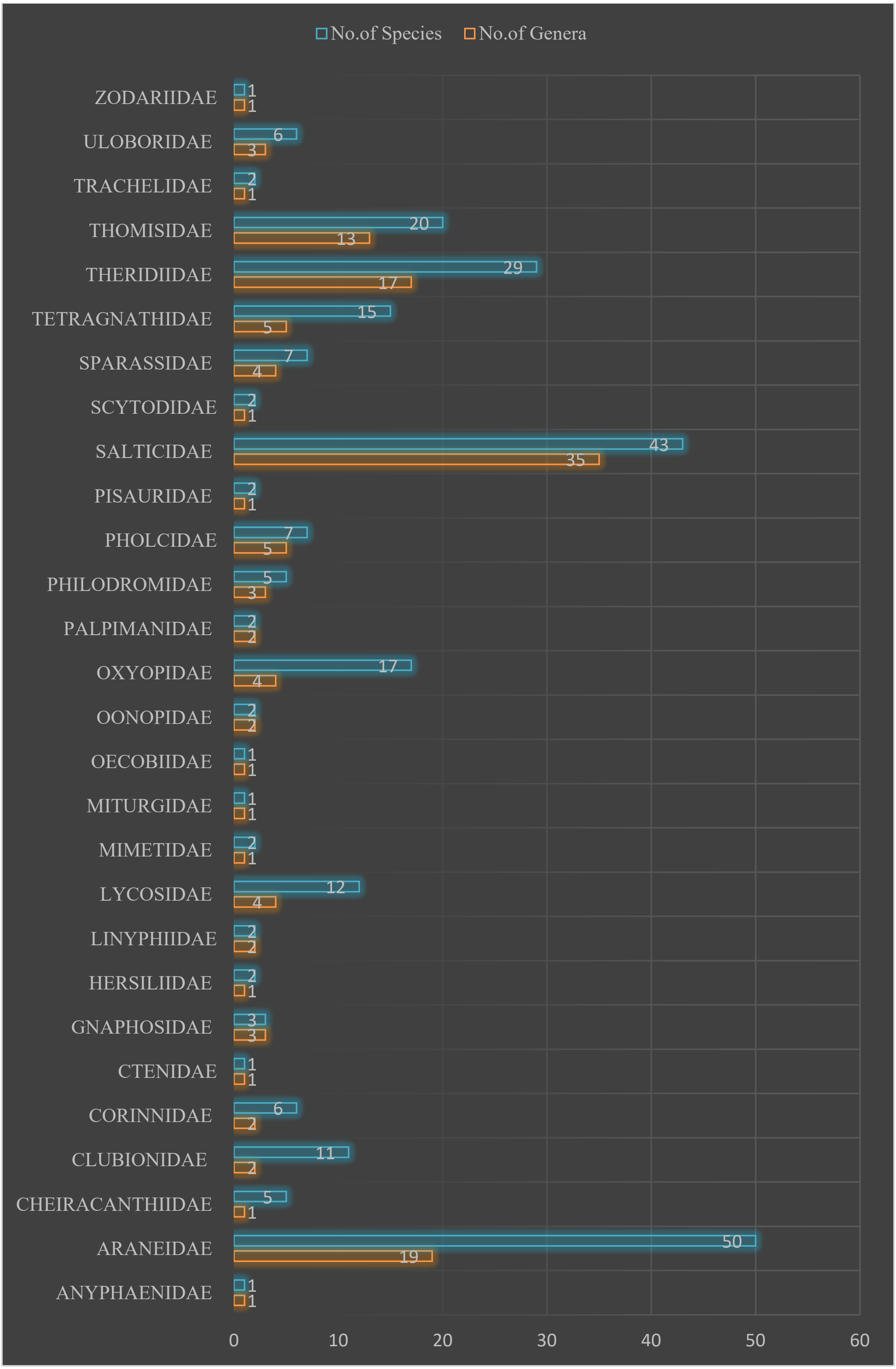


Figure 2. Representation of genera and species in different spider families of the entire spider assemblage recorded in the study area.

Table 4. Representation of species in different spider families of the entire spider assemblage recorded in the study area.

	CHECKLIST OF SPIDERS COLLECTED FROM SACRED GROVES
	I) ANYPHAENIDAE Bertkau, 1878
1	*Anyphaena* sp.
	II) ARANEIDAE Clerck, 1757
2	*Anepsion maritatum* (O. Pickard-Cambridge, 1877)
3	*Arachnura* sp.
4	*Araneus ellipticus* (Tikader & Bal, 1981)
5	*Araneus mitificus* (Simon, 1886)
6	*Araneus* sp. I
7	*Araneus* sp. II
8	*Araneus* sp. III
9	*Argiope aemula* (Walckenaer, 1841)
10	*Argiope catenulata* (Doleschall, 1859)
11	*Argiope pulchella* Thorell, 1881
12	*Chorizopes* sp.
13	*Chorizopes quadrituberculata* Roy et al., 2014
14	*Cryptaranea* sp.
15	*Cyclosa bifida* (Doleschall, 1859)
16	*Cyclosa confraga* (Thorell,1892)
17	*Cyclosa hexatuberculata* Tikader, 1982
18	*Cyclosa moonduensis* Tikader, 1963
19	*Cyclosa neilensis* Tikader, 1977
20	*Cyrtarachne* sp.
21	*Cyrtophora cicatrosa* (Stoliczka, 1869)
22	*Cyrtophora unicolor* (Doleschall, 1857)
23	*Eriovixia excelsa* (Simon, 1889)
24	*Eriovixia laglaizei* (Simon, 1877)
25	*Eriovixia palawanesis* (Barrion & Litsinger, 1995)
26	*Eriovixia porcula* (Simon, 1877)
27	*Eriovixia sakiedaorum* Tanikawa, 1999
28	*Eriovixia* sp. I
29	*Eriovixia* sp. II
30	*Gasteracantha dalyi* Pocock, 1900
31	*Gasteracantha geminata* (Fabricius, 1798)
32	*Gasteracantha hasselti* (C. L. Koch, 1837)
33	*Gasteracantha kuhli* C. L. Koch, 1837
34	*Gea spinipes* C. L. Koch, 1843

35	*Gea subarmata* Thorell, 1890
36	*Herennia multipuncta* (Doleschall, 1859)
37	*Nephila pilipes* (Fabricius, 1793)
38	*Neoscona bengalensis* Tikader & Bal, 1981
39	*Neoscona molemensis* Tikader & Bal ,1980
40	*Neoscona mukerjei* Tikader, 1980
41	*Neoscona theisi* (Walckenaer, 1841)
42	*Neoscona vigilans* (Blackwall, 1865)
43	*Neoscona* sp. I
44	*Neoscona* sp. II
45	*Neoscona* sp. III
46	*Paraplectana* sp.
47	*Parawixia dehaani* (Doleschall, 1859)
48	*Poltys coloumnaris* Thorell,1890
49	*Poltys* sp.
50	*Porcataraneus bengalensis* (Tikader, 1975)
51	*Plebs mitratus* (Simon, 1895)
	III) CHEIRACANTHIIDAE Wagner, 1887
52	*Cheiracanthium danieli* Tikader, 1975
53	*Cheiracanthium melanostomum* (Thorell, 1895)
54	*Cheiracanthium mysorense* Majumder & Tikader, 1991
55	*Cheiracanthium* sp. I
56	*Cheiracanthium* sp. II
	IV) CLUBIONIDAE Wagner, 1887
57	*Clubiona bilobata* Dhali et al., 2016
58	*Clubiona drassodes* O. Pickard-Cambridge, 1874
59	*Clubiona hexadentata* Dhali et al., 2016
60	*Clubiona nicobarensis* Tikader, 1977
61	*Clubiona pila* Dhali et al., 2016
62	*Clubiona tridentata* Dhali et al., 2016
63	*Clubiona* sp. I
64	*Clubiona* sp. II
65	*Clubiona* sp. III
66	*Clubiona* sp. IV
67	*Matidia virens* Thorell, 1878
	V) CORINNIDAE Karsch, 1880
68	*Castianeira furva* Sankaran et al., 2015
69	*Castianeria zetes* Simon, 1897
70	*Castianeira* sp. I
71	*Castianeira* sp. II
72	*Corinnomma* sp. I
73	*Corinnomma* sp. II

	VI) CTENIDAE Keyserling, 1877
74	*Ctenus cochinensis* Gravely, 1931
	VII) GNAPHOSIDAE Pocock, 1898
75	*Drassodes* sp.
76	*Scotophaeus blackwalli* (Thorell, 1871)
77	*Zelotes ashae* Tikader & Gajbe, 1976
	VIII) HERSILIIDAE (Thorell, 1870)
78	*Hersilia savignyi* Lucas, 1836
79	*Hersilia* sp.
	IX) LINYPHIIDAE Blackwall, 1859
80	*Linyphia* sp.
81	*Neriene macella* (Thorell, 1898)
	X) LYCOSIDAE Sundevall, 1833
82	*Hippasa agelenoides* (Simon, 1884)
83	*Hippasa holmerae* Thorell, 1895
84	*Hippasa madraspatana* Gravely, 1924
85	*Lycosa bistriata* Gravely, 1924
86	*Lycosa mackenziei* Gravely, 1924
87	*Pardosa birmanica* Simon, 1884
88	*Pardosa chambaensis* Tikader & Malhotra, 1976
89	*Pardosa mysorensis* Tikader & Mukerji, 1971
90	*Pardosa pseudoannulata* (Bosenberg & Strand, 1906)
91	*Pardosa sumatrana* (Thorell, 1890)
92	*Paradosa* sp.
93	*Trochosa* sp.
	XI) MIMETIDAE Simon, 1881
94	*Mimetus* sp. I
95	*Mimetus* sp. II
	XII) MITURGIDAE Simon, 1886
96	*Systaria* sp.
	XIII) OECOBIIDAE Blackwall, 1862
97	*Oecobius* sp.
	XIV) OONOPIDAE Simon,1890
98	*Gamasomorpha* sp.
99	*Opopaea* sp.
	XV) OXYOPIDAE Thorell, 1870
100	*Hamadruas sikkimensis* (Tikader,1970)
101	*Hamadruas* sp. I
102	*Hamadruas* sp. II
103	*Hamataliwa* sp. I
104	*Hamataliwa* sp. II
105	*Oxyopes birmanicus* Thorell, 1887

106	*Oxyopes forcipiformis* Xie & Kim, 1996
107	*Oxyopes hindostanicus* Pocock, 1901
108	*Oxyopes javanus* Thorell, 1887
109	*Oxyopes lineatipes* (C. L. Koch, 1847)
110	*Oxyopes salticus* Hentz, 1845
111	*Oxyopes shweta* Tikader, 1970
112	*Oxyopes sunandae* Tikader, 1970
113	*Oxyopes* sp. I
114	*Oxyopes* sp. II
115	*Peucetia ananthakrishnani* Murugesan et al., 2006
116	*Peucetia viridana* (Stoliczka, 1869)
	XVI) PALPIMANIDAE Thorell, 1870
117	*Palpimanus* sp. I
118	*Sarascelis raffrayi* Simon, 1893
	XVII) PHILODROMIDAE Thorell, 1870
119	*Philodromus* sp. I
120	*Philodromus* sp. II
121	*Thanatus indicus* Simon, 1885
122	*Thanatus* sp.
123	*Tibellus elongatus* Tikader, 1960
	XVIII) PHOLCIDAE C. L. Koch, 1850
124	*Artema atlanta* Walckenaer, 1837
125	*Crossopriza lyoni* (Blackwall, 1867)
126	*Pholcus phalangioides* (Fuesslin, 1775)
127	*Pholcus* sp. I
128	*Pholcus* sp. II
129	*Smeringopus pallidus* (Blackwall, 1858)
130	*Pribumia atrigularis* (Simon, 1901)
	XIX) PISAURIDAE Simon, 1890
131	*Dendrolycosa gitae* (Tikader, 1970)
132	*Dendrolycosa robusta* (Thorell, 1895)
	XX) SALTICIDAE Blackwall, 1841
133	*Ajaraneola* sp.
134	*Asemonea tenuipes* (Cambridge, 1869)
135	*Bianor albobimaculatus* (Lucas, 1846)
136	*Brancus calebi* Kanesharatnam & Benjamin, 2018
137	*Brettus albolimbatus* Simon, 1900
138	*Brettus anchorum* Wanless, 1979
139	*Brettus cingulatus* Thorell, 1895
140	*Brettus* sp.
141	*Carrhotus viduus* (C. L. Koch, 1846)
142	*Chalcotropis pennata* Simon, 1902

143	*Chrysilla volupe* (Karsch, 1879)
144	*Cocalus lacinia* Sudhin et al., 2019
145	*Epeus tener* (Simon, 1877)
146	*Epeus triangulopalpis* Malamel et al., 2019
147	*Epocilla aurantiaca* (Simon, 1885)
148	*Euophrys evae* Żabka, 1981
149	*Eupoa* sp.
150	*Evarcha flavocincta* (C. L. Koch, 1846)
151	*Habrocestum* sp.
152	*Hasarius adansoni* (Audouin, 1826)
153	*Hyllus semicupreus* (Simon, 1885)
154	*Indopadilla insularis* (Malamel et al., 2015)
155	*Langona* sp.
156	*Lyssomanes* sp.
157	*Marpissa decorata* Tikader, 1974
158	*Marengo sachintendulkar* Malamel et al., 2019
159	*Menemermus bivittatus* (Dufour,1831)
160	*Myrmaplata plataleoides* (O. P. Cambridge, 1869)
161	*Phaeacius lancearius* (Thorell, 1895)
162	*Phidippus yashodharae* Tikader, 1977
163	*Phintella vittata* (C. L. Koch, 1846)
164	*Plexippus paykulli* (Audouin, 1826)
165	*Portia fimbriata* (Doleschall, 1859)
166	*Portia labiata* (Thorell, 1887)
167	*Rhene flavigera* (C. L. Koch, 1846)
168	*Rhene rubrigera* (Thorell, 1887)
169	*Siler semiglaucus* (Simon, 1901)
170	*Siler* sp.
171	*Stenaelurillus albus* (Sebastian et al., 2015)
172	*Stenaelurillus lesserti* Reimoser, 1934
173	*Telamonia dimidiata* (Simon, 1899)
174	*Thiania bhamoensis* Thorell, 1887
175	*Thyene imperialis* (Rossi, 1846)
	XXI) SCYTODIDAE Blackwall, 1864
176	*Scytodes fusca* Walckenaer, 1837
177	*Scytodes thoracica* (Latreille, 1802)
	XXII) SPARASSIDAE Bertkau, 1872
178	*Heteropoda nilgirina* (Pocock, 1901)
179	*Heteropoda venatoria* (Linnaeus, 1767)
180	*Heteropoda* sp. I
181	*Heteropoda* sp. II
182	*Pseudopoda straminiosa* (Kundu et al., 1999)

183	*Thelcticopis* sp.
184	*Olios milleti* (Pocock, 1901)
	XXIII) TETRAGNATHIDAE Menge, 1866
185	*Guizygiella nadleri* (Heimer, 1984)
186	*Leucauge decorata* (Blackwall, 1864)
187	*Leucauge dorsotuberculata* Tikader, 1982
188	*Leucauge pondae* (Tikader, 1970)
189	*Leucauge tessellata* (Thorell, 1887)
190	*Leucauge* sp.
191	*Opadometa fastigata* (Simon, 1877)
192	*Tetragnatha cochinensis* Gravely, 1921
193	*Tetragnatha javana* (Thorell, 1890)
194	*Tetragnatha keyserlingi* Simon, 1890
195	*Tetragnatha mandibulata* Walckenaer, 1842
196	*Tetragnatha squamata* Karsch, 1879
197	*Tetragnatha viridorufa* Gravely, 1921
198	*Tylorida striata* (Thorell, 1877)
199	*Tylorida ventralis* (Thorell, 1877)
	XXIV) THERIDIIDAE Sundevall, 1833
200	*Achaearanea durgae* Tikader, 1970
201	*Achaearanea* sp.
202	*Argyrodes ambalikae* (Tikader, 1970)
203	*Argyrodes argentatus* O. Pickard-Cambridge, 1880
204	*Argyrodes flavescens* O. Pickard-Cambridge, 1880
205	*Argyrodes gracilis* (L. Koch, 1872)
206	*Argyrodes gazedes* Tikader, 1970
207	*Argyrodes kumadai* Chida et al., 1999
208	*Argyrodes* sp.
209	*Ariamnes flagellum* (Doleschall, 1857)
210	*Chrysso angula* (Tikader, 1970)
211	*Chrysso urbasae* (Tikader, 1970)
212	*Enoplognatha* sp.
213	*Episinus affinis* Bösenberg & Strand, 1906
214	*Meotipa argyrodiformis* (Yaginuma, 1952)
215	*Meotipa multuma* Murthappa et al., 2017
216	*Meotipa picturata* Simon, 1895
217	*Molione triacantha* Thorell, 1892
218	*Nesticodes rufipes* (Lucas, 1846)
219	*Nihonhimea mundula* (L. Koch, 1872)
220	*Parasteatoda celsabdomina* (Zhu, 1998)
221	*Phycosoma martinae* (Roberts, 1983)
222	*Phycosoma* sp. I

223	*Phycosoma* sp. II
224	*Phoroncidia septemaculeata* O. Pickard-Cambridge, 1873
225	*Rhomphaea projiciens* O. Pickard-Cambridge, 1896
226	*Theridion manjithar* (Tikader, 1970)
227	*Theridula angula* (Emerton,1882)
228	*Thwaitesia margaritifera* O. Pickard-Cambridge, 1881
	XXV) THOMISIDAE Sundevall, 1833
229	*Amyciaea albomaculata* (O. Pickard-Cambridge, 1874)
230	*Amyciaea forticeps* (O. P. Cambridge, 1873)
231	*Boliscus tuberculatus* (Simon, 1886)
232	*Camaricus formosus* Thorell, 1887
233	*Camaricus khandalaensis* Tikader, 1980
234	*Indoxysticus minutus* (Tikader, 1960)
235	*Massuria sreepanchamii* (Tikader, 1962)
236	*Misumena* sp.
237	*Oxytate greenae* (Tikader, 1980)
238	*Oxytate virens* (Thorell, 1891)
239	*Ozyptila* sp.
240	*Runcinia roonwali* Tikader, 1965
241	*Strigoplus netravati* Tikader,1963
242	*Thomisus lobosus* Tikader, 1965)
243	*Thomisus projectus* Tikader, 1960
244	*Tmarus histrix* Caporiacco, 1954
245	*Xysticus bengalensis* Tikader & Biswas, 1974
246	*Xysticus cristatus* (Clerck, 1757)
247	*Xysticus minor* (Charitonov, 1946)
248	*Xysticus viveki* Gajbe, 2005
	XXVI) TRACHELIDAE Simon, 1897
249	*Utivarachna rama* (Chami-Kranon & Likhitrakarn, 2007)
250	*Utivarachna* sp.
	XXVII) ULOBORIDAE Thorell, 1869
251	*Miagrammopes extensus* Simon, 1889
252	*Miagrammopes* sp.
253	*Uloborus danolius* Tikader, 1969
254	*Uloborus khasiensis* Tikader, 1969
255	*Uloborus krishnae* Tikader, 1970
256	*Zosis geniculata* (Olivier, 1789)
	XXVIII) ZODARIIDAE Thorell, 1881
257	*Suffasia* sp.

4.1.2 Details of the families collected from sacred groves.

1. Family: Anyphaenidae, Bertkau: 1878 (Anyphaenid sac spiders)

Identification features: It is a family of araneomorph spiders, the main distinguishing feature from the sac spiders of the family Clubionidae and other spiders by having the abdominal spiracle placed one third to one half of the way anterior to the spinnerets toward the epigastric furrow on the underside of the abdomen. The spiracle is just anterior to the spinnerets in most of the spiders. Like clubionids, anyphaenids have eight eyes arranged in two rows, conical anterior spinnerets and are wandering predators that build silken retreats, or sacs, usually on plant terminals, between leaves, under bark or under rocks.

The family is cosmopolitan distribution and includes such common genera as *Anyphaena* (worldwide except tropical Africa and Asia) and *Hibana* (New World). Only one species *A. accentuata* occurs in northwestern Europe. Species in the *Hibana* genus are important predators in several agricultural systems, especially tree crops. They are able to detect and feed on insect eggs, despite their poor eyesight. They share this ability at least with some miturgid spiders.

Genera; species in worldwide -56; 575

Genera; species in India -1; 1

List of species in present study - 1; 1

Anyphaena sp.

2. Family: Araneidae, Simon: 1895 (Orb web spiders)

Identification features: Frequently flat cephalothorax, variable; cephalic region usually separated from the thoracic region by an oblique depression, fovea distinct to absent. Two rows eight eyes are present, Size and variation is very less in different genera; laterals widely separated from medians, medians form a quadrangle either a square or a trapezium; laterals usually close and often projecting on angular tubercles. Heart shaped or triangular sternum and narrowing behind, thus coxae IV nearly contiguous. Wider labium with swollen distal edge (rebordered). Maxillae widest distally and generally not longer than wide. Chelicerae strong, vertical and not divergent, provided with lateral condyle (boss) on each, fang furrow armed with two rows of strong teeth, clothed with hairs and spines, three tarsal claws and auxiliary foot claws, trichobothria present on all leg segments except tarsi. Size and shape of abdomen variable, usually globose, overhanging cephalothorax, dorsum frequently with distinct pattern and humps, covered with serrated setae. Simple six spinnerets with aggregate silk gland spigots and colulus. Epigyne complex consists of completely or partially sclerotized, frequently with scapus, epigynal plate with a transverse furrow. Pedipalp with single claw in female; male palp complex, paracymbium usually has a sclerotized hook and attached to proximal end of cymbium, median apophys is present, bulbus rotated within cymbium. Many species of this family are commonly present in different habitats and most of them construct perfect orb webs for prey capture. They use the "spin-wrap-attack" method to subdue their prey. Spiders hang in the web head down position and are sit-and-wait predators and the web can be considered as the spider's home territory. The general shape, number of radii, spirals, shape of hub and decorations of the web vary between genera and sub families. Some spiders decorate the web with stabilimentum. Both the size and the weight of the spider as well as the web's site can influence web design (Plates 7-12).

Genera; species in worldwide -177; 3059

Genera; species in India -37; 185

List of species in present study-19; 50

Anepsion maritatum (Cambridge, 1877), (Plate-7, Fig-1)
Arachnura sp. (Plate-7, Fig-2)
Araneus ellipticus (Tikader & Bal, 1981), (Plate-7, Fig-3)
Araneus mitificus (Simon, 1886), (Plate-7, Fig-4)
Araneus sp. I, (Plate-7, Fig-5)
Araneus sp. II, (Plate-7, Fig-6)
Araneus sp. III
Argiope aemula (Walckenaer, 1841), (Plate-7, Fig-7)
Argiope catenulata (Doleschall, 1859), (Plate-7, Fig-8)
Argiope pulchella Thorell, 1881, (Plate-8, Fig-9)
Chorizopes sp., (Plate-8, Fig-10)
Chorizopes quadrituberculata Roy et al., 2014
Cryptaranea sp.
Cyclosa bifida (Doleschall, 1859), (Plate-8, Fig-11)
Cyclosa confraga (Thorell, 1892), (Plate-8, Fig-12)
Cyclosa hexatuberculata Tikader, 1982, (Plate-8, Fig-13)
Cyclosa moonduensis Tikader, 1963, (Plate-8, Fig-14)
Cyclosa neilensis Tikader, 1977, (Plate-8, Fig-15)
Cyrtarachne sp., (Plate-8, Fig-16)
Cyrtophora cicatrosa (Stoliczka, 1869), (Plate-9, Fig-17)
Cyrtophora unicolor (Doleschall, 1857), (Plate-9, Fig-18)
Eriovixia excelsa (Simon, 1889), (Plate-9, Fig-19)
Eriovixia laglaizei (Simon, 1877), (Plate-9, Fig-20)
Eriovixia palawanesis (Barrion & Litsinger, 1995), (Plate-9, Fig-21)
Eriovixia porcula (Simon, 1877), (Plate-9, Fig-22)
Eriovixia sakiedaorum Tanikawa, 1999, (Plate-9, Fig-23)
Eriovixia sp. I., (Plate-9, Fig-24)
Eriovixia sp. II., (Plate-10, Fig-25)
Gasteracantha dalyi Pocock, 1900, (Plate-10, Fig-26)
Gasteracantha geminata (Fabricius, 1798), (Plate-10, Fig-27)
Gasteracantha hasselti (C. L. Koch, 1837), (Plate-10, Fig-28)
Gasteracantha kuhli C. L. Koch, 1837, (Plate-10, Fig-29)

Gea spinipes C. L. Koch, 1843, (Plate-10, Fig-30)

Gea subarmata Thorell, 1890, (Plate-10, Fig-31)

Herennia multipuncta (Doleschall, 1859), (Plate-10, Fig-32)

Nephila pilipes (Fabricius, 1793), (Plate-11, Fig-33)

Neoscona bengalensis Tikader & Bal, 1981, (Plate-11, Fig-34)

Neoscona molemensis Tikader & Bal ,1980, (Plate-11, Fig-35)

Neoscona mukerjei Tikader, 1980, (Plate-11, Fig-36)

Neoscona theisi (Walckenaer, 1841), (Plate-11, Fig-37)

Neoscona vigilans (Blackwall, 1865)

Neoscona sp. I., (Plate-11, Fig-38)

Neoscona sp. II., (Plate-11, Fig-39)

Neoscona sp. III

Paraplectana sp., (Plate-11, Fig-40)

Parawixia dehaani (Doleschall, 1859), (Plate-12, Fig-41)

Poltys coloumnaris Thorell,1890, (Plate-12, Fig-42)

Poltys sp., (Plate-12, Fig-43)

Porcataraneus bengalensis (Tikader, 1975), (Plate-12, Fig-44)

Plebs mitratus (Simon, 1895), (Plate-12, Fig-45)

3. Family: Cheiracanthiidae, **Wagner: 1887** (Sac spiders)

Identification features: Cheiracanthidae is a cosmopolitan family whose members are free living spiders living in foliage. They are ecribellate, entelygyne spiders with eight eyes; the eyes are wide and occupying almost the entire head-width. These spiders were previously part of Clubionidae family, then passed into the Miturgidae, then it moved in to the Eutichuridae and now have their own family. They are distinguished from Clubionidae by their first pair of more elongated legs and the absence of thoracic streak. They are generally detained during the day in a silk shelter often installed on the plants, but sometimes also under the stones. Their chelicerae are quite imposing. The size can vary from 5 to 15mm (Plates 12-13).

Genera; species in worldwide - 14; 362

Genera; species in India -2; 31

List of species in present study - 1; 5

Cheiracanthium danieli Tikader, 1975, (Plate-12, Fig-46)

Cheiracanthium melanostomum (Thorell, 1895), (Plate-12, Fig-47)

Cheiracanthium mysorense Majumder & Tikader, 1991

Cheiracanthium sp. I., (Plate-12, Fig-48)

Cheiracanthium sp. II., (Plate-13, Fig-49)

4. Family: Clubionidae, Wagner: 1887 (Sac spiders)

Identification features: Cephalothorax ovoid, distinctly longer; fovea shallow to absent, pale yellowish white or brownish; chelicerae and anterior region of eyes usually dark brown. Two rows of eight eyes, small and uniform in size, posterior eye row slightly longer than anterior row. Maxillae longer, with oblique indentation medially on lateral side, apex truncated and furnished with scopulae. Labium longer than wide. Chelicerae long, slender or stout, promargin with 2 to 7 teeth, retromargin with 2 to 4 small teeth; in some, particularly male, strongly developed with a long fang. Legs longer, strongly spined, with tarsi and metatarsi scopulate, tarsi furnished with ungual tufts and two claws, trochanters with or without notches, leg formula 1423, two claws with dense claw tufts and scopulae. Oval abdomen, males sometimes with small dorsal scutum. Anterior spinnerets conical or cylindrical and contiguous, median spinnerets cylindrical in both sexes, posterior spinnerets two segmented with apical segment short; anterior spinnerets in contact. Epigynal plate convex and sometimes sclerotized. Male palp with variable retrolateral apophysis, embolus and cymbium present. These are hunting spiders normally found on foliage or on the ground, where they make tubular retreats in rolled up leaves or beneath debris in litter. The flattened egg sac is suspended inside the retreat and the female guards it. They are aggressive in nature and use front legs to detect and grab prey (Plate 13).

Genera; species in worldwide -15; 639

Genera; species in India -3; 28

List of species in present study - 2; 11

Clubiona bilobata Dhali et al., 2016
Clubiona drassodes Cambridge, 1874
Clubiona hexadentata Dhali et al., 2016
Clubiona nicobarensis Tikader, 1977
Clubiona pila Dhali et al., 2016
Clubiona tridentata Dhali et al., 2016
Clubiona sp. I., (Plate-13, Fig-50)
Clubiona sp. II
Clubiona sp. III
Clubiona sp. IV
Matidia virens Thorell, 1878, (Plate-13, Fig-51)

5. Family: Corinnidae, Karsch: 1880 (Ant mimicking sac spiders)

Identification features: Cephalothorax ovoid in dorsal view occasionally elongated in ant mimics, sometimes heavily sclerotized. Eyes in two rows widely spaced or closely grouped or bulging anteriorly; posterior eye row straight or curved. Sternum oval, flat or slightly impressed, marginate and apex ends bluntly in front of posterior coxae. Chelicerae sturdy, convex, with strong curved setae on upper edge, both rows with teeth. Labium slightly convex, usually depressed transversely. Legs long and slender in ant mimics, sturdy with variable setae on front legs, with two claws, claw tufts present with light scopule, tarsal trichobothria present. Abdomen ovoid, elongate in ant like species, sometimes with scutum or transverse bands or patches or white setae. Integument fully with recumbent feathery setae, which frequently form lines or other patterns. Colulus triangular in shape, scelrotised. Anterior spinnerets sturdy and contiguous, posterior spinnerets slightly further apart than anterior pair; median spinnerets with three and posterior spinnerets with two large cylindrical gland spigots and it is absent in males. Epgiyne complex and variable. Male palp with tegulum tapering gradually towards embolus, sperm ducts with a conspicuous loop in proximal part of tegulum, bulbus without median apophysis in most genera. Corinnids are free-living ground dwellers, usually occur in debris, litter or humus in shaded areas. Some members of the subfamily Castianeirinae are good ant mimics. Their movements are ant like, including rapid movements with jerky pauses and swift changes in direction. While walking, the abdomen moves up and down and the front legs are held in the air to mimic the antennae of ants. Certain species are dark to metallic, or dark to yellowish brown with a shiny red to reddish brown carapace and a pale abdomen. They construct silky retreats in rolled up leaves and plant debris. If disturbed, they run rapidly and are very difficult to catch (Plate 13).

Genera; species in worldwide -70; 795

Genera; species in India -7; 17

List of species in present study - 2;6

Castianeira furva Sankaran et al., 2015, (Plate-13, Fig-52)
Castianeria zetes Simon, 1897, (Plate-13, Fig-53)
Castianeira sp. I
Castianeira sp. II
Corinnomma sp. I., (Plate-13, Fig-54).
Corinnomma sp. II., (Plate-13, Fig-55)

6. Family: Ctenidae, Keyserling: 1877 (False lycosids / Wandering spiders)

Identification features: Medium-to-very large, two-clawed, eight-eyed hunting spiders; eyes arranged in three rows. Complex epigyne with horns. Trochanters deeply notched; anterior spinnerets conical. Male palp with a dorsal median concave apophysis. Cephalothorax ovoid with a deep depression, high in region of foveae. Body brown to fawn. Both rows of eyes recurved but anterior row strongly recurved so that the anterior lateral comes in line with posterior medians, thus forming three rows of eyes: 2, 4, 2. Anterior medians smaller than anterior laterals. Sternum flat, oval or round. Maxillae converging slightly, apex truncated, entirely clothed with dense setae. Labium with dense band of long setae. Chelicerae strong, both margins toothed, inner margin armed with four or sometimes five teeth. Legs strong, stout, two clawed with spines and scopulae. Anterior tibiae with numerous pairs of ventral spines. The first two legs are armed with strong bristles on the lower side. Trochanters with a ventral notch. Abdomen ovoid, longer than wide. Dorsum sometimes with median band, patterns or rows of spots. Anterior spinnerets contiguous, median spinnerets compressed; two segmented posterior spinnerets long and more slender than anterior. Epigyne complex with broad median septum and lateral horns. Tibial apophysis of palp with lamina always present, median apophysis usually cup shaped.

This is a family of big spiders, which are free-living nocturnal hunters and appear to roam aimlessly over the leaf litter in rain forests and commonly found under fallen logs on the ground. They are principally litter-dwelling hunters and many are diurnal and may be confused with lycosids. Spiders of this family have a tendency to attack humans in large numbers with high speed if surprised or provoked. Reports of people getting “chased” by these spiders are not unusual. Due to this aggressive nature combined with very toxic venom and a tendency to “wander” into human habitation, ctenids are considered to be one of the world's most dangerous spiders. These are found in tropical and sub-tropical parts of the world (Plate 13).

Genera; species in worldwide - 49; 524

Genera; species in India- 5; 18

List of species in present study - 1; 1

Ctenus cochinensis Gravely, 1931, (Plate-13, Fig-56)

7. Family: Gnaphosidae, Pocock: 1898 (Mouse spiders)

Identification features: Cephalothorax ovoid, smoothly convex at sides and rather low, gradually or narrowed towards front; usually with distinct fovea. Eight small eyes in two transverse rows of four each; anterior eyes round and the remaining eyes round, ovoid or angular, depending on the genus; posterior medians flattened, irregular in shape. Sternum flat, ovoid, with pointed apex, truncate in front. Maxillae obliquely depressed ventrally with serrula. Chelicerae short, robust, tapered from base to tip and hairy in front; promargin with or without teeth or with a carina; retromargin with keel or rounded laminae. Legs short, stout, hairy with two-toothed claws and claw tufts. Tarsi I and II often with dense scopulae, leg formula 4123, preening comb present in metatarsi IV in some species. Abdomen oval to elongate, somewhat cylindrical; cluster of erect, curved setae present on anterior edge; usually uniform in color or decorated with bands or other markings; usually with dorsal scutum in adult males. Anterior spinnerets parallel, large, cylindrical and usually well separated; piriform gland spigots of anterior spinnerets greatly enlarged, with widened base and shaft and a slit like opening. Epigyne complex with conspicuous cuticular margins. Male palp variable, usually with a stout, pointed, retrolateral tibial apophysis, bulb convex, tegulum large, sub tegulum smaller and slender embolus. Most gnaphosids are ground dwellers, with only a few living on plants where they roll up leaves similar to clubionids. Most of the ground dwelling species build a silk retreat in debris within which they remain during inactive period. They do not spin a web and catch their prey using speed, force and agility. Their eyesight is poor and prey is perceived by chemotactic or tactile stimuli. Feed on a variety of ground-dwelling animals such as ants, termites or other insects. The ant is attacked head-on and the bite is delivered at the base of the antennae. The spider then withdraws and waits until the ant is paralysed. The ant is then tucked underneath the spider's body and carried away from other ants (Plate 14)

Genera; species in worldwide -162; 2549

Genera; species in India -31; 154

List of species in present study -3; 3

Drassodes sp., (Plate-14, Fig-57)
Scotophaeus blackwalli (Thorell, 1871)
Zelotes ashae Tikader & Gajbe, 1976, (Plate-14, Fig-58)

8. Family: Hersiliidae, Thorell: 1870 (Two tailed spiders)

Identification features: Cephalothorax ovoid and flattened, with narrow longitudinal fovea and radiating striations; densely covered with plumose setae. Eight eyes in two strongly recurved rows on a large tubercle. Anterior medians larger than posterior medians. Sternum heart shaped with straight or slightly concave anterior edge. Labium free with rounded tip; maxillae converging. Chelicerae weak with very small cheliceral fang, furrow with or without teeth. Legs with three simple claws, a few spines and trichobothria. Males with very long legs, third leg the shortest, autospasy occurs at patella-tibia joint. Abdomen flat, wider behind than in front, densely covered with plumose setae. Posterior spinnerets as long as abdomen, cylindrical with elongated and tapering apical segments inner surface with a series of tubules producing thin silk threads; colulus present. Epigyne complex with broad central septum. Male palp without tibial apophysis; bulb tubular, ovoid or circular; conductor filiform and pointed. These are very fast running active hunting spiders. The most easily distinguishable feature of hersiliids is the extremely long posterior lateral spinnerets which are often longer than the abdomen and sometimes approaching the total body length, hence the name two-tailed spiders. The flattened body permits them to lie very close to the substratum without casting any shadow. When disturbed, the spider runs very quickly to the opposite side with the spinnerets raised like a pair of horns. When a small insect comes close, the insect triggers those silk and the spider senses this. The spider will swiftly run around the insect in circles, with the insect in centre. The spider will also lay more silk at the same time, till the insect is entangled by the silk, and becomes the meal of the spider (Plate 14).

Genera; species in worldwide - 16; 182

Genera; species in India - 3; 12

List of species in present study -1; 2

Hersilia savignyi Lucas, 1836, (Plate-14, Fig-59)
Hersilia sp., (Plate-14, Fig-60)

9. Family: Linyphiidae, Blackwall: 1859 (Sheet web spiders)

Identification features: Cephalothorax variable in shape, clypeus height generally exceeding that of median ocular region, some species with raised or with modified frontal region. Eight heterogeneous eyes in two rows, anterior medians slightly darker. Sternum variable but usually heart shaped, pointed or truncated at the back, labium rebordered with parallel sided maxillae. Chelicerae robust, generally with strong teeth on fang furrow and lateral stridulating file. Legs three clawed, slender and provided with setae especially on tibiae and metatarsus; female palp usually with tarsal claw. Abdomen usually longer than wide, sometimes with characteristic pattern, scutum present in some males. Six spinnerets, anterior and posterior pair short, conical and concealing median pair, colulus present. Epigyne complex, variable, often simple with flat surface modified by groove, pit or notches or with scapus. Male palp lacks tibial apophysis but paracymbium well developed. Linyphiids are identified as sheet web spiders, which can be flat, domed or hammock shaped, above the sheet isolated threads form a scaffolding web. The spider hangs upside down under the sheet and does not construct any retreat. Prey is bitten from below through the sheet, and is then pulled through the sheet before being consumed. Webs are found either in tall grass or occasionally close to the ground. When disturbed, the spider suddenly disappears into the vegetation. Linyphiids make dense sheet webs in green vegetation and often are found in large numbers on the surfaces of field margins. The web may have a funnel in the center and the spider waits for its prey below the entrance to this funnel (Plate 14).

Genera; species in worldwide - 619; 4671

Genera; species in India - 27; 61

List of species in present study -2; 2

Linyphia sp., (Plate-14, Fig-61)
Neriene macella (Thorell, 1898), (Plate-14, Fig-62)

10. Family: Lycosidae, Sundevall: 1833 (Wolf spiders)

Identification features: Cephalothorax longer than wide, narrower and higher in cephalic region; fovea elongated; carapace covered with dense setae; sternum oval shaped. Eyes eight in three rows of 4, 2, 2; all dark colour, unequal size; anterior row with four small eyes lying in straight or often slightly curved line, second row with two large eyes which approximately as wide as front row and third row with two eyes of intermediate size which is as wide as or usually wider than second row situated on anterio-lateral surface of carapace. Labium as wide as long, half the length of maxillae. Chelicerae strong with toothed furrow and condyles. Legs three clawed, usually with scopulae and spines; trochanters notched. Abdomen oval and covered with dense setae. In some species with characteristic hairs over the surface of the abdomen for carrying spiderlings on the body of mother. Spinnerets are of normal type; colulus absent. Epigyne commonly complex with a well sclerotized median septum. Male palp without tibial apophysis and with varying embolus. Females carry their cocoons attached to the spinnerets. Abdomen often brownish or greyish colour, some are sandy coloured with cryptically marked abdomen while some small species are brown to almost black in colour. Most members of this family are free running, especially in undisturbed open areas, they are the commonest spiders likely to be encountered in the field. Larger lycosids build burrows in the ground. Others make silken webs and retreats in the grass, whereas some of the smaller species do not make webs at all. Females of many small lycosid species attach the egg sac to their spinnerets and carry them underneath their abdomen. These egg sacs are often white or light coloured and often larger than the female's abdomen. The young spiderlings climb onto the mother's back after emerging from the egg sac where they continue until the second moult. They do not eat during the time when the young are attached to the body of their mother. These spiders are real hunters and have excellent eyesight. The spiders vigorously attack their prey crushing it with their stout chelicerae. Most species hunt during day, but some are nocturnal. When at rest, they are usually found below debris. Their sense of touch is highly developed. Contrary to the common belief, recent studies indicate that they adopt a sit and wait strategy for foraging. Prey is grabbed with the legs, forming a basket around the prey before it is bitten (Plate 14-15).

Genera; species in worldwide - 124; 2430

Genera; species in India - 19; 130

List of species in present study - 4; 12

Hippasa agelenoides (Simon, 1884), (Plate-14, Fig-63)
Hippasa holmerae Thorell, 1895, (Plate-14, Fig-64)
Hippasa madraspatana Gravely, 1924, (Plate-15, Fig-65)
Lycosa bistriata Gravely, 1924, (Plate-15, Fig-66)
Lycosa mackenziei Gravely, 1924
Pardosa birmanica Simon, 1884
Pardosa chambaensis Tikader & Malhotra, 1976
Pardosa mysorensis (Tikader & Mukerji, 1971), (Plate-15, Fig-67)
Pardosa pseudoannulata (Bosenberg & Strand, 1906), (Plate-15, Fig-68)
Pardosa sumatrana (Thorell, 1890), (Plate-15, Fig-69)
Paradosa sp.
Trochosa sp.

11.Family: Mimetidae, Simon: 1881 (Pirate spiders)

Identification features: Cephalothorax with sloping thoracic region, small deep fovea, cephalic region varies from long and attenuated to short and sharply convex in middle; carapace sometimes with rows of long spines. Small-to-medium sized spiders, Chelicerae with peg teeth, tarsi with three claws, tibiae and metatarsi I and II modified with prolateral spines, epigyne complex. Eight-eyed spiders., anterior medians usually largest, equal sized laterals raised on a small common protuberance and well separated from medians, anterior medians frequently raised on a small square protuberance. Sternum longer than wide, oval or triangular. Labium as wide as long or longer than wide. Maxillae long, almost parallel, ventrally with fairly sub marginal serrula. Chelicerae relatively long, vertically directed, fused at base, inner side separated by a narrow, triangular, elongated, membranous fissure; promargin with peg teeth. Legs three clawed, banded, long and slender with strong spines; tibiae and metatarsi I and II with modified prolateral spination consisting of a series of short spines, interspersed with a series of longer, slightly curved spines. Abdomen differ in shape, with humps, integument generally with very strong isolated setae and usually pale yellowish with dark spots or markings. Spinnerets enlarged, rounded; incised cylindrical gland spigots and colulus present. Single tracheal spiracle opens near the base of spinnerets. Epigyne distinct, complex, heavily sclerotised with lobed posterior extensions. Male palp completely long with strongly developed paracymbial process; bulbus with strongly curved embolus. Most mimetids are specialised predators of web-living spiders. They enter the web of other spiders and make use of the vibratory patterns that simulate the movement of captured prey or courting males, trick and kill the host. Using the rake like spines on their legs, they first immobilize the legs of host, then a quick bite is delivered to inject a fast-acting venom that kills the host immediately. They move very sluggishly on the ground among debris, on low plants and in shrubs (Plate-15)

Genera; species in worldwide - 8; 154

Genera; species in India - 2; 3

List of species in present study - 1; 2

Mimetus sp. I., (Plate-15, Fig-70)

Mimetus sp. II., (Plate-15, Fig-71)

12. Family: Miturgidae, Simon: 1885 (Dark Sac spiders)

Identification features: Cephalothorax longer than wide, red brown to dark brown in colour; eight eyes in two rows; sternum oval and flat, apex with obtuse angle; labium long and usually truncated anteriorly; maxillae enlarged with or without lateral notch. Chelicerae strong with teeth on fang furrow. Legs prograde, with two claws and claw tufts or with three claws. Claw tuft varies from weak to dense; scopulae dense; two rows of tarsal trichobothria; trochanters shallow to deeply notched; tibiae of front legs with paired setae; long and sturdy legs in females, longer and slender in males. Abdomen oval with markings, bands, chevrons or spots. Posterior spinnerets two segmented, distal segment distinctly conical, apical segment either as long as or shorter than basal segment; anterior spinnerets conical in shape; colulus present. Cribellum entire or divided with an oval or elongated area of densely spaced calamistral setae in some genera. Epigyne complex, with a small median plate with anterior extensions and heavily sclerotized internal ducts. Male palp with distally expanded retrotibial apophysis and prolateral embolus. These free-living spiders are commonly found in the sac-like retreats made up of green leaves. Different types of sacs are used for resting, mating and breeding. While the eggs are developing, the female encloses herself with the eggs and guards them (Plate-15).

Genera; species in worldwide - 29; 140

Genera; species in India - 1; 1

List of species in present study - 1; 1

Systaria sp., (Plate-15, Fig-72)

13. Family: Oecobiidae, Blackwall: 1862 (Dwarf round-headed spiders / Star-legged spiders)

Identification features: Small-to-medium sized, three-clawed spiders; six or eight eyes, cribellate or ecribellate, two segmented anal tubercle with double fringe of curved setae. Cephalothorax subcircular, wider than long; clypeus may be snout like without fovea. Six to eight eyes arranged in the centre of carapace as a compact group in two rows, posterior medians variable in size and shape. Sternum heart-shaped, wider than long, apex pointed; males with a fringe of specialised spatulate setae on sternal margin. Labium free and wider. Maxillae converging and almost touching. Chelicerae short, without boss, fangs also short, no teeth on furrow. Legs short, three clawed, with or without spines, subequal in length and star like arrangement around cephalothorax. Female palp stout, with pectinate claw. Abdomen oval to round, more or less flattened and slightly overlapping carapace; large two segmented anal tubercle with a double row of fringed setae; darker pattern with white in colour due to guanine granules. Anterior spinnerets two segmented, short and domed; distal segment long and curved in two segmented posterior spinnerets. Colulus may comprise of a large plate. Tracheal spiracle inconspicuous in front of spinnerets. They are cribellate or ecribellate, if they persist of cribellum which is found to be as divided in nature. Calamistrum biseriate in females; absent in males. Epigyne complex with a variable plate, sometimes with caudal notch and anterior pit, epigynal region transversely furrowed. Male palp with unmodified or globular tibia, short embolus with a hooked or long curved spine, conductor varies from a complex sclerite to a membranous appendage, apophyses absent. These are live in star-shaped mesh webs made over cracks, crevices and in corners of rocks or walls. The web serves as a protective retreat while the anchor threads attached to the substrate warn the spider of approaching prey. The spider rest beneath the web on the substrate with its back facing the sheet. When prey touches a thread, the spider rushes out and while rapidly circling the prey in an anti-clock wise direction, encapsulates it in silk using the stout curved setae of the anal tubercle to comb the silk from the large posterior spinnerets. When disturbed, the spider runs swiftly away from the retreat into a crevice nearby. Some species can be found inside the home walls as synanthropes. A total of 5 species of two genera are reported from India so far (Plate-16).

Genera; species in worldwide - 6; 120

Genera; species in India - 2; 6

List of species in present study - 1; 1

Oecobius sp. (Plate-16, Fig-73)

14. Family: Oonopidae, Simon: 1890 (Dwarf hunting spiders / goblin spiders)

Identification features: Very small haplogyne spiders with two biserially teethed claws, tarsus with onychium, compact six eyes or eyes absent, abdomen of some species have dorsal or ventral scuta with anterior displacement of posterior tracheae. Cephalothorax flat to convex, narrowed anteriorly without fovea, surface often smooth and shiny or granular. A compact group of six eyes, medians largest and contiguous with anterior laterals. Termite nest inhabiting species without eyes. Sternum broad, oval shaped, apex blunt. Labium variable; maxillae broad at base and narrow at tip. Chelicerae free, subchelate, unlaminated, broad at base and attenuated at tip; long and arched fangs, furrow without teeth. Legs short, with two dentate claws, teeth arranged in two rows; tibiae and tarsi I and II with series of paired spines in certain species; scopulae absent; tarsi with distinct onychium.

Female palp short, without any claw. Abdomen oval, enclosed in shield in some species or soft bodied in others, sometimes brightly coloured, orange, yellow, greenish or pink; species without scuta are pale in colour. Both spinnerets of equal length, colulus absent or replaced by a plate with two setae. Posterior pair of tracheae with spiracles situated behind epigastric folds which bring about well-developed tracheae, book lungs reduced. Epigyne simple, with a sclerotised slit, composed of two distinct elements associated with both the anterior and posterior abdominal walls. Male palp simple, with variable embolus and without conductor. These are nocturnal ground-dwelling hunters that actively chase prey. They are present in a variety of habitats such as birds, termite nests and web of other spiders. During daytime, they hide under dark places. The egg sac is simple and consists of an irregular mass of fluffy silk covering on eggs (Plate-16).

Genera; species in worldwide - 114; 1874

Genera; species in India - 13; 46

List of species in present study - 2; 2

Gamasomorpha. sp., (Plate-16, Fig-74)
Opopaea sp., (Plate-16, Fig-75)

15. Family: Oxyopidae, Thorell: 1870 (Lynx spiders)

Identification features: Cephalothorax longer than wide, high and convex anteriorly, sloping posteriorly, typically with conspicuous stripes and spots, clothed with thin setae and wide clypeus. Clypeus very high and vertical, generally with visible stripes and spots. Eight eyes in two rows occupying a small area on the edge of carapace, eyes form a hexagon by slightly procurved posterior row and strongly recurved anterior row. Anterior median eyes smallest, much smaller than the anterior lateral eyes. Scutiform sternum tapers between coxae IV, labium longer than wide, maxillae long and converging. Chelicerae long and tapering at distal end with short fangs. Margin of Chelicerae short and armed with one tooth on each side or without teeth. The boss on the anterior lateral face of the chelicerae not so prominent. Legs long, three clawed, with prominent spines; trochanters shallowly notched, without scopulae. Abdomen posteriorly tapering, with bands or patches. Colour of the body varies from bright green to yellowish brown or dark brown. Integument clothed in thin setae and sometimes with iridescent scales. Spinnerets of normal type with small median pair, colulus present. Epigyne complex, structure varies between genera from a semicircular dark rim surrounding a shallow median depression to a deep pit in front with paired projections or median depression with scape like projection. Male palp with tibial apophysis and paracymbium. Mostly foliage dwelling spiders, commonly found on green leaves. They are commonly known as lynx spiders because of the way in which prey is hunted. Diurnal or nocturnal hunters with good vision, allowing quick detection of prey. They move around on plants, leaping from leaf to leaf. Prey is caught with legs, and often by jumping a few centimeters or more into the air to seize a passing insect in full flight or executing short jumps in pursuit of prey flying over plants. The eggs sac is fastened to twig or leaf or hung in small irregular web. The eggs are guarded by the female (Plate-16-17).

Genera; species in worldwide - 9; 438

Genera; species in India - 4; 83

List of species in present study - 4; 17

Hamadruas sikkimensis (Tikader,1970), (Plate-16, Fig-76)
Hamadruas sp. I
Hamadruas sp. II

Hamataliwa sp. I

Hamataliwa sp. II

Oxyopes birmanicus Thorell, 1887, (Plate-16, Fig-77)

Oxyopes forcipiformis Xie & Kim, 1996, (Plate-16, Fig-78)

Oxyopes hindostanicus Pocock, 1901, (Plate-16, Fig-79)

Oxyopes javanus Thorell, 1887, (Plate-16, Fig-80)

Oxyopes lineatipes (C. L. Koch, 1847), (Plate-17, Fig-81)

Oxyopes salticus Hentz, 1845

Oxyopes shweta Tikader, 1970, (Plate-17, Fig-82)

Oxyopes sunandae Tikader, 1970, (Plate-17, Fig-83)

Oxyopes sp. I

Oxyopes sp. II

Peucetia ananthakrishnani Murugesan et al., 2006

Peucetia viridana (Stoliczka, 1869), (Plate-17, Fig-84)

16. Family: Palpimanidae, Thorell: 1870 (Palp-footed spiders)

Identification features: Small-to-medium sized, six-to-eight eyed spiders. heavily sclerotized cephalothorax, tarsi with two or three claws, first pair of legs enlarged and stronger than others, number of spinnerets reduced. Cephalothorax sub-oval in shape or anteriorly truncated; cephalic region evenly rounded and sloping towards thoracic region, covered with hard granular epidermis and distinct fovea, often dark to bright red or bright orange colour. Six or eight eyes in two rows, posterior medians small or large and irregular in shape, lateral eyes either contiguous or widely separated. Sternum scutiform, as wide as long and strongly granular with extensions around coxae. Labium triangular; maxillae converging and almost touching, with strong serrula. Chelicerae stout and short, cheliceral furrow weakly developed, teeth may be present on retromargin, promargin with peg teeth. Legs two or three clawed, anterior pair of legs enlarged and much stronger than other three pairs with femora I greatly expanded dorsally, patellae elongated, metatarsi and tarsi reduced in size; thick scopula consists of spatulate setae distally on prolateral surface of tibiae, metatarsi and tarsi. Tarsal claws dissimilar in size, anterior tarsi with extremely small claw and larger on posterior legs. Female palp without claws but a brush likes setae on tarsi. Abdomen oval with a sparse cover of short setae. Epigastric region deeply sclerotised, sometimes a ring shaped scutum extending dorsally to the encircle pedicel. Spinnerets encircled by a sclerotised ring, anterior pair large, posterior and median pairs condensed to spigots, colulus absent. Two book lungs with a single tracheal spiracle near spinnerets. Simple epigyne, with two large membranous sacs opening into a common atrium with large secretory glands near base; small spermatheca laterally connected to atrium by a long duct. Palp with an elaborate conductor and often other terminal accessory sclerites and embolus. These are slow-moving ground dwellers. They are found during the day in small irregular sac-like retreats under stones. When walking, the strong front legs are held up in the air. Some species feed on other spiders. Only 3 species of 2 genera are reported from India (Plate-17).

Genera; species in worldwide - 20; 157

Genera; species in India - 3; 3

List of species in present study - 2; 2

Palpimanus sp., (Plate-17, Fig-85)
Sarascelis raffrayi Simon,1983, (Plate-17, Fig-86)

17. Family: Philodromidae, Thorell: 1870 (Elongated crab spiders)

Identification features: Cephalothorax slightly flattened, wide or elongated and smoothly convex on lateral sides, clothed in soft recumbent setae, white to pale cream and reddish brown or grayish brown in colour, frequently mottled with longitudinal bands or chevrons. Eight eyes in two rows, eye rows recurved, sometimes posterior row strongly recurved. Apex of sternum with an obtuse point between coxae IV. Labium slightly longer than wide. Chelicerae normally without teeth. Legs slender, laterigrade, with two claws and semi-erect or recumbent spines; femora I without cluster of erect spines; legs I, III and IV nearly equal in length, leg II usually longer, sometimes much longer; tarsi I and II with scopulae and claw tufts. Abdomen oval or elongated, covered with soft recumbent setae; typically, with a dark, heart shaped mark and a series of chevrons. Spinnerets simple, colulus absent. Epigyne complex, small, generally with median septum, sometimes with folds and copulatery openings on the laterals; spermatheca kidney shaped. Male palp with small apophysis on tibia, embolus long to short, slender and arched at the distal end of tegulum. Philodromidae are small-to-medium sized spiders, closely resembling the family Thomsidae interms of erratic movements and laterigrade legs. These are free living hunters normally found on foliage. Their movements are erratic and using their claw tufts and scopulae, they are able to move fast. Their elongated, straw-coloured bodies with dark longitudinal lines, as well as their posture, render them inconspicuous on dry grass. Most of the philodromids inhabit marshes, grasses and mate in the rainy season, female lays eggs at the onset of summer. The female makes egg sacs on the folded grass leaf (Plate-17).

Genera; species in worldwide - 31; 536

Genera; species in India - 8; 45

List of species in present study - 3; 5

Philodromus sp. I

Philodromus sp. II

Thanatus indicus Simon, 1885

Thanatus sp.

Tibellus elongatus Tikader, 1960, (Plate-17, Fig-87)

1**8. Family: Pholcidae, Koch, 1851** (Daddy long leg spiders)

Identification features: Cephalothorax short and broad, almost rounded; cephalic region generally elevated on the sides with deep striations; thoracic region with deep median longitudinal fovea; clypeus high, occasionally concave beneath eyes; pedicel dorsally with two parallel or "V" shaped chitinous bands. Six or eight eyes occupying entire width of carapace, anterior medians smallest or absent, the rest large and forming two triads on each side. Sternum flat or slightly convex, broadly truncated posteriorly, wider than long; labium fused to sternum. Chelicerae chelate, cylindrical and weak; cheliceral margin with tooth like transparent lamina or lobed. Legs extremely long, thin, fragile and slender; equipped with three claws and very short membranous onychium, tarsi flexible. Abdomen either globose or cylindrical to elongated, epigastric region well developed, triangular shaped large anal tubercle. Anterior spinnerets cylindrical and thick, slightly separated by small colulus in between; posterior spinnerets conical, smaller and compressed. Tracheal spiracle missing in some genera. Female lacks an epigyne but has a swollen, sclerotized area on underside of abdomen. Male palp complex, large, with very small patella, tibia large and swollen, tarsus divided into two parts. These spiders are inactive in habit and construct loose tangled webs of different configurations. Some webs are irregular with long threads criss crossing in an irregular fashion; or the centre of the web consisting of a large, more compactly woven sheet, with a network of irregular threads above and below. The females always carry the agglutinated mass of eggs in their chelicerae. They suspended upside down in the webs and when disturbed, vibrate themselves so vigorously that they blur themselves in the eyes of the intruder (Plate-17-18).

Genera; species in worldwide - 94; 1812

Genera; species in India - 6; 13

List of species in present study - 5; 7

Artema atlanta Walckenaer, 1837, (Plate-17, Fig-88)
Crossopriza lyoni (Blackwall, 1867), (Plate-18, Fig-89)
Pholcus phalangioides (Fuesslin, 1775), (Plate-18, Fig-90)
Pholcus sp. I., (Plate-18, Fig-91)
Pholcus sp. II., (Plate-18, Fig-92)
Smeringopus pallidus (Blackwall, 1858), (Plate-18, Fig-93)
Pribumia atrigularis (Simon, 1901), (Plate-18, Fig-94)

19. Family: Pisauridae, Simon: 1890 (Nursery web spiders)

Identification features: Cephalothorax longer than wide, clothed with plumose setae, wide and rounded near the rear, broad truncated front, clypeus in some genera with blunt tubercles on antero-lateral edge. Commonly decorated with a broad longitudinal dark brown stripe running the length of cephalothorax. Dark homogenous eyes, in two or three rows, at least one pair of eyes on shallow tubercles. Labium and Sternum longer than wide, sternal apex blunt. Powerful chelicerae are toothed, and provided with boss and scopulae. Three clawed legs are long and tapered, sometimes slightly laterigrade, numerous trichobothria intermittently distributed in the tibia, metatarsi and tarsi; trochanters deeply notched, inferior claw with 2-3 teeth, sometimes onychium present. Abdomen generally elongate, widest and rounded at the front, and narrowing toward the spinnerets and covered with plumose setae. There is often with longitudinal bands, folium or spots. Anterior and posterior spinnerets similar in size. Complex epigyne consists of two integument folds, forming two lateral elevations with median area, vulva complex consisting of a base with enlarged lumen and stalk leading to spermathecae. Tibial apophysis of palp generally present, anteriorly elongated cymbium, bulbus oval, longitudinal axis frequently inclined, median apophysis present, embolus varies from simple and short to long and curved. They are active wanders and mostly do not spin webs. Some species are found in open areas of grass and dwarf shrub while others are found along the edges of streams and ponds, where they prey on fish. Females carry egg sac under the sternum, held in position by the chelicerae and palpi. Just before the young emerge, the female produces a framework of silk, known as nursery web, in which the eggs are placed. After emerging from the egg-sac, the young remain in the nursery web until dispersal commences, hence they are commonly called as "nursery web spiders" (Plate-18).

Genera; species in worldwide - 51; 353

Genera; species in India - 9; 18

List of species in present study - 1; 2

Dendrolycosa gitae (Tikader, 1970), (Plate-18, Fig-95)
Dendrolycosa robusta (Thorell, 1895), (Plate-18, Fig-96)

20. Family: Salticidae, Blackwall, 1841 (Jumping spiders)

Identification features: Very small to medium sized, active, hunting spiders have the ability of jumping or leaping to a distance. Most characteristic feature is the ocular clad on the cephalothorax delimited by eight eyes arranged in three or four rows. Front row formed of forwardly directed four eyes among which the anterior median eyes are very large and easily noticeable. Legs are two clawed with claw tufts. Distinctively designed cephalothorax with anterior cephalic region formed of a broad rectangular ocular clad often covered with setae in attractive patterns and colours. Eyes are present around the ocular clad. Anterior end of it is broadly truncated and occupied the first row, formed of four eyes. Among these forwardly looking eyes, the anterior median eyes are very large and prominent. The two anterior lateral eyes, only about half the size of anterior median eyes, commonly arranged in the front row or in some genera form the second row. Two posterior median eyes, usually smaller than anterior lateral eyes form the next row. Two posterior lateral eyes nearly same as to anterior lateral eyes, positioned at the posterior corners of the ocular clad constitute the last row. These eyes together provide excellent eyesight about 360 degree. Jumping spiders are capable of recognizing colours and distinguishing the prey from a considerable distance. Thoracic region is in continuation with the cephalic part in most but remains clearly separated by a constriction in some. Sternum is variable in size and shape. Labium is usually a triangular plate with a blunt anterior edge frequently bears scopula. Maxillae formed as fairly long plates, broad distally also bear thick scopulae. Maxillary palps are simple in female but very complex in male and act as copulatory organs. They often bear tibial apophysis and sometimes femoral protuberances. Chelicerae present a fang and teeth on outer and inner margins in variable numbers and shape. In males of some genera, they are elongated. Legs are segmented, usually long and stout ending in hairy tuft having two claws. Structure of legs especially that of the first pair vary in some genera and sometimes with fringes of hairs. Cephalothorax remains connected to the abdomen by a pedicel not visible in most. Then in some genera it is long and clearly visible. Abdomen generally small, oval or round but in some elongated. It is commonly covered with hairs forming attractive designes and colour patterns especially on dorsal side; helpful in distinguishing species. Spinnerets situated at the posterior end of the abdomen are two pairs and almost similar. Epigyne is situated on the ventral side of the abdomen towards the anterior end. It is highly variable and sometimes complex in structure. Jumping spiders are diurnal, move by walking, running, jumping or leaping and use all these movements for prey capture. They hunt the prey by stalking, chasing and leaping over it. Prey includes mainly insects; some also prefer other spiders or ants. Few salticids also exhibit aggressive mimicry or even invading of webs of other spiders as aids in prey capture. Generally, they do not use web for capturing the prey. Salticids make silken retreat in the form of tube or sac fastened to various substrata. They use the retreat to moult, sometimes to mate, egg laying or as night shelter. In most species shows clear sexual dimorphism. Courtship behaviour varies according to species (Plates-19-23).

Genera; species in worldwide - 659; 6325

Genera; species in India - 99; 275

List of species in present study - 35; 43

Ajaraneola sp., (Plate-19, Fig-97)
Asemonea tenuipes (Cambridge, 1869), (Plate-19, Fig-98)
Bianor albobimaculatus (Lucas, 1846), (Plate-19, Fig-99)
Brancus calebi Kanesharatnam & Benjamin, 2018, (Plate-19, Fig-100)
Brettus albolimbatus Simon, 1900, (Plate-19, Fig-101)
Brettus anchorum Wanless, 1979
Brettus cingulatus Thorell, 1895, (Plate-19, Fig-102)
Brettus sp., (Plate-19, Fig-103)
Carrhotus viduus (C. L. Koch, 1846), (Plate-19, Fig-104)
Chalcotropis pennata Simon, 1902, (Plate-20, Fig-105)
Chrysilla volupe (Karsch, 1879), (Plate-20, Fig-106)
Cocalus lacinia Sudhin et al., 2019, (Plate-20, Fig-107)
Epeus tener (Simon, 1877), (Plate-20, Fig-108)

Epeus triangulopalpis Malamel et al., 2019, (Plate-20, Fig-109)

Epocilla aurantiaca (Simon, 1885), (Plate-20, Fig-110)

Euophrys evae Żabka, 1981

Eupoa sp.

Evarcha flavocincta (C. L. Koch, 1846), (Plate-20, Fig-111)

Habrocestum sp., (Plate-20, Fig-112), (Plate-20, Fig-112)

Hasarius adansoni (Audouin, 1826), (Plate-21, Fig-113)

Hyllus semicupreus (Simon, 1885), (Plate-21, Fig-114)

Indopadilla insularis (Malamel et al., 2015), (Plate-21, Fig-115)

Langona sp., (Plate-21, Fig-116)

Lyssomanes sp.

Marpissa decorata Tikader,1974

Marengo sachintendulkar Malamel et al., 2019, (Plate-21, Fig-117)

Menemermus bivittatus (Dufour,1831), (Plate-21, Fig-118)

Myrmaplata plataleoides (Cambridge, 1869), (Plate-21, Fig-119)

Phaeacius lancearius (Thorell, 1895), (Plate-21, Fig-120)

Phidippus yashodharae Tikader, 1977, (Plate-22, Fig-121)

Phintella vittata (C. L. Koch, 1846), (Plate-22, Fig-122)

Plexippus paykulli (Audouin, 1826), (Plate-22, Fig-123)

Portia fimbriata (Doleschall, 1859), (Plate-22, Fig-124)

Portia labiata (Thorell, 1887), (Plate-22, Fig-125)

Rhene flavigera (C. L. Koch, 1846), (Plate-22, Fig-126)

Rhene rubrigera (Thorell, 1887), (Plate-22, Fig-127)

Siler semiglaucus (Simon, 1901), (Plate-22, Fig-128)

Siler sp.

Stenaelurillus albus (Sebastian et al., 2015), (Plate-23, Fig-129)

Stenaelurillus lesserti Reimoser, 1934, (Plate-23, Fig-130)

Telamonia dimidiata (Simon, 1899), (Plate-23, Fig-131)

Thiania bhamoensis Thorell, 1887, (Plate-23, Fig-132)

Thyene imperialis (Rossi, 1846)

21. Family: Scytodidae, Blackwall: 1864 (Spitting spiders)

Identification features: Glabrous and shiny cephalothorax domed towards thoracic region, fovea absent, decorated with symmetrical spots or dark stripes. It has a distinctive shape with a domed, oversized cephalothorax which holds an anterior venom gland that is connected toa posterior section that synthesises sticky silk used for defence and prey capture. Six small eyes arranged in three well separated contiguous diads. Apex blunt, oval sternum with sclerotized edge. Labium as wide as long with slightly concave anterior margin fused to sternum, maxillae converging. Basally fused chelate chelicerae with very short fangs, conspicuous chitinous lamina on outer margin of basal segment. Long and slender legs with three claws and onychium, metatarsi longer than tarsi and slightly covered with setae and absence of spines. Claws also present in female palp. Broad oval abdomen with slight covering of dark setae, chitinous depression behind genital groove on ventral side. Anterior contiguous spinnerets slightly larger than others, pointed large colulus with numerous setae. Simple epigyne with scattered glands on paired vulva and multiple spermatheca. Male palp has slender embolus and without basal haematodocha. These are nocturnal cursorial spiders with a specialized way of prey capture. These are the only spiders known to possess prosomal gland that produce silk. This gland can produce venom and gluey silk. They squirt a mixture of venom and gluey silk from the chelicerae up to a distance of 2cm. The prey is glued to the substrate and paralyzed by the action of venom. Females build silk retreats with a few threads during egg laying. Eggs are simply held together by silk threads and carried in the chelicerae (Plate-23).

Genera; species in worldwide - 5; 246

Genera; species in India - 2; 12

List of species in present study - 1; 2

Scytodes fusca Walckenaer, 1837, (Plate-23, Fig-133)
Scytodes thoracica (Latreille, 1802), (Plate-23, Fig-134)

22. Family: Sparassidae, Bertkau: 1872 (Giant crab spiders)

Identification features: Broadly oval cephalothorax longer than wide, narrower in eye region, covered with a dense layer of fine setae, fovea present, cream to dark brown or grey or green or white, often with dark stripes and mottles pattern in colour. Eight eyes in two rows, size of anterior eyes varies between genera, medians generally largest, posterior row evenly spaced. Apex-pointed sternum longer than wide to almost circular. Free labium short and rebordered distally, never beyond half the length of maxillae, maxillae with thick serula and scopula. Chelicerae with two rows of teeth on fang furrow and boss. Long laterigrade legs held at right angles to body, I and II legs larger than III and IV, leg scopulae well developed, tarsal claws with claw tufts, trochanters are slightly notched, apical ends of metatarsi furnished with a soft trilobate membrane. Due to their laterigrade legs they run sideways. Female palp also with claw. Abdomen round to oval, clothed in dense layer of fine setae, often with dark, median, heart shaped mark. Colulus absent. Complex epigyne scelrotised and conspicuous. Male palp with strong tibial apopohysis. The typical body and leg colours are grey, brown and black, often with enough mottling to provide useful camouflage when the spiders are resting in dry grass. They are nocturnal, females with their egg sac hide by day. Females of some species carry their egg sac below the body by clasping it with their pedipalp. They do not spin webs, only construct silk retreats (Plate-23-24)

Genera; species in worldwide - 87; 1256

Genera; species in India - 13; 84

List of species in present study - 4; 7

Heteropoda nilgirina Pocock, 1901
Heteropoda venatoria (Linnaeus, 1767), (Plate-23, Fig-135)
Heteropoda sp. I
Heteropoda sp. II
Olios milleti (Pocock, 1901), (Plate-23, Fig-136)
Pseudopoda straminiosa (Kundu et al., 1999)
Thelcticopis sp., (Plate-24, Fig-137)

23. Family: Tetragnathidae, Menge, 1866 (Long jawed spiders)

Identification features: Cephalothorax longer than wide, general color fawn to dull brown or grey with silvery markings, often with grey and silvery folium. Eight eyes in two rows, lateral eyes contiguous or apart. Longer than wide sternum pointed posteriorly, labium rebordered and maxillae parallel. Chelicerae variable, stout and short or long and well developed, with row of large teeth and strong projecting spurs. Slender and long three clawed legs, with or without spines, some species have conspicuous tufts or setae on femora and tibia of legs or posterior femora with a double fringe of trichobothria on prolateral surface of basal half or rows of straight trichobothria on tibia of all legs. Abdomen variable, elongated and cylindrical or round to ovoid, in some species extending caudally beyond spinnerets, epigastric furrow nearly straight. Anterior and posterior spinnerets same in size. In some species, tracheal spiracle half way between spinnerets and epigyne. Complex epigyne with unsclerotized genital plate, male paracymbim movable and separate, spherical tegulum with coiled embolus and conductor at distal tip, median apophysis absent, embolus tegulum membrane present. It is orb weavers occupying a variety of habitats (Plate-24-25).

Genera; species in worldwide - 50; 989

Genera; species in India - 12; 55

List of species in present study - 5; 15

Guizygiella nadleri (Heimer,1984), (Plate-24, Fig-138)
Leucauge decorata (Blackwall, 1864), (Plate-24, Fig-139)
Leucauge dorsotuberculata Tikader, 1982
Leucauge pondae Tikader, 1970, (Plate-24, Fig-140)
Leucauge tessellata (Thorell, 1887), (Plate-24, Fig-141)
Leucauge sp.
Opadometa fastigata (Simon, 1877), (Plate-24, Fig-142)
Tetragnatha cochinensis Gravely, 1921, (Plate-24, Fig-143)
Tetragnatha javana (Thorell, 1890), (Plate-24, Fig-144)
Tetragnatha keyserlingi Simon, 1890, (Plate-25, Fig-145)
Tetragnatha mandibulata Walckenaer,1842, (Plate-25, Fig-146)
Tetragnatha squamata Karsch, 1879, (Plate-25, Fig-147)
Tetragnatha viridorufa Gravely, 1921, (Plate-25, Fig-148)
Tylorida striata (Thorell, 1877), (Plate-25, Fig-149)
Tylorida ventralis (Thorell, 1877), (Plate-25, Fig-150)

24. Family: Theridiidae, Sundevall: 1833 (Comb footed Spiders)

Identification features: Cephalothorax variable in shape, high to flat, clypeus relatively high, in some species frontal region of cephalothorax show modifications. Eight eyes in two rows, more or less parallel, generally encircled by brownish ring, anterior medians dark and the rest are pale. Scutiform to triangular sternum attenuated posteriorly, maxillae normally converging slightly. Chelicerae occasionally very long and without cheliceral teeth or few in number. Three-clawed legs are relatively long and curved, femur without spines, tibia and metatarsi; tarsi usually tapering towards tip. Large theridiids have a series of bristles on tarsi IV, called tarsal comb, the comb may be reduced or absent in smaller species and males, tarsal comb is used to lengthen the throw of sticky silk threads over the prey. Trichobothria are arranged in two rows on each tibia, female palp with a claw. Shape of abdomen varies from oval to round and high to elongate, extending beyond spinnerets, some species with a dorsal stridulating plate near pedicel, cryptic with darker designs on a brownish grey background in colour, colulus absent or present. Complex epigyne with single or double pairs of spermatheca. Male palp without apophysis, paracymbium forming a hook on distal margin of cymbium. These spiders have diverse life styles. Most species build different shaped three-dimensional space webs. Some webs enable the spider to catch flying insects and consist of crisscross viscid threads. The threads breakdown easily and prey glued to them becomes more entangled during escape activities. Some species construct special retreats inside or outside the frame and use plant or soil particles to camouflage the web. Some species, hide in a dark or debris covered silken retreat which is built in a corner or angle with the web stretched out below. Some of them do not make web at all, they may be found walking in leaf litter or in the ground or in the case of certain cryptic species just resting on bare twigs (Plates-25-28)

Genera; species in worldwide - 124; 2596

Genera; species in India - 32; 85

List of species in present study - 17; 29

Achaearanea durgae Tikader,1970, (Plate-25, Fig-151)
Achaearanea sp.
Argyrodes ambalikae Tikader, 1970
Argyrodes argentatus Cambridge, 1880, (Plate-25, Fig-152)
Argyrodes flavescens Cambridge, 1880, (Plate-26, Fig-153)

Argyrodes gracilis (L. Koch, 1872)

Argyrodes gazedes Tikader, 1970, (Plate-26, Fig-154)

Argyrodes kumadai Chida et al., 1999, (Plate-26, Fig-155)

Argyrodes sp., (Plate-26, Fig-156)

Ariamnes flagellum (Doleschall, 1857), (Plate-26, Fig-157)

Chrysso angula (Tikader, 1970), (Plate-26, Fig-158)

Chrysso urbasae (Tikader, 1970), (Plate-26, Fig-159)

Enoplognatha sp.

Episinus affinis Bösenberg & Strand, 1906, (Plate-26, Fig-160)

Meotipa argyrodiformis (Yaginuma, 1952)

Meotipa multuma Murthappa et al.,2017, (Plate-27, Fig-161)

Meotipa picturata Simon, 1895, (Plate-27, Fig-162)

Molione triacantha Thorell, 1892, (Plate-27, Fig-163)

Nesticodes rufipes (Lucas, 1846)

Nihonhimea mundula (L. Koch, 1872), (Plate-27, Fig-164)

Parasteatoda celsabdomina (Zhu, 1998), (Plate-27, Fig-165)

Phycosoma martinae (Roberts, 1983)

Phycosoma sp. I., (Plate-27, Fig-166)

Phycosoma sp. II

Phoroncidia septemaculeata Cambridge, 1873, (Plate-27, Fig-167)

Rhomphaea projiciens Cambridge, 1896, (Plate-27, Fig-168)

Theridion manjithar Tikader, 1970

Theridula angula (Emerton,1882)

Thwaitesia margaritifera Cambridge, 1881, (Plate-28, Fig-169)

25. Family: Thomisidae, Sundevall: 1833 (Crab spiders)

Identification features: Cephalothorax varies from semicircular, ovoid to elongated, usually with simple erect setae, certain species with strong rounded or distinct protuberances or eye tubercles. Dark and homogenous eight eyes in two rows, often outline in white, posterior row is generally recurved, usually lateral eyes are elevated on tubercles, which may be joined, medians commonly larger than others. Sternum heart shaped, labium and maxillae generally longer than wide. Chelicerae free, boss present usually, cheliceral teeth absent, sometimes cusps or small denticles on promargin, retromargin indistinct and unarmed, scopulae poorly developed. Two clawed laterigrade legs, first two pairs bear paired ventral spines, more enlarged and stronger than third and fourth pairs, I and II longer than III and IV, anterior tarsi without scopulae, usually claw tuft absent. The spinous powerful legs are used for seizing the prey as these spiders construct no webs but hunt by stealth and ambush. Abdomen is sometimes large and more variable in shape than the cephalothorax, from round to ovoid or elongated, extending caudally beyond spinnerets and generally covered with scattered simple setae. The body colour may be white, green or brown to match the colour of the surface. Anterior spinnerets short, conical and narrowly separated, colulus present. Epigyne complex normally with hood and bordered atrium. Male palp with ventral and retrolateral apophysis on tibia, disc like tegulum. The members typically have a peculiar crab like appearance. The common habitats are leaves or flowers where the spider's surfaces are roughened to improve the camouflage. They generally do not produce webs. They are mostly active during the day and their gait is sideways or crab-like, hence their common name. Although they have weak chelicerae and secrete extremely potent venom that enables them to attack big insects. Cheliceral teeth are absent and prey is not mashed but sucked dry (Plate-28-29)

Genera; species in worldwide - 169; 2153

Genera; species in India - 40; 179

List of species in present study - 13; 20

Amyciaea albomaculata (Cambridge, 1874), (Plate-28, Fig-170)
Amyciaea forticeps (Cambridge, 1873), (Plate-28, Fig-171)
Boliscus tuberculatus (Simon, 1886), (Plate-28, Fig-172)

Camaricus formosus Thorell, 1887, (Plate-28, Fig-173)
Camaricus khandalaensis Tikader, 1980, (Plate-28, Fig-174)
Indoxysticus minutus (Tikader, 1960), (Plate-28, Fig-175)
Massuria sreepanchamii (Tikader, 1962), (Plate-28, Fig-176)
Misumena sp., (Plate-29, Fig-177)
Oxytate greenae (Tikader, 1980)
Oxytate virens (Thorell, 1891), (Plate-29, Fig-178)
Ozyptila sp.
Runcinia roonwali Tikader, 1965, (Plate-29, Fig-179)
Strigoplus netravati Tikader,1963, (Plate-29, Fig-180)
Thomisus lobosus Tikader, 1965, (Plate-29, Fig-181)
Thomisus projectus Tikader, 1960, (Plate-29, Fig-182)
Tmarus histrix Caporiacco, 1954, (Plate-29, Fig-183)
Xysticus bengalensis Tikader & Biswas, 1974
Xysticus cristatus (Clerck, 1757)
Xysticus minor (Charitonov, 1946)
Xysticus viveki Gajbe, 2005

26. Family: Trachelidae, Simon: 1897(Ground Sac Spiders)

Identification features: Trachelidae is cosmopolitan family whose members are characterized by reduced leg spination especially on posterior legs and dorsally on all femora. Nevertheless, they lack macro seatae on legs and males have cusples. They are ecribellate entelegyne spiders with eight eyes. Body colour is orange to dark coloured spiders of massive build with wide, convex head, a usually granulated or pitted carapace and sternum and virtually spineless legs. The anterior eye row is procurved, the posterior eye row is straight or recurved. The thoracic groove is small, the chelicerae slender. the anterior surface flat. The anterior metatarsi and tibiae in males are provided with cusps. The apex of the posterior metatarsi has a ventral comb. The posterior lateral spinnerets in the female have two cylindrical gland spigots and several small aciniform gland spigots. The posterior median spinnerets are elongate, with many spindle-shaped spigots in the ventral part and five large cylindrical gland spigots in the dorsal part. The male palp has an apical filiform embolus without conductor, the tegulum shows a tendency to expansion. The female palpal tarsi are club-shaped. The epigyne is complex, with conspicuously coloured ducts connecting the copulatory openings with the anterior thin-walled sacs (bursae). The elongate spermathecae have one or more coils. Spiders of this family differing among other things in the shape of the posterior end of the carapace and the configuration of the posterior eyes. It has given rise to some interesting adaptations: males in some species have a long stalk between cephalothorax and abdomen and apparently mimic specialised ichneumid hymenopterans. Besides, several of the species treated here were found to have two syntopic ecomorphs with different colouration; these are obviously associated with the substrate they were found on. Most species are known by a light form with spotted legs only and are found on green leaves. In live specimens, the legs are pale green, this pigment dissolves in alcohol and the colour becomes a dull yellow. The other ecomorph, a uniform dark brown form. was found living on the ground. Species in this family inhabit relatively undisturbed rainforests with high humidity. Sometimes two or more species occur syntopically (Plate-29-30).

Genera; species in worldwide - 19; 248

Genera; species in India - 3; 6

List of species in present study - 1; 2

Utivarachna rama Chami-Kranon & Likhitrakarn, 2007, (Plate-29, Fig-184)
Utivarachna sp. II., (Plate-30, Fig-185)

27. Family: Uloboridae, Thorell: 1869 (Hackled web spiders)

Identification features: Shape of cephalothorax variable with a pair of lateral swellings posterior or median to posterior lateral eyes. Eight homogenous dark eyes arranged in two well separated rows or four eyes in a single posterior row only. Sometimes posterior laterals on a tubercle. Sternum long, oval or triangular, in certain species two separate sternites with coxae II and III surrounded by a sternal plate. Free labium long or semicircular and distally pointed. Chelicerae with or without a boss, and the fang margins may possess several small teeth to only one large tooth. Unlike other spiders, uloborids lack a venom gland. Legs with 3 claws, femora with rows of long trichobothria, metatarsi IV ventrally with a row of macrosetae, this segment dorsally compressed and curved below uniseriate calamistrum. Female palp present toothed claw. Slender abdomen with one or two humps, narrow and elongated, sometimes extending beyond spinnerets, anal tubercle generally large and two segmented, normally dull, shades of cream, grey or brown in colour. Anterior spinnerets three segmented with ring shaped very short second segment, third segment domed, median spinnerets unsegmented, posterior spinnerets with two cylindrical segments. Undivided cribellumin front of spinnerets. Spiders from this family spin modified versions of orb webs made up of cribellated silk. Web modifications range from a single thread to triangular. The web is generally tugged forcefully to locate and entangle the prey while the spider is approaching it. The first pair of legs and to a lesser extent the second pair is used for tugging. The front leg is used to lightly touch the prey. Hanging from the first and second pair of legs, the spider uses the fourth pair to cast silk on to the prey to subdue it. It faces away from the prey while wrapping it. These spiders lack venom glands but pour strong digestive enzymes on to the prey to kill it. The silk wrapped around the prey becomes transparent after absorbing some of the enzymes. The spiders do not use their chelicerae while wrapping the prey (Plate-30).

Genera; species in worldwide - 19; 287

Genera; species in India -5; 25

List of species in present study -3; 6

Miagrammopes extensus (Simon, 1889), (Plate-30, Fig-186)
Miagrammopes sp.
Uloborus danolius Tikader, 1969, (Plate-30, Fig-187)
Uloborus khasiensis Tikader, 1969, (Plate-30, Fig-188)
Uloborus krishnae Tikader, 1970, (Plate-30, Fig-189)
Zosis geniculata (Olivier, 1789), (Plate-30, Fig-190)

28. Family: Zodariidae, Thorell :1881 (Burrowing spiders/Armoured spiders**)**

Identification features: Small-to-large sized, 2-3 clawed, 6-8 eyed free-living ground dwellers. Very short cheliceral fang, lateral teeth on superior claw implanted on lateral side facing opposite claw, long anterior spinnerets. Cephalothorax oval in general and narrowed anteriorly, fovea differs from deep well developed to poorly developed or absent. Integument contrasts from entirely smooth to densely granulate or with tiny perforations, pale to dark brown or black in colour, smooth and strongly convex, high anteriorly and sometimes sloping in the longitudinal fovea. Six or eight eyes in two or three rows, sometimes with a row of strong setae between anterior and posterior rows, anterior eye row slightly procurved, posterior eye row straight to strongly procurved. Sternum generally oval, sometimes with triangular projections corresponding to slight concavities in coxae or intercoxal or precoxal sclerites, and often rebordered sternum. Maxillae strongly converging. Strong chelicerae with well-developed boss on lateral side, sometimes fused or separated by a triangular inter cheliceral membrane. Fangs usually thick and short at base, furrow with teeth.

Three or two clawed legs moderately long, without spine, inferior claw often situated on onychium, superior claw with several teeth inserted on to lateral side facing opposite claw. Leg formula 4123 or 4132, spination normally well developed, digging species mainly with numerous strong spines on posterior legs and trichobothria in rows, scopulae replaced by dense short spines in many species, sometimes with femoral gland, apicoventral of metatarsi usually with a mat of black hairs. Female palpal tarsus differs in shape, tarsal claw usually finely toothed to well developed and toothless. Abdomen normally ovoid, occasionally twice as long as wide or higher at back than in front, sometimes male with scutum, generally decorated with simple patterns like lighter spots or chevrons. Median and posterior spinnerets reduced, often anterior spinnerets on a retractile common base, obscuring the other four. Epigyne complex sometimes with a central plate and copulatory ducts originating medially. Tibia of male palp with one or numerous dorsolateral or lateral apophyses, cymbium oval, sub tegulum present, tegulum complex with several apophyses. These are nomadic spiders and almost all are ground dwellers with adaptations for burrowing and they form an important component of ground dwelling spider fauna (Plate-30).

Genera; species in w triangular to worldwide - 87; 1184

Genera; species in India -11; 30

List of species in present study -1; 1

Suffasia sp. (Plate-30, Fig-191)

4.1.3. KEY TO FAMILIES

1a. Cribellum and calamistrum present…………………..……..**ULOBORIDAE**

1b. Cribellum and calamistrum absent ……………………………………….**2**

2a. With less than eight eyes………………………………………….........**3**

2b. With eight eyes……………………………………………………....... **5**

3a. Eyes in two well separated triads……………………...…....**PHOLCIDAE**

3b. Eyes arranged otherwise…………………………………………......**4**

4a. Carapace domed towards thoracic region…………………...**SCYTODIDAE**

4b. Carapace differently shaped……………………………......**OONOPIDAE**

5a. Tarsus with two claws………………………………………….........**6**

5b. Tarsus with three claws…………………………………………….... **18**

6a. Anterior pair of legs much stronger than other legs…...…**PALPIMANIDAE**

6b. Legs different…………………………………………..……..…......**7**

7a. Eyes in three rows, anterior median eyes very large………… **SALTICIDAE**

7b. Eyes arranged differently…………………………………..…..... **8**

8a. Legs laterigrade, directed towards side or forwards……………………...... **9**

8b. Legs prograde, 1 and 2 directed forwards, 3 and 4 backwards…..................**11**

9a. Tarsi and metatarsi without scopulae, legs I and II usually much longer than legs III and IV ……………………………………….....**THOMISIDAE**

9b. Tarsi and sometimes metatarsi with scopulae, legs different……….......**10**

10a. Small to medium-size spiders, chelicerae without teeth or at most one on retromargin, tarsus-metatarsus joint allowing movement in one plane only…………………………………….……….. **PHILODROMIDAE**

10b. Medium-size to large spiders, chelicerae with at least two teeth (rarely one) on retromargin, membranous connection to metatarsus permits free movement of tarsus……………………………..……..... **SPARASSIDAE**

11a. Tracheal spiracle about 1/3 abdominal length from spinnerets…………………………………….……….... **ANYPHAENIDAE**

11b. Tracheal spiracle in front of spinnerets………………………………….... **12**

12a. Spinnerets long and cylindrical, far apart……………....... **GNAPHOSIDAE**

12b. Spinnerets normal……………………………………………………….…..... **13**

13a. Tarsi with auxiliary claws, sternum as wide as long…....... **TRACHELIDAE**

13b. Tarsi without auxiliary claws, sternum mostly longer than wide…………. **14**

14a. Eyes in three rows (2:4:2), epigyne with lateral horns……….... **CTENIDAE**

14b. Eyes in two rows (4:4), epigyne without lateral horns…………………… **15**

15a. Posterior spinnerets clearly two-segmented with distal segment distinctly conical……………………………………...…………......**MITURGIDAE**

15b. Posterior spinnerets with one segment only or if two-segmented, distal segment rounded………..……………………………………….......**16**

16a. Male palp pear-shaped with short distal embolus, without median apophysis, median spinnerets of female with three and posterior spinneret with two large cylindrical gland spigots……………………………….……**CORINNIDAE**

16b. Genitalia differently shaped, median and posterior spinnerets of female without such spigot …………………………..……………….............**17**

17a. Median spinnerets of females laterally flattened, with at least one row of large spigots…………..………………………..…. **CHEIRACANTHIIDAE**

17b. Median spinnerets of females not flattened, without rows of large spigots……….……………………………………………. **CLUBIONIDAE**

18a. Tarsi with trichobothria, often in a row…………………………….…... **19**

18b. Tarsi without trichobothria………………………………………....... **22**

19a. Eyes either in three to four rows or in three groups……………………..… **20**

19b. Eyes in two rows……………………………………………..**ZODARIIDAE**

20a. Clypeus very high, posterior eyes and anterior lateral eyes forming a hexagonal group in front of small anterior median eyes, numerous long spines on tibiae and metatarsi……………………………....... **OXYOPIDAE**

20b. Clypeus not as high, eye position and setae on legs different…………..… **21**

21a. Eyes sessile, not on tubercles, abdomen oval, smoothly rounded posteriorly, male palpal tibiae without retrolateral apophysis, cocoon attached to spinnerets, anal tubercle with one segment ……………..….....**LYCOSIDAE**

21b. At least one pair of eyes on shallow tubercles, abdomen almost always elongate, tapered to back, male palpal tibia with retrolateral apophysis, anal tubercle biarticulate, labium hardly longer than wide, anterior lateral eyes normal, egg cocoon carried between chelicerae and palpi …...**PISAURIDAE**

22a. Posterior spinnerets very long, last segment at least three times longer than wide... **23**

22b. Posterior spinnerets not unusually long…………………………………....**24**

23a. Anal tubercle very large, with fringe of long hairs, posterior spinnerets curved around it, carapace almost circular …………………......**OECOBIIDAE**

23b. Anal tubercle normal, carapace differently shaped, posterior spinnerets with a median row of spigots …………………………….. …....**HERSILIIDAE**

24a. Anterior tibiae and patellae with a prolateral row of alternating long and short curved spines, chelicerae with peg teeth ……………... **MIMETIDAE**

24b. Legs without such spines……………………………………………...... **25**

25a. Paracymbium is a separate sclerite, tarsi usually cylindrical or sometimes fusiform, chelicerae often with stridulating file …………….**LINYPHIIDAE**

25b. Paracymbium fused to cymbium or rudimentary, no cheliceral stridulating file, tarsi variable….……………………….. **26**

26a. Tarsi IV with ventral comb of serrated hairs, brownish rings around the eyes, femora without spines, paracymbium a small hook at the distal promargin of the cymbium, labium not rebordered, male palpal tibia broadened towards the extremity with typical fan of widely spaced setae …...…**THERIDIIDAE**

26b. Tarsi without ventral comb of serrated hairs, eyes without brownish rings..**27**

27a. Male palp complex, with median apophysis, chelicerae often swollen but not modified for courtship, epigyne often with scape….…………**ARANEIDAE**

27b. Male palp fairly simple,chelicerae usually long or swollen, modified for courtship in males, epigyne usually indistinct ……....**TETRAGNATHIDAE**

4.1.4. FIRST REPORTS

Of the species documented from the study area, one species from family Thomisidae was recorded for the first time in India. Redescription of male and female of one species from family Theridiidae were produced. The details are included in the following section.

4.1.4.1 FIRST REPORT OF *Amyciaea albomaculata* (Cambridge, 1874)

Family: Thomisidae.

Collecting locations: Kasargod: Koyithatta Sree Dharmasastha Kavu (12°17’11.4’’ N, 075°14’53.88’’ E, 121 m alt)

Material examined: 1♀ (KS287)

Amyciaea is a genus of ant mimicking crab spiders that was first described by Simon in 1885. As of December 2020, this genus contains five species, found in Africa, Asia, and Oceania. They are *Amyciaea albomaculata* (Cambridge, 1874) Australia, New Guinea, *Amyciaea forticeps*-type specieman (Cambridge, 1873) India, China to Malaysia, *Amyciaea hesperia* (Simon, 1895) Sierra Leone, IvoryCoast, Amyciaea lineatipes (Cambridge, 1901) Singapore, Indonesia (Sumatra) and *Amyciaea orientalis* (Simon, 1909) Vietnam.

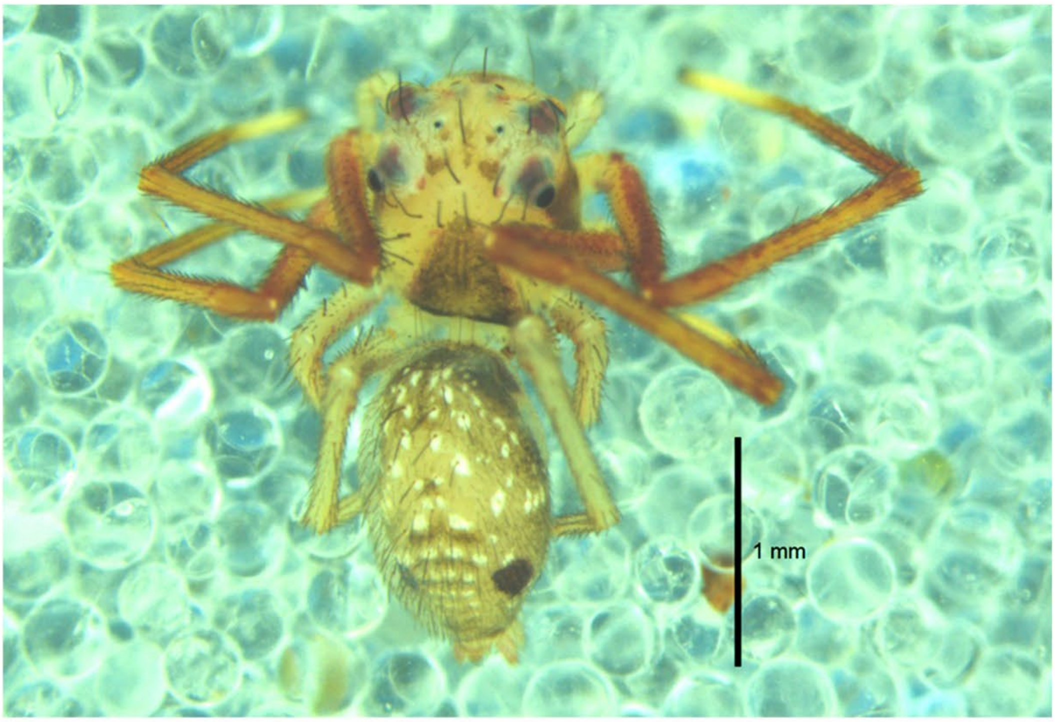
Diagnostic characters: This spider is remarkably similar to *Amyciaea forticeps* **(**O. Pickard-Cambridge, 1874**)** both in form, general color and structure. In the present species, however, the abdomen has none of the dark markings of *Amyciaea forticeps*, but has instead on the upper side a tolerably regular pattern of distinct white spots of different sizes; these are most conspicuous in the female; they form two longitudinal lines enclosing a very elongated sub diamond-shaped area, with a few other similar spots on the sides. The two round black blotches so conspicuous on the hinder part of the upper side of the abdomen of *Amyciaea forticeps* are also present in *Amyciaea albomaculata* (Plate-4). It is possible that the comparison of both these species might prove them to be merely varieties of each other. The occurrence of this genus is in Northern Australia and New Guinea. Reason for the occurrence of this species in the study area is, in previous literature mentioned that there may be a possibility to find these species in Cyelon, Sumatran and Javan chain of islands (Pickard-Cambridge, 1874 & Kulczyński, 1911). Presently the identification is over and detailed taxonomic description of this specimen will be done in future. Specimen kept in the Museum of Centre for Animal Taxonomy and Ecology, Department of Zoology, Christ College, Irinjalakuda.

Natural history. These spider looks like a common red ant. Two dark spots on the abdomen mimic the eye of the ant. Excessively arched cephalothorax gives the impression of abdomen of ant. Usually found along with ants and feeding on them. The first two pairs of legs are often jerkily held up and down while the spider moves in the colony of red ants. In suitable time, it pounces on the ant. It falls into the air with the help of safety silk line while holding the ant in its jaws. So, the ant has no chance for a counterattack. The ant becomes unconscious suddenly due to the potential effect of spider venom.

Distribution. India (Kerala [new record]), Australia (Pickard-Cambridge, 1874) and New Guinea (Kulczyński, 1911)

Plate 4

Amyciaea albomaculata (Cambridge, 1874)
Family: Thomisidae.



(A)

(B)

(C)

(A). *Amyciaea albomaculata* female dorsal view, (B). Same lateral view, (C). Same eye pattern

4.1.4.2. Redescription and new records of *Phoroncidia septemaculeata* (Cambridge, 1873)

Collecting locations: Thrissur, Kodungallur, Sankukulangara Kavu (10º16'39.5" N 76º09'59.6" E, 9 m alt).

Material examined: 1 ♂, 1 ♀ (CATE10301C).

The genus *Phoroncidia* Westwood 1835 is now represented by 81 species and is cosmopolitan in distribution. Presently, four species are known from India, namely *Phoroncidia aculeata* (Westwood 1835), *Phoroncidia maindroni* (Simon 1905), *Phoroncidia septemaculeata* (Cambridge, O. P., 1873) and *Phoroncidia testudo* (Cambridge, 1873) (World Spider Catalog 2020). *P. septemaculeata* Cambridge, 1873 was described based on a few specimens collected by Mr G. H. K. Thwaites in 1871 from Sri Lanka and it was mostly derived from the somatic features of the species. Recently, Patil *et al.* (2018) reported two sub adult males presumed to be *Phoroncidia septemaculeata* from the Maharashtra state in India. A detailed redescription of *P.septemaculeata*, including illustrations of male and female genitalia for the first time, based on fresh materials collected from different localities in the Coastal Plains and Western Ghats of Kerala state and Coastal plains of Tamil Nadu was published. Additionally, the current distributional range and new records of the species is mapped.

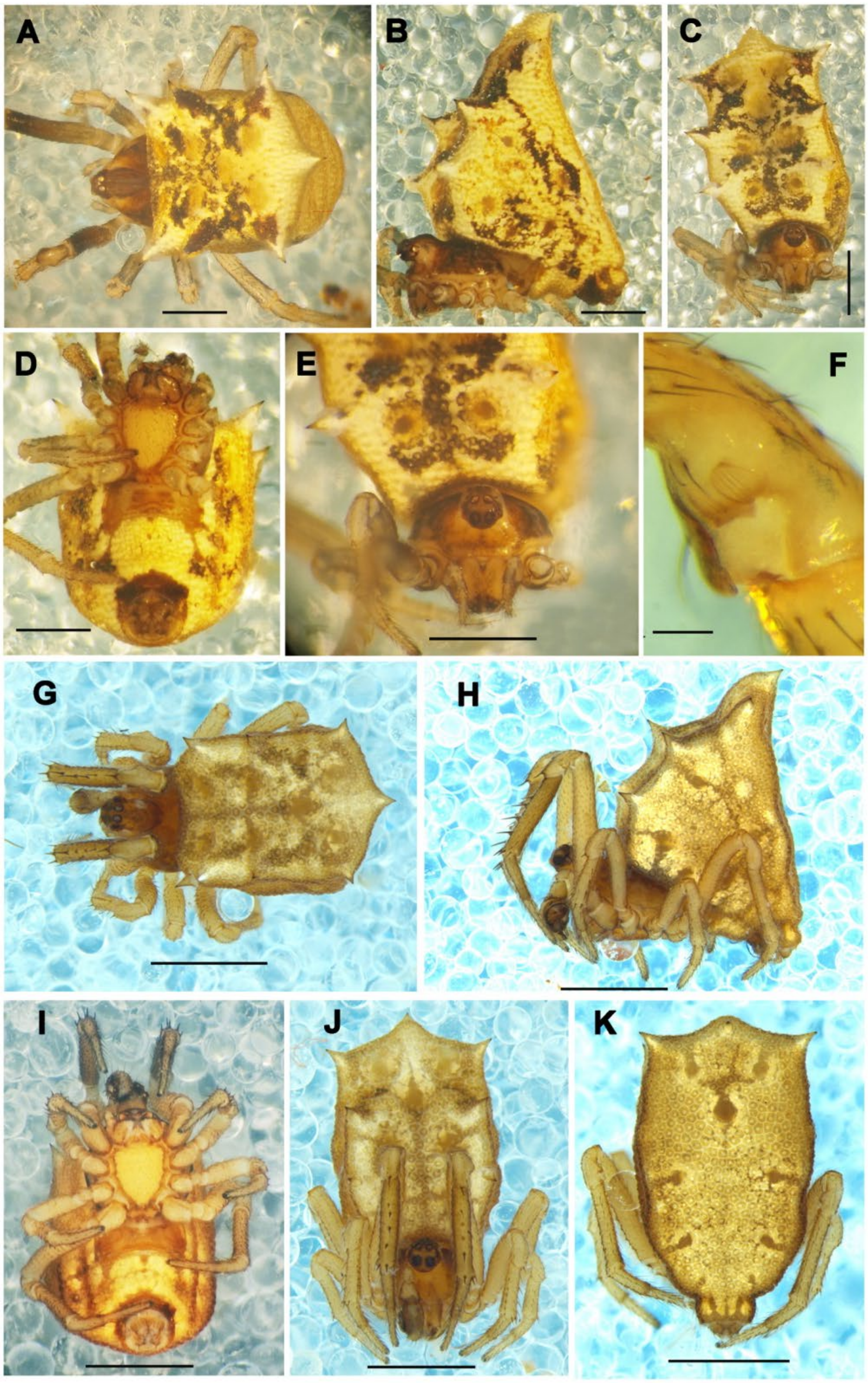
Diagnostic characters. *P. septemaculeata* can be readily distinguished from its congeners by the subtriangular shape of abdomen in lateral aspect, which is slightly humped anteriorly, anterior abdomen adorned with seven short and stout spines originating from protuberances, and shield-shaped posterior. (Plate 5). The genitalia of *P. septemaculeata* is closest to *P. americana*, but can be distinguished from the latter by the following features: male palp with conductor on the prolateral side ventral to TTA (positioned retrolaterally, dorsal to embolic base in *P. americana*), embolic base lobed, almost heart-shaped, with a deep v-shaped excavation on prolateral side (irregularly shaped with a shallow excavation distally in *P. americana*); vulva of female genitalia with copulatory duct forming a loop over the posterior half of spermathecae (forms a loop almost over the entire spermathecae in *P. americana*), posterior spermathecae and fertilisation duct slightly bent laterally (bent 180 degrees medially in *P. americana*)(Plate-6).

Natural history. *P. septemaculeata* spins single almost horizontal thread, and hangs around the centre of the strand during night time.

Distribution. India (Kerala & Tamil Nadu [new record]), Malaysia (Levi & Levi 1962), Sri Lanka (Cambridge, 1873).

Plate 5

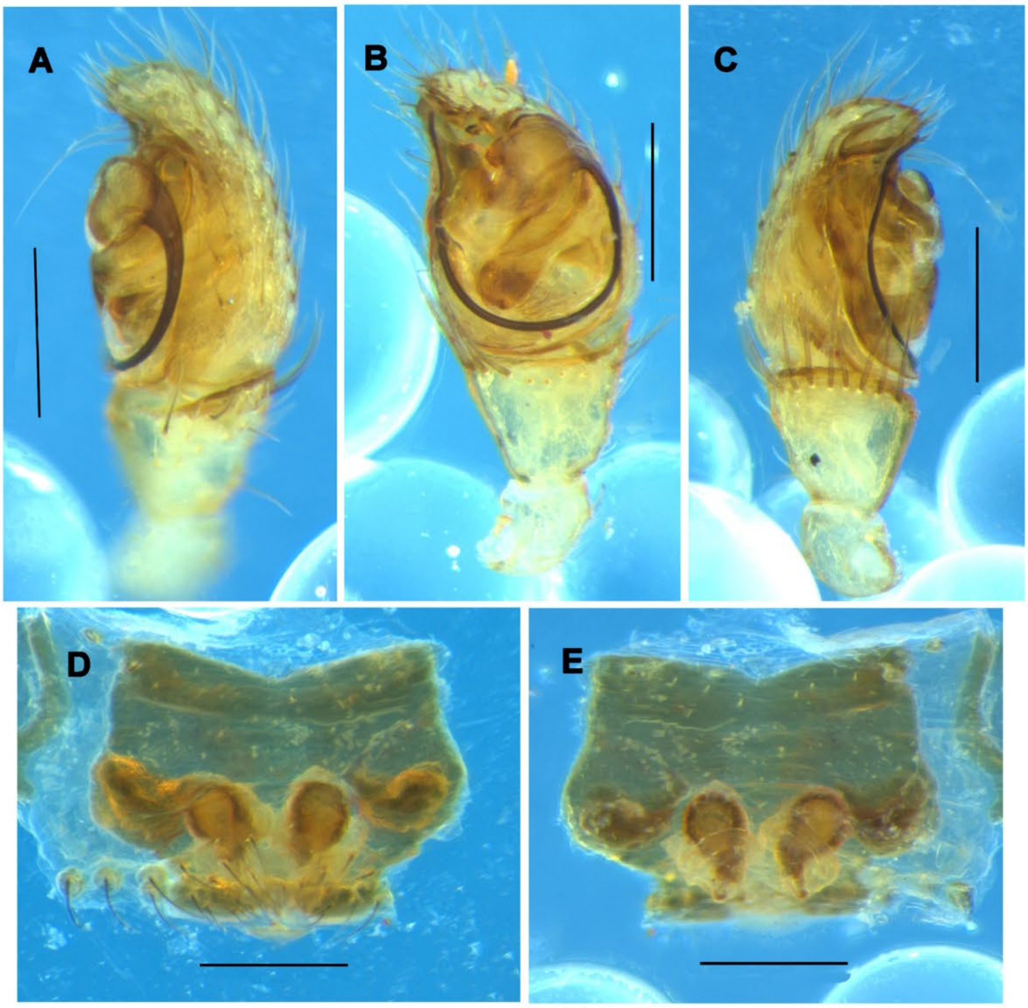
Phoroncidia septemaculeata (Cambridge 1873)



Phoroncidia septemaculeata. A, Female, dorsal view. B, Same, lateral view. C, Same, frontal view. D, Same, ventral view. E, Same, eye region. F, Male, Patella IV, showing lyriform organ. G, Same, dorsal view. H, Same, lateral view. I, Same, ventral view. J, Same, frontal view. K, Same, posterior view.

Plate 6

Phoroncidia septemaculeata (Cambridge 1873)



Phoroncidia septemaculeata. A, Male left palp, retrolateral. B, Same, ventral view. C, Same, prolateral view; D, Epigynum, ventral view. E, Same, dorsal view.

4.2. DIVERSITY, ABUNDANCE AND RICHNESS OF SPIDERS

One of the objectives of this study was to analyze the abundance, diversity, richness and similarity in the occurrence of spiders in the different habitat type of the sacred groves of Northern Kerala. In this study the study areas categorized into five major habitats they are evergreen (EVN), semi-evergreen (SEN), moist-deciduous (MDS), myristica (MYA) and mangrove (MGE) habitat. A total of 15 sacred groves from Kannur and Kasargod districts were selected for sampling from the study area. Out 15, 7 of them are comes under evergreen habitat, 4 of them are in semi-evergreen habitat, 2 of them are in myristica habitat and 1 each in moist-deciduous and mangrove habitat. Edayilekadu Kavu (ED), Koyithatta Sree Dharmasastha Kavu (KS), Payyamkulam Kavu (PA), Chama Kavu (CK), Konganichal Kavu (KO), Neeliaar Kottam (NE), Palathara Kunji Kavu (PK) included in evergreen habitat. Mannam Purathu Kavu (MP), Sree Malliyodan Kavu (ME), Periyanganam Sree Dharmasastha Kavu (PS), Puthiya Parambathu Kavu (PP) included in semi-evergreen habitat. Kammadom Kavu (KK) and Poongottu Kavu (PO) included in myristica habitat. Madayi Kavu (MK) included in moist deciduous habitat and Thazhe Kavu (TK) with mangrove habitat. For the ease, duration of the study was divided in to three major seasons like Pre-Monsoon, Monsoon, and Post-Monsoon.

4.2.1. Abundance and diversity in different habitats

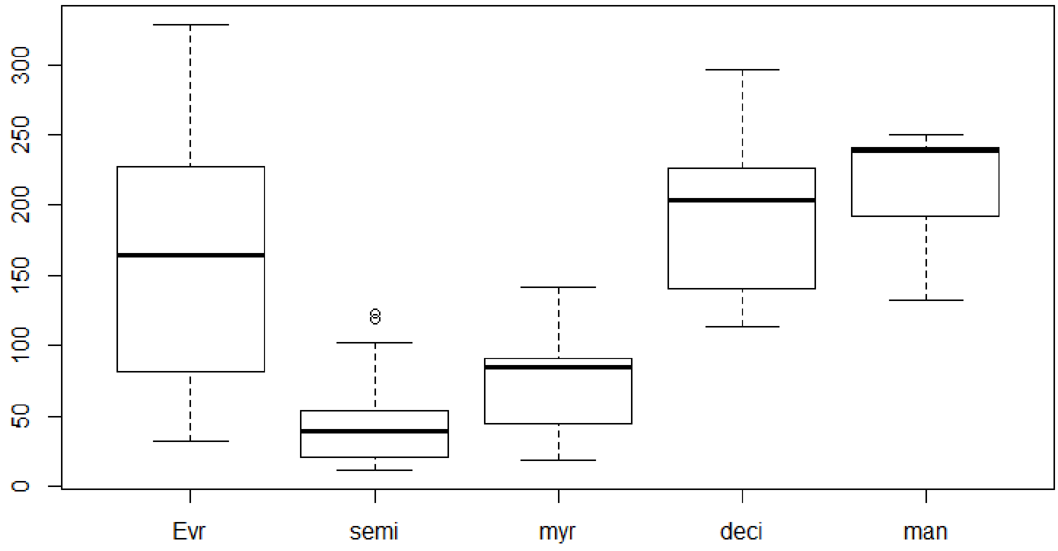
Analysis of the diversity pattern revealed that diversity varied between habitats. Among the five habitats studied the EVN recorded the highest diversity. A total of 172 species of spiders were collected from this habitat. The second highest species diversity was reported from the MYA habitat and it represents 84 species of spiders. SEN supports spider diversity with 70 species. MDS represents 57 species of spiders. Least value of diversity was recorded from the MGE habitat and it represents 36 species of spiders. Among five habitats studied, the EVN habitat shows the maximum number recorded with 6805 individuals, followed by MGE with 1292 individuals, MDS with 1182 individuals, SEN with 1106 individuals and MYA ecosystem with 923 individuals. Maximum Singleton and doubleton was higher in EVN habitat and minimum in mangrove habitat. Coming to the unique species and rare species percentage, maximum number of unique species was recorded in EVN and rare species percentage was maximum in MYA habitat (Table 5).

Table 5. Number of total individuals, species, singleton, doubleton, unique species and rare species percentage with respect to habitat types.

PARAMETER	EVN	SEN	MYA	MDS	MGE
Individuals	6805	1106	923	1182	1292
Mean abundance±sd	162.02±88.31, n=42	46.08±31.86, n=24	76.91±38.6, n=12	197±64.88, n=6	215±45.65, n=6
Total no. of species	172	70	84	57	36
Singletons	16	10	12	10	0
Doubletons	19	11	11	4	1
Unique species	19	11	13	10	0
Rare species %	55.81	67.14	71.43	64.91	36.11

*n = No. of samples

The abundance of spiders showed considerable difference in five areas (Fig.3), EVN showed highest abundance at 162.02 ± 88.31 (Mean ± SD), followed by MGE (215 ± 45.65), MDS (197 ± 64.88), MYA (76.91 ± 38.6) and SEN reported the lowest (46.08 ± 31.86) abundance.



Various diversity indices including, Estimated Shannon diversity, Average observed Shannon diversity, Overall Shannon index and Average observed Simpson's index, were calculated across the five habitat types and the values are summarized in Table 6. The higher Estimated Shannon diversity were recorded in MYA at 27.43 ± 3.08 (Mean ± SD) and lowest in SEN at 15.071 ± 3.12. Average observed Shannon diversity was higher in MYA (20.31 ± 12.57) and lowest in SEN (0.07 ± 3.57). Overall Shannon index was maximum in EVN with 39.45 ± 0.82 and lower in MGE at 18.17 ± 00.56. Average observed Simpson's index was higher in EVN at 13.37 ± 6.86 and lower in SEN at 7.93 ± 2.92. So, the diversity rich habitat was EVN and it comprises a remarkable variety of flora and fauna. The diversity of spiders is influenced by the organization of the vegetation in the habitat. The least of diversity indices were found in the MGE. The poor diversity of spiders in this ecosystem is mainly due to scarce vegetation, monospecies of plants and limited space for web formation. Thus, it was concluded that spider communities fluctuated as an increase or decrease in these habitat types due to the diverse ecological conditions.

Table 6. Summary of statistical analysis performed indifferent habitats.

Diversity indices	EVN	SEN	MYA	MDS	MGE
Est. Shannon diversity±se	22.94±2.07	15.071±3.12	27.43±3.08	19.71±1.95	18.33±1.27
Average observed Shannon±sd	19.45±9.74	0.07±3.57	20.31±12.57	16.89±1.32	16.87±1.65
Overall Shannon±se	39.45±0.82	27.74±1.16	36.64±1.3	19.8±0.79	18.17±0.56
Average observed Simpson diversity±sd	13.37±6.86	7.93±2.92	15.91±9.71	10.52±0.92	11.65±0.82

The relative abundance based Morisita - Horn indices showed in different habitats were represented as follows. In EVN habitat similarity was 78.77%, with a 95% confidence interval of (78.14, 79.41), in SEN habitat it was 67.86% with a 95% confidence interval of (66.20, 69.51), in MYA 70.17% with a 95% confidence interval of (67.85, 72.5), in MDS 91.90% with a 95% confidence interval of (90.17, 93.63) and in MGE 95.78% with a 95% confidence interval of (94.47, 97.08).

The pair wise similarity indicated a higher similarity between EVN -MDS at 76.25% with a 95% confidence interval of (74.02, 78.49) and the lowest similarity between SEN - MGE at 41.02% with a 95% confidence interval of (34.52, 47.52).

4.2.2. Species richness in habitats

The local diversity or alpha diversity of EVN in terms of species richness was 172. The species richness of SEN was 70, the MDS was 84, the MYA was 57 and the MGE ecosystem was 36. The species richness estimator, Chao 1 predicted 179.66 ± 4.75 species of spiders from EVN, 74.46 ± 3.64 species from SEN, 88.84 ± 3.68 species from MDS, 60.21 ± 2.85 species from MYA and 36 species from MGE ecosystem (Table 7).

Table 7. Summary of statistical analysis performed for species richness in different habitats.

Diversity indices	EVN	SEN	MYA	MDS	MGE
Richness	172	70	84	57	36
Est. richness±se	179.66±4.75	74.46±3.64	88.84±3.68	60.21±2.85	36
Mean richness±sd	32.4±14.81	13.95±5.25	26.75±15.71	34.66±3.72	30.16±2.63

In sacred groves, the number of individuals collected from EVN habitat was 6805 and the observed Species richness, Shannon Diversity and Simpson Diversity (Hill numbers for q=0, 1, 2) for this sample were 43.915, 20.835 and 13.167 respectively (Fig. 4). The number of individuals for SEN was 1106 and the observed Hill numbers for q=0, 1, 2 were 74.541, 29.428 and 16.621 (Fig. 5). The number of individuals for MYA was 923 and the observed Hill numbers for q=0, 1, 2 were 90.538, 46.019 and 28.756 (Fig. 6). The number of individuals for MDS was 1182 and the observed Hill numbers for q=0, 1, 2 were 69.489, 20.304 and 11.814 (Fig. 7). Whereas, the number of individuals for MGE was 1292 and the observed Hill numbers for q=0, 1, 2 were 36, 18.416 and 12.232 (Fig. 8). It is evident from the standardized sample that MYA habitat appears to have higher observed species richness, Shannon Diversity and Simpson Diversity than others.

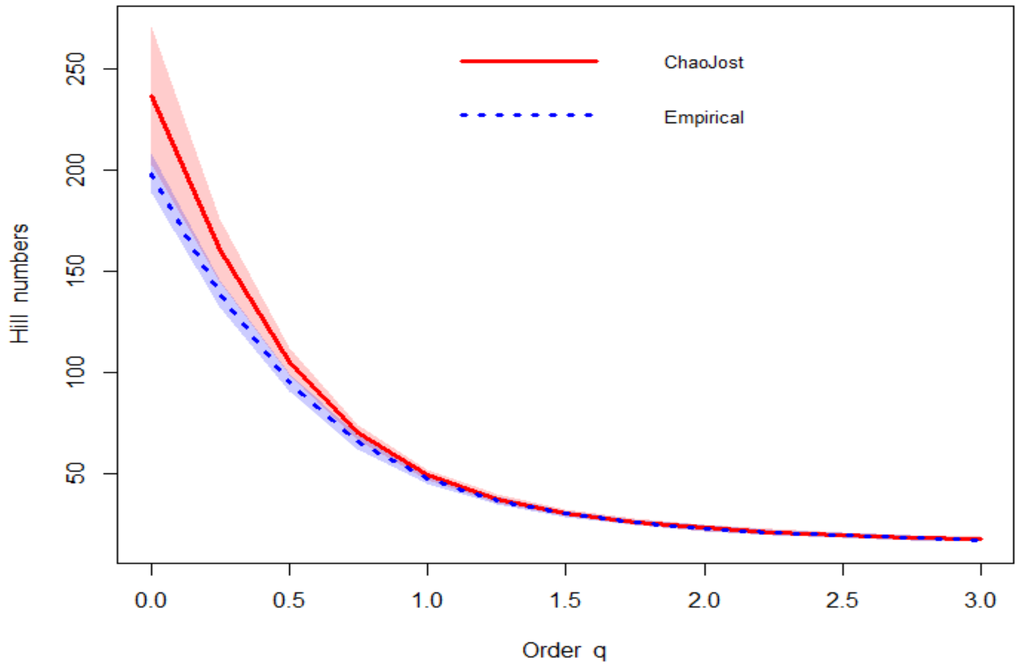


Figure 4. Diversity profile curve of Evergreen habitat.

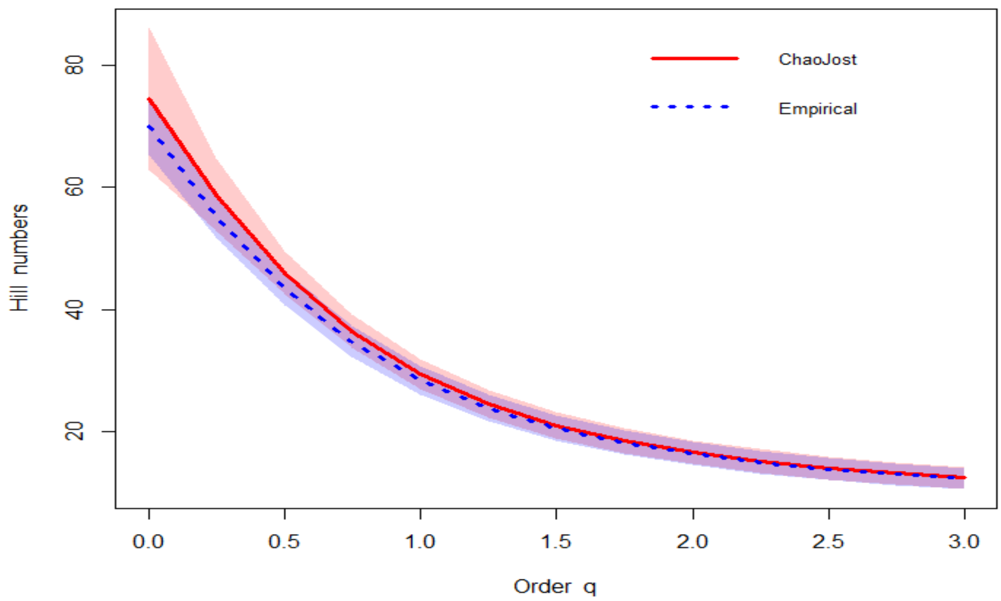


Figure 5. Diversity profile curve of Semi-evergreen habitat.

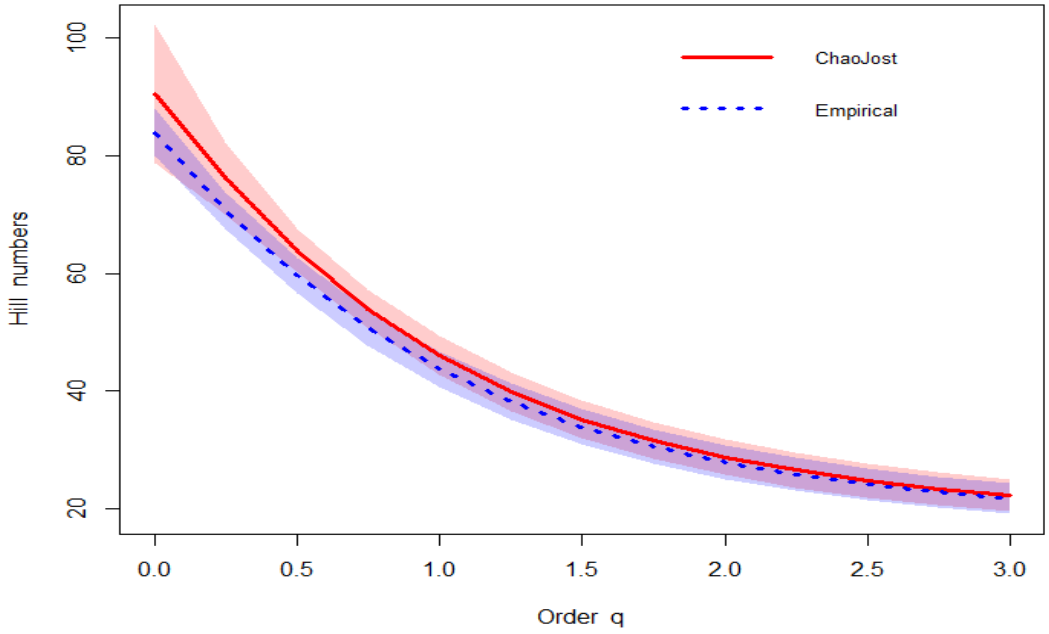


Figure 6. Diversity profile curve of Myristica habitat.

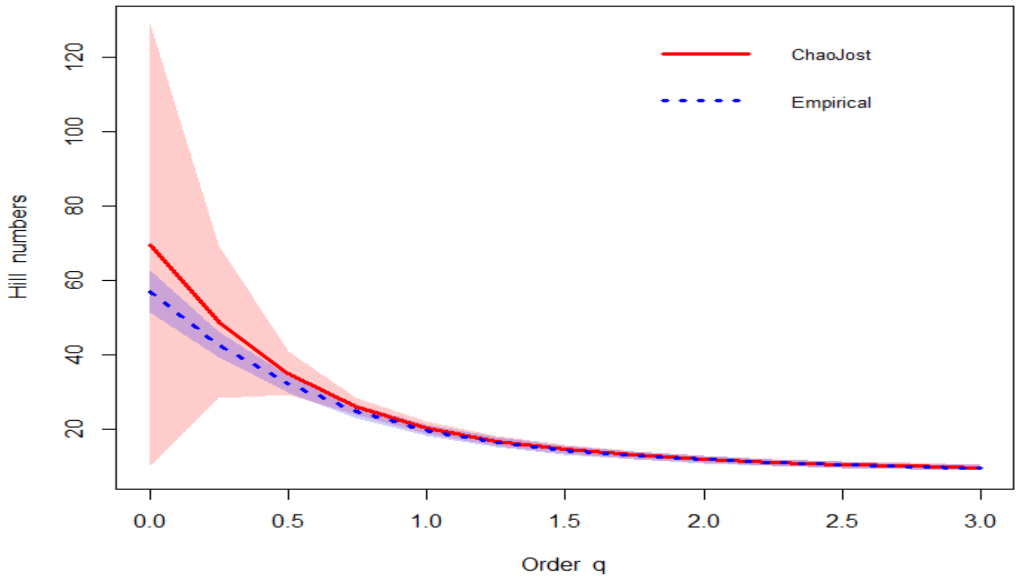


Figure 7. Diversity profile curve of Moist-deciduous habitat.

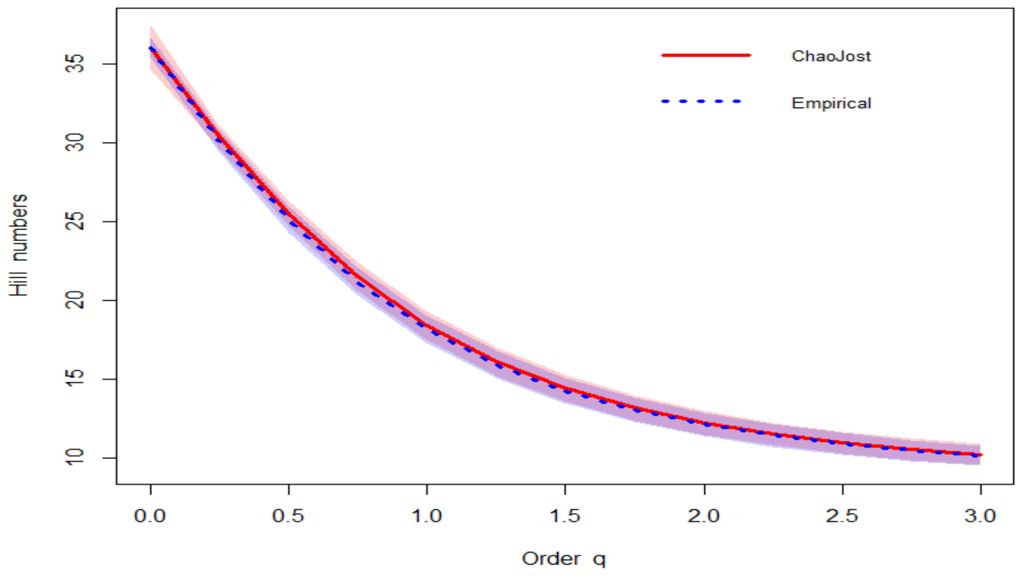


Figure 8. Diversity profile curve of Mangrove habitat.

4.2.3. Seasonal abundance and diversity

Analysis of the diversity pattern revealed that diversity varied between seasons. Among three seasons studied the Post-monsoon season recorded the highest diversity. A total of 232 species of spiders were collected from this season. The second highest species diversity was reported in monsoon season with 214 species. Pre-monsoon season supports spider diversity with 198 species. Coming to the abundance maximum was recorded in Post-monsoon season with 5181 individuals, followed by Pre-monsoon season with 3615 individuals and least abundance were in monsoon season with 2677 individuals. Maximum Singleton and doubleton was in monsoon season and minimum in Post-monsoon season (Table 8) Coming to the unique species and rare species percentage, maximum number of unique species and rare species percentage was maximum in monsoon season (Table 8).

Table 8. Number of total individuals, species, singleton, doubleton, unique species and rare species percentage with respect to different seasons.

PARAMETER	PRE-MONSOON	MONSOON	POST-MONSOON
Individuals	3615	2677	5181
Mean abundance±sd	141.29±27.85	111.65±36.88	181.98±43.67
Total no. of species	198	214	232
Singletons	48	56	44
Doubletons	30	35	27
Unique species	58	79	58
Rare species %	73.23	81.78	70.69

The abundance of spiders showed considerable difference in three seasons. Post- monsoon season showed highest abundance at 181.98 ± 43.67 (Mean ± SD), followed by Pre- monsoon season 141.29 ± 27.85, monsoon season reported the lowest (111.65 ± 36.88) abundance (Fig. 9).

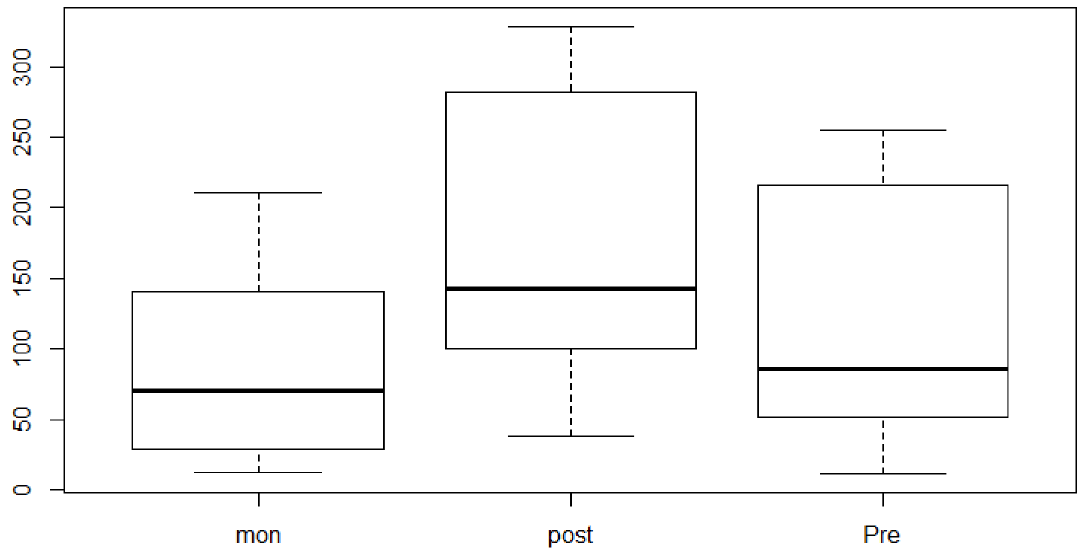


Figure 9. Box plots showing the abundance of spiders per season.

Various diversity indices including, Estimated Shannon diversity, Average observed Shannon diversity, Overall Shannon index and Average observed

Simpson's index, were calculated across three seasons and are summarized in Table 9. The higher estimated Shannon diversity values were recorded in monsoon season at 24.28 ± 10.37 (Mean ± SD) and in Post-monsoon and Pre-monsoon seasons recorded same values at 18.81 ± 11.31. Average observed Shannon diversity was higher in Post-monsoon at 18.30 ± 9.73 and lowest in Pre-monsoon at 15.28 ± 8.75. Overall Shannon index was maximum in monsoon (55.25 ± 1.99) and lower in Pre-monsoon (44.75 ± 1.36). Average observed Simpson's index was higher in post-monsoon at 12.82 ± 7.31and lower in Pre-monsoon at 10.86 ± 6.37. So, the diversity rich season was monsoon.

Table 9. Summary of statistical analysis performed in different seasons.

Diversity indices	PRE-MONSOON	MONSOON	POST-MONSOON
Est. Shannon diversity±se	18.81±11.31	24.28±10.37	18.81±11.31
Average observed Shannon±sd	15.28±8.75	16.58±9.02	18.30±9.73
Overall Shannon±se	44.75±1.36	55.25±1.99	52.62±1.18
Average observed Simpson diversity±sd	10.86±6.37	12.18±6.05	12.82±7.31

The relative abundance based Morisita–Horn index in different seasons were represented as follows. In Pre-monsoon season similarity was 68.54 %, with a 95% confidence interval of (67.44, 69.63), in Monsoon season it was 66.51% with a 95% confidence interval of (65.15, 67.88) and in Post-monsoon 68.93% with a 95% confidence interval of (68.00, 69.85).

The pair wise similarity indicated a higher similarity between Monsoon and Post-monsoon at 98.13% with a 95% confidence interval of (97.17, 99.10) and the lowest similarity between Pre-monsoon and Monsoon at 98.06% with a 95% confidence interval of (96.88, 99.23).

4.2.4. Seasonal species richness

The local diversity or alpha diversity of Post-monsoon season in terms of species richness was 232. The species richness of Monsoon was 214 and Pre-monsoon was 198. The species richness estimator Chao 1 estimator predicted 263 species of spiders in Monsoon season, 253 species in Post-monsoon season and 226 species in Pre-monsoon season (Table 10).

Table 10. Summary of statistical analysis performed for species richness in different seasons.

Diversity indices	PRE-MONSOON	MONSOON	POST-MONSOON
Richness	198	214	232
Est. richness	226	263	253

In sacred groves, the number of individuals collected from Pre-monsoon season was 3615 and the observed Species richness, Shannon Diversity and Simpson Diversity (Hill numbers for q = 0, 1, 2) for this sample were 236.389, 49.131 and 22.952 respectively (Fig.10). The number of individuals for Monsoon season was 2677 and the observed Hill numbers for q = 0, 1, 2 were 258.782, 63.316 and 28.287 (Fig. 11). Whereas, the number of individuals for Post-monsoon season was 5181 and the observed Hill numbers for q = 0, 1, 2 were 267.845, 56.178 and 25.561 (Fig.12). It is evident from the standardized sample that Post-monsoon season appears to have higher observed species richness than others and Shannon Diversity and Simpson Diversity were higher in Monsoon season.

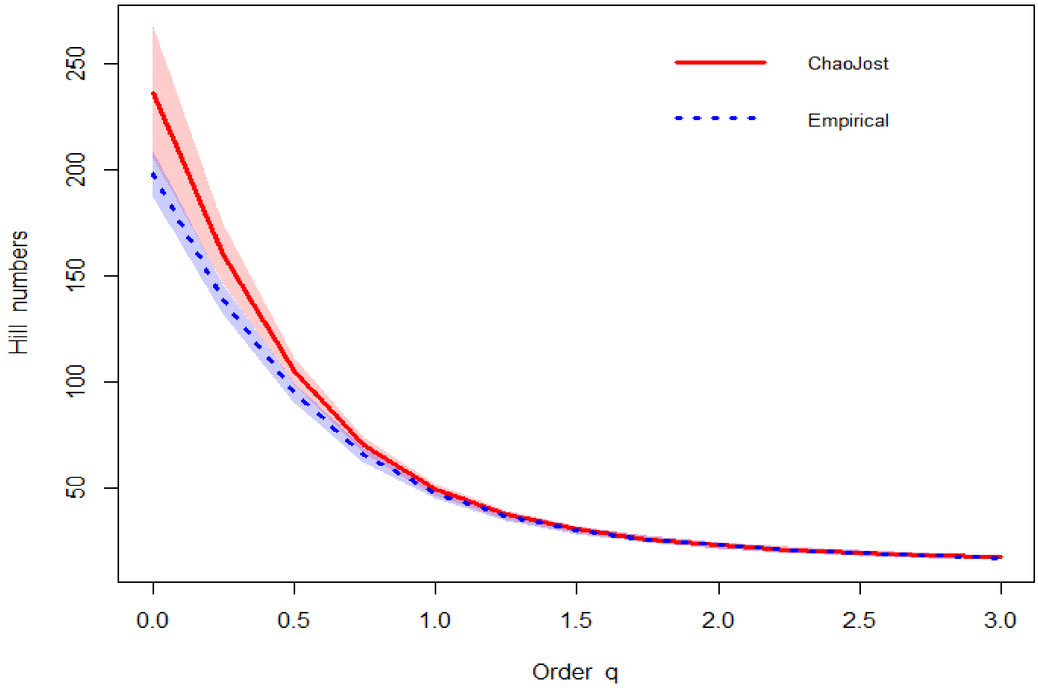


Figure 10. Diversity profile curve of Pre-monsoon season.

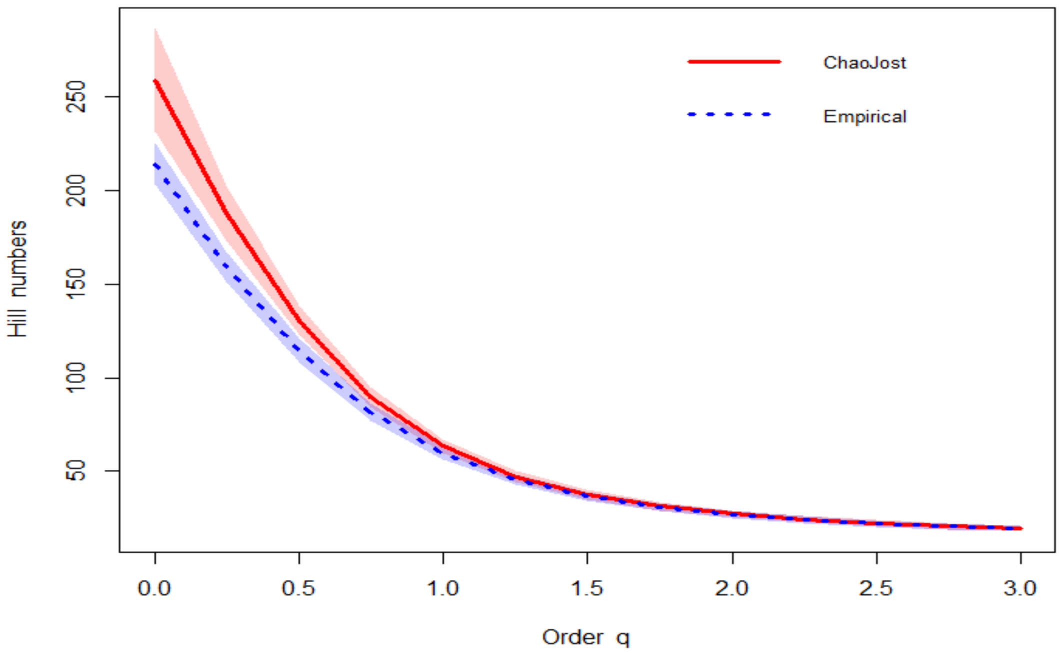


Figure 11. Diversity profile curve of Monsoon season.

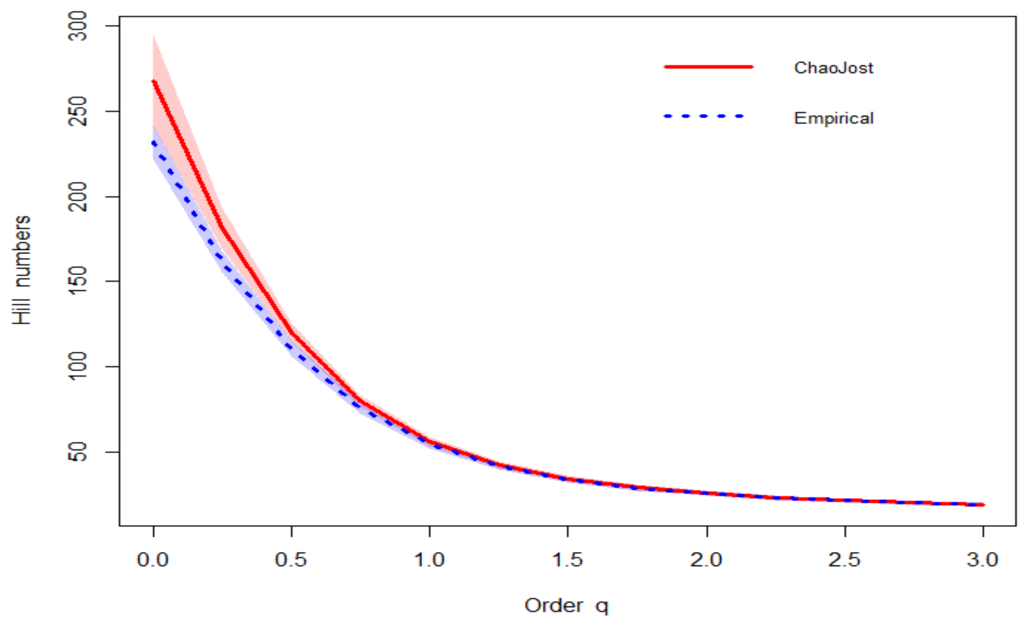


Figure 12. Diversity profile curve of Post-monsoon season.

4.2.5. Beta diversity of spiders in sacred groves

The variation of diversity among the different habitats were analysed using the PERMANOVA test (Anderson et al., 2011), done using adonis function of vegan with 999 permutations and was visualized using the nMDS plot. This was done using a dissimilarity matrix derived from Horn index using the vegdist() function of the vegan package. The abundance data was double root transformed to normalise the distribution. To check if the differences were brought about by the dispersions of the sample sites, homogeneity of multivariate dispersions was done. But no significant difference was found between the centroids of each habitat in Adonis. In EVN it was 0.28365, SEN it was 0.47798, in MYA it was 0.47523, in MDS it was 0.12801 and MGE 0.06237. That means the species composition does not vary among the habitats. However, there is some observable separation between the evergreen and semi evergreen (Fig. 13). Others seem to overlap.

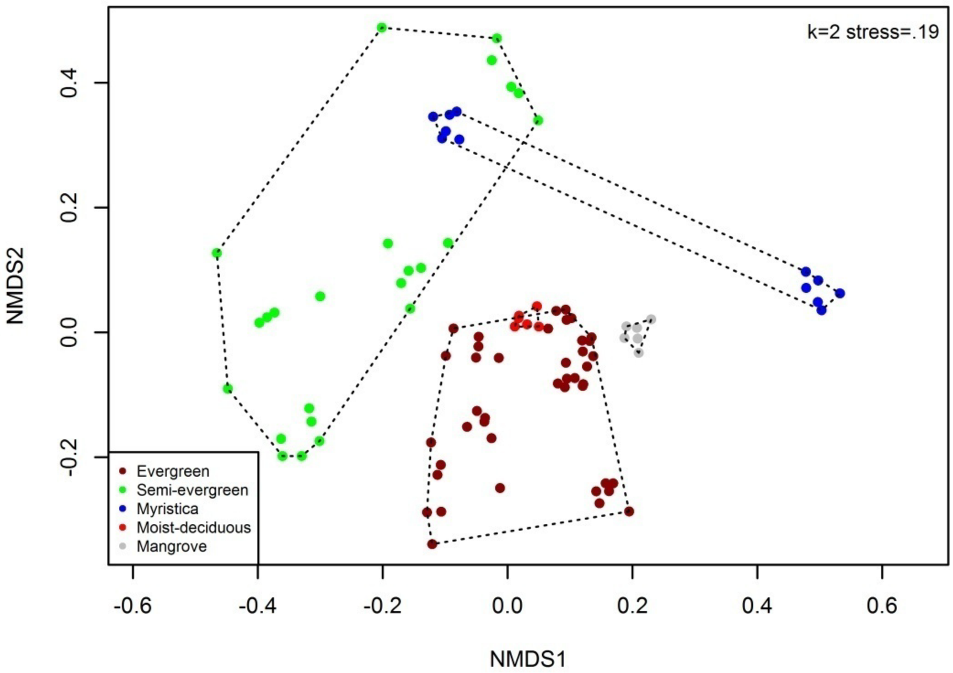


Figure 13. nMDS plots of sampling sites based on species composition.

In this study, tested two habitats alone to see if there is any significant difference in the species composition among habitat (stress = 0.19). But it was not significant (Fig. 14).

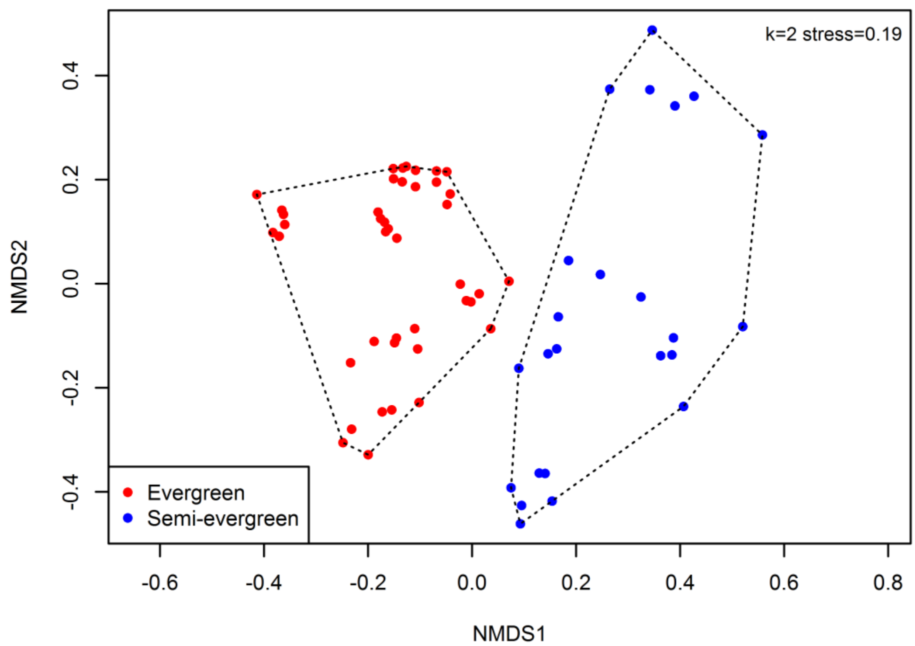


Figure 14. nMDS plots of Evergreen and Semi-evergreen habitat based on species composition.

Analysis of variance test conducted to check is there any differences in the abundance among seasons in EVN and SEN habitat. In EVN (ANOVA: $F_{2,39}$=8.0863, P < 0.01). Tukey HSD pair wise comparisons: Post-monsoon – Monsoon shows significant difference in the abundance (P < 0.01). The same was done in SEN habitat (ANOVA: $F_{2, 21}$ = 8.4724, P < 0.01). Tukey HSD pair wise comparisons: Post-monsoon – Monsoon shows significant difference in the abundance (P < 0.01). Same procedure followed to check if any significant difference in estimated Shannon diversity. There was no significant difference shown in EVN and SEN habitat.

4.2.6. Overall diversity

The study resulted in the documentation of a total of 11308 individuals of spiders belonging to 257species, 136 genera and 28 families. Of all the species collected 74 % of were identified to species level and the remaining 26 % were identified to genus level. The sample coverage was 0.998. Observed Species richness, Shannon Diversity and Simpson Diversity (Hill numbers for q=0, 1, 2) for this sample were 269.018, 55.413 and 25.079 respectively (Fig.15).

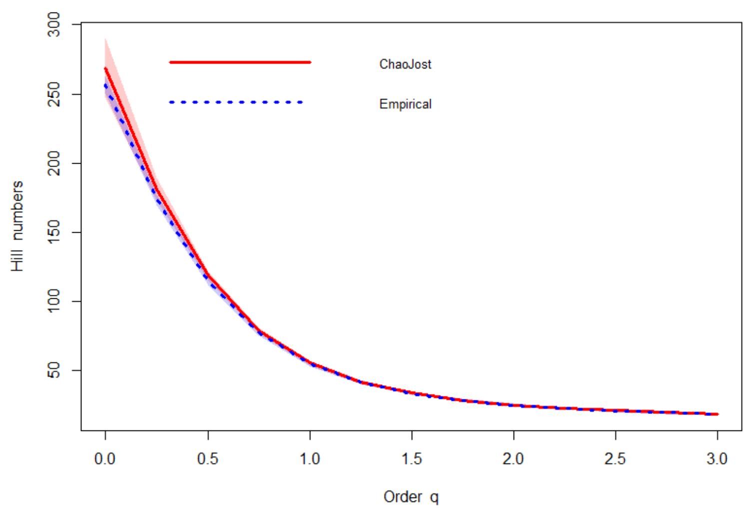


Figure 15. Diversity profile curve of pooled data.

4.2.7. Species accumulation curve

Figure 16 shows the species accumulation curve for the entire spider assemblage. The plot depicts the observed species richness. As recommended by Gotelli & Colewell (2001) to compare the sample-based abundance data. The accumulation curve rescaled to numbers of individuals rather than numbers of samples. The curve reached in a plateau represents that the sampling effort was almost complete and collected majority of specimens from the study area. Total sample coverage was 99.8% and only 0.2% remaining.

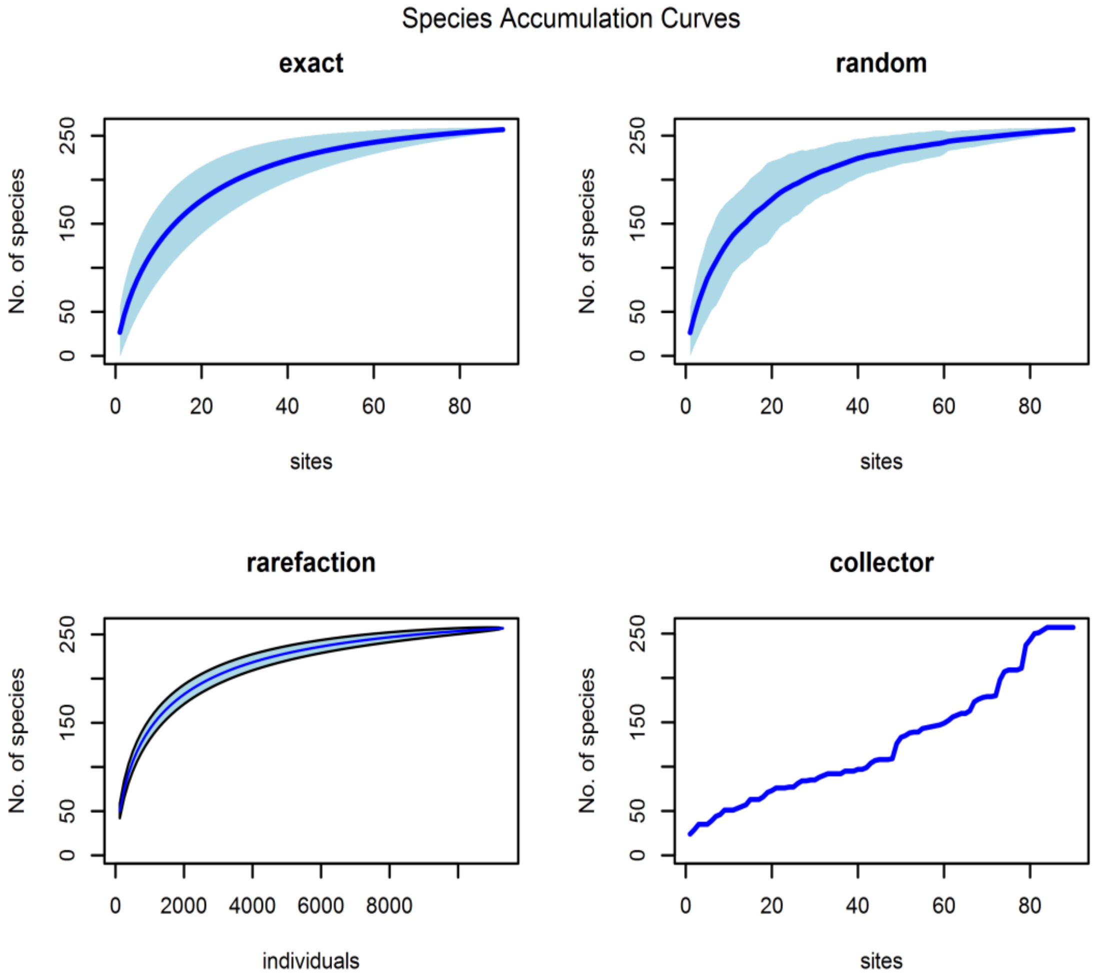


Figure 16. Species accumulation curves of the pooled samples.

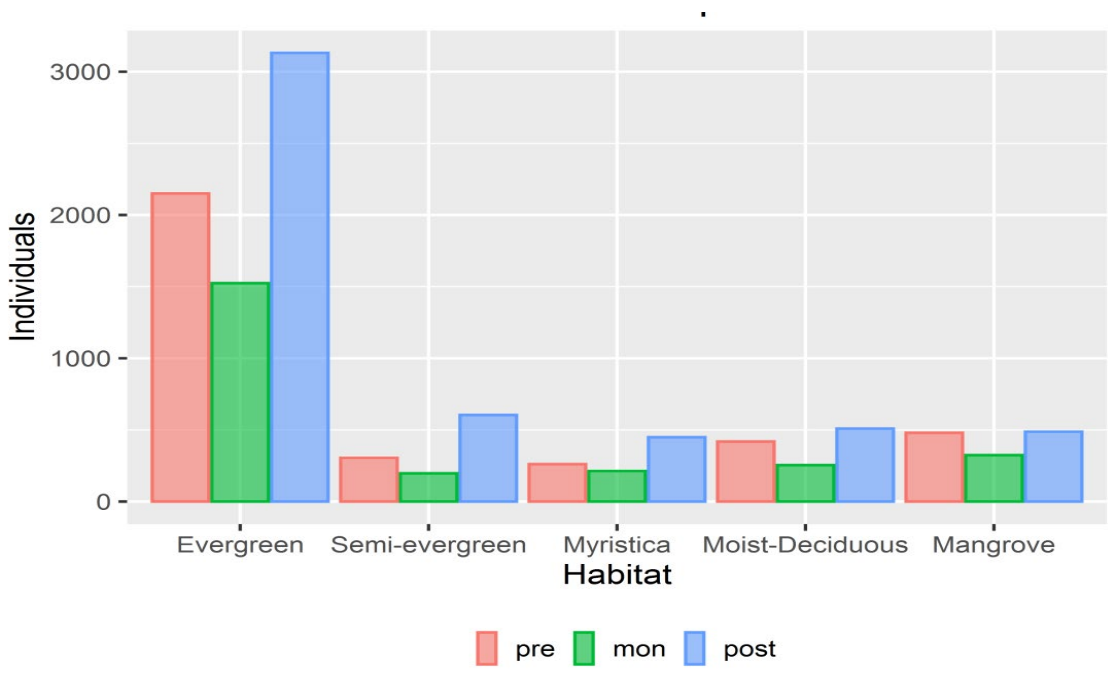


Figure 17. Abundance of spiders per season in different habitats.

4.2.8. Abundance of spiders per season in different habitats

Analysis of the diversity pattern revealed that diversity varied between seasons in different habitats (Fig. 17). Among three seasons studied the Post-monsoon season recorded the highest abundance in all habitats. In EVN, a total of 2150 individuals collected in Pre-monsoon season. In Monsoon it was 1524 individuals and Post-monsoon with 3131 individuals. In SEN 305 individuals in Pre-monsoon, 197 individuals in Monsoon and 604 individuals in Post-monsoon. In the case of MYA 261 individuals in Pre-monsoon, 213 individuals in Monsoon and 449 individuals in Post-monsoon. Coming to MDS Pre-monsoon consisted of 419 individuals, Monsoon with 254 individuals and Post-monsoon consisted of 509 individuals. In MGE 480 individuals in Pre-monsoon, 324 individuals in Monsoon and 488 individuals in Post-monsoon season. Species abundance was higher in Post-monsoon season of EVN habitat with 3131 individuals. But lower in monsoon season of SEN with 197 individuals.

The above results indicate that different seasons significantly influences the abundance of spiders. From these collection 20 species of spiders shows abundance greater than 100 so they are given in the table and Fig.18.

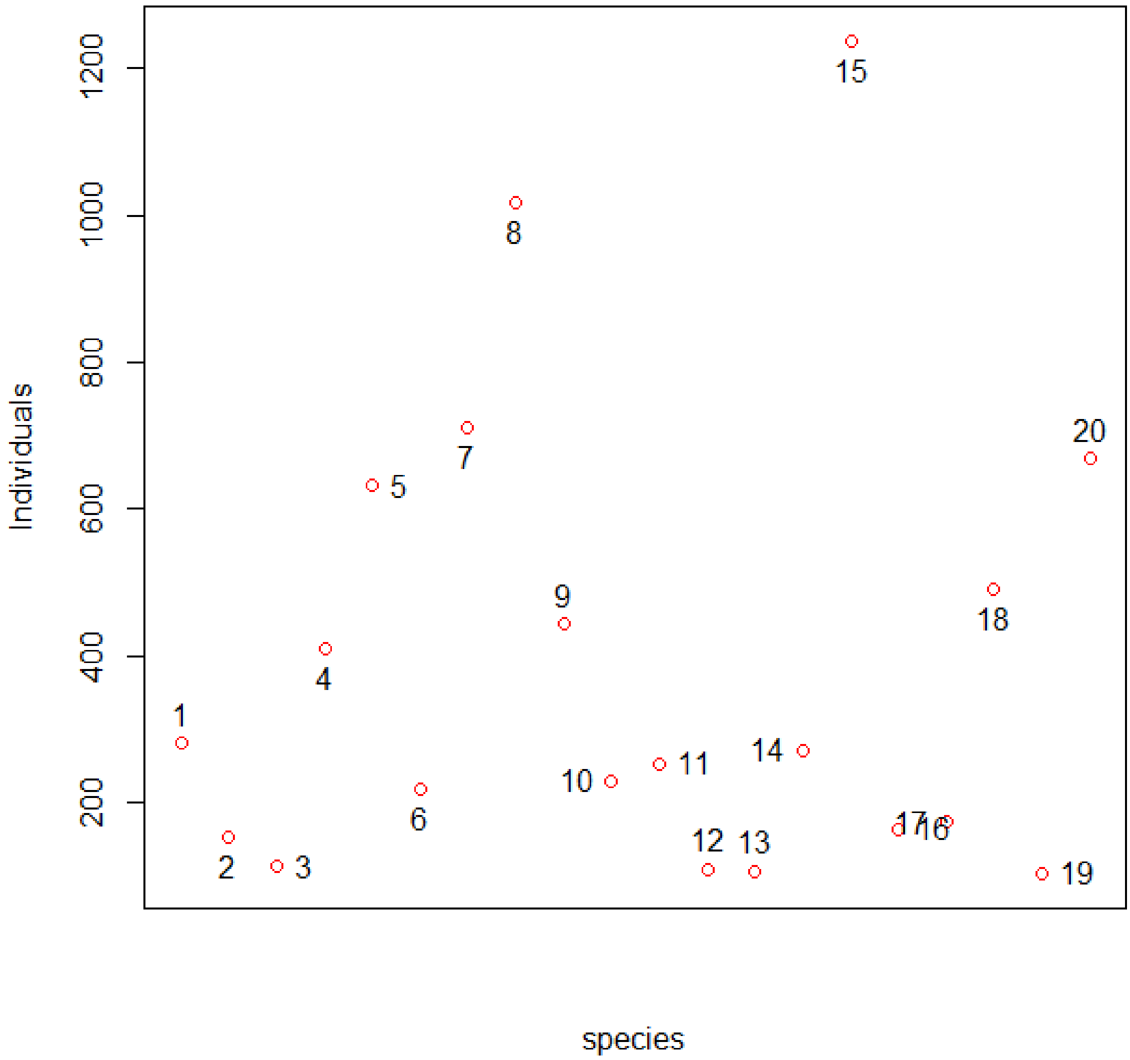


Figure 18. Abundance of species greater than 100

Table 11. Species with greater than 100 individuals.

Sl.No	Species	Individuals
1	*Araneus* sp.I	281
2	*Nephila pilipes* (Fabricius, 1793)	154
3	*Oxyopes birmanicus* Thorell, 1887	113
4	*Pholcus phalangioides* (Fuesslin, 1775)	411
5	*Epeus triangulopalpis* Malamel, 2019	631
6	*Epeus tener* (Simon, 1877)	220
7	*Indopadilla insularis* (Malamel et al., 2015)	712
8	*Hyllus semicupreus* (Simon, 1885)	1017
9	*Phintella vittata* (C. L. Koch, 1846)	443
10	*Rhene flavigera* (C. L. Koch, 1846)	229
11	*Stenaelurillus lesserti* Reimoser, 1934	253
12	*Telamonia dimidiata* (Simon, 1899)	109
13	*Tylorida striata* (Thorell, 1877)	106
14	*Tylorida ventralis* (Thorell, 1877)	271
15	*Oxytate virens* (Thorell, 1891)	1238
16	*Strigoplus netravati* Tikader,1963	165
17	*Tmarus histrix* Capriacco,1954	173
18	*Boliscus tuberculatus* (Simon, 1889)	491
19	*Indoxysticus minutus* (Tikader, 1960)	103
20	*Uloborus krishnae* Tikader, 1970	668

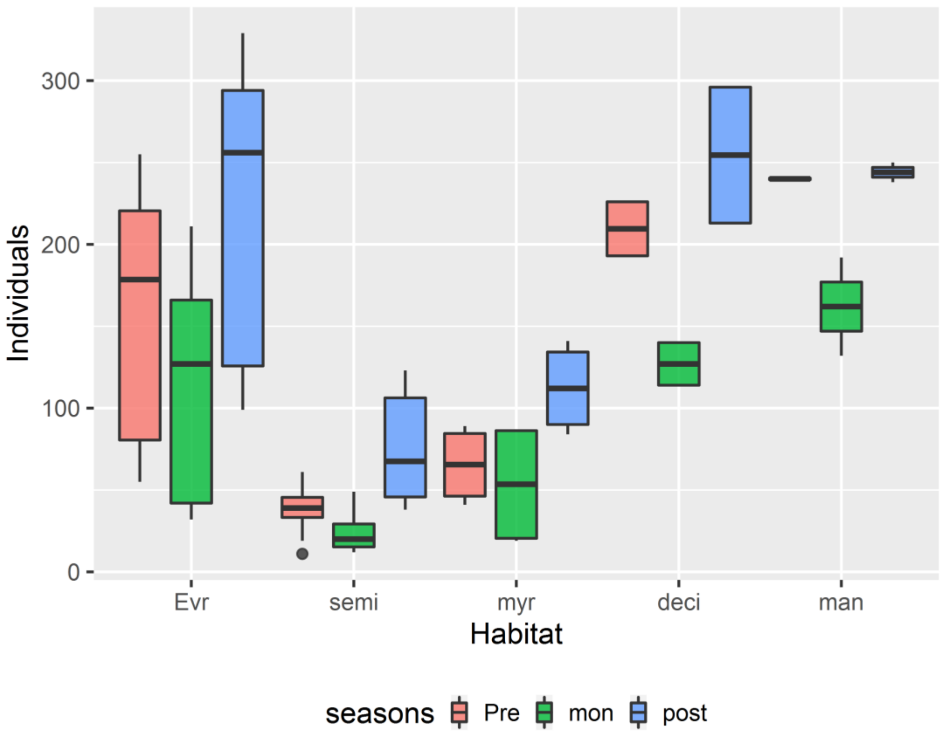


Figure 19. Box plots showing average species abundance per season in different habitats.

4.2.9. Average species abundance of spiders in different habitats per seasons

The average species abundance of spiders in different habitats per seasons shown in Figure 19. In EVN habitat Pre-monsoon season was 153.6 ± 73.5 with a maximum of 255 and a minimum of 55. In Monsoon season, it was 108.9 ± 66.49, 211 and 32. Followed by Post-monsoon season with 223 ± 86.96, 329 and 99 respectively. In SEN habitat Pre-monsoon season was 38.12 ± 16.74 with a maximum of 61 and a minimum of11. In Monsoon season, it was 24.62 ± 13.76, 49 and 12. Followed by Post-monsoon season with 75.50 ± 35.77, 123 and 38 respectively. In MYA habitat Pre-monsoon season was 65.25 ± 24.25 with a maximum of 89 and a minimum of 41. In the Monsoon season, it was 53.25 ± 38.4, 87 and 19. Followed by Post-monsoon season with 112.2 ± 28.43, 141 and 84 respectively. In MDS habitat Pre-monsoon season was 209.5 ± 23.33 with a maximum of 226 and a minimum of 193. In the monsoon season, it was 127 ± 18.38, 140 and 114. Followed by Post-monsoon season with 254.5 ± 58.69, 296 and 213 respectively. In MGE habitat Pre-monsoon season was 240 ± 1.41 with a maximum of 241 and a minimum of 239. In the monsoon season, it was 162 ± 42.43, 192 and 132. Followed by Post-monsoon season with 244 ± 8.49, 250 and 238 respectively. Average species abundance was higher in Post-monsoon season of MDS habitat with a value of 254.5 individuals. But lower in Monsoon season of SEN with 38.12 individuals.

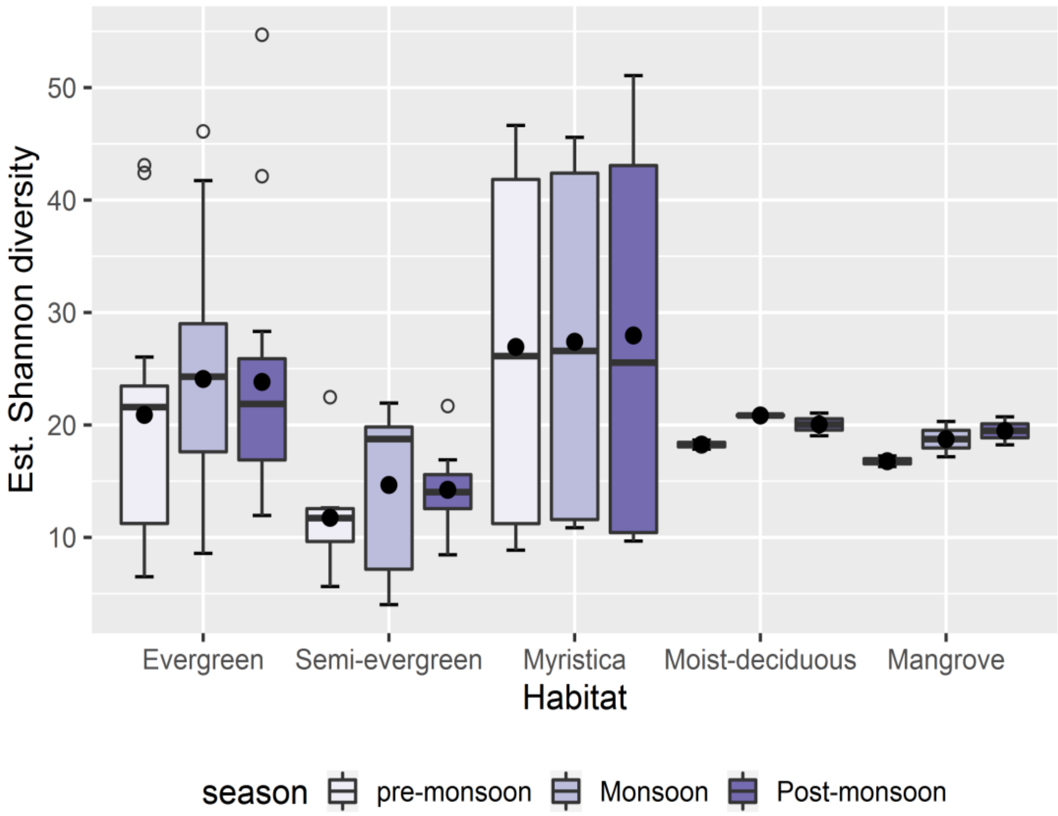


Figure 20. Box plots showing estimated Shannon diversity per season indifferent habitats.

4.2.10. Average estimated Shannon diversity of spiders in different habitats per seasons.

The average estimated Shannon diversity of spiders in different habitats per seasons shown in the Fig. 20. In EVN habitat Pre- monsoon season was 20.85 ± 1.86 with a maximum of 43.098 and a minimum of 6.502. In Monsoon season, it was 24.088 ± 2.52, 46.105 and 8.578. Followed by Post-monsoon season with 23.83 ± 1.73, 54.70 and 11.95 respectively. In SEN habitat Pre-monsoon season was 11.745 ± 2.63 with a maximum of 22.469 and a minimum of 5.635. In Monsoon season, it was 14.663 ± 4.58, 21.944 and 4.020. Followed by Post-monsoon season with 14.233 ± 2.08, 21.684 and 8.453 respectively. In MYA habitat Pre-monsoon season was 26.937 ± 3.46 with a maximum of 46.638 and a minimum of 8.865. In the Monsoon season, it was 27.40 ± 4.01, 45.58 and 10.86. Followed by Post-monsoon season with 27.957 ± 2.61, 51.070 and 9.675 respectively. In MDS habitat Pre-monsoon season was 18.25 ±1.97 with a maximum of 18.66 and a minimum of 17.85. In Monsoon season, it was 20.84 ± 2.72, 20.95 and 20.74. Followed by Post-monsoon season with 20.05 ± 1.46, 21.05 and 19.04 respectively. In MGE habitat Pre-monsoon season was 16.77± 1.38 with a maximum of 17.24 and a minimum of 16.30. In Monsoon season, it was 18.74 ± 1.38, 20.31 and 17.17. Followed by Post-monsoon season with 19.48 ± 1.21, 20.72 and 18.23 respectively. Average estimated Shannon index was higher in Post-monsoon season of MYA habitat with 27.957 ± 2.61. But lower in Pre-monsoon season of SEN with a value of 11.745 ± 2.63.

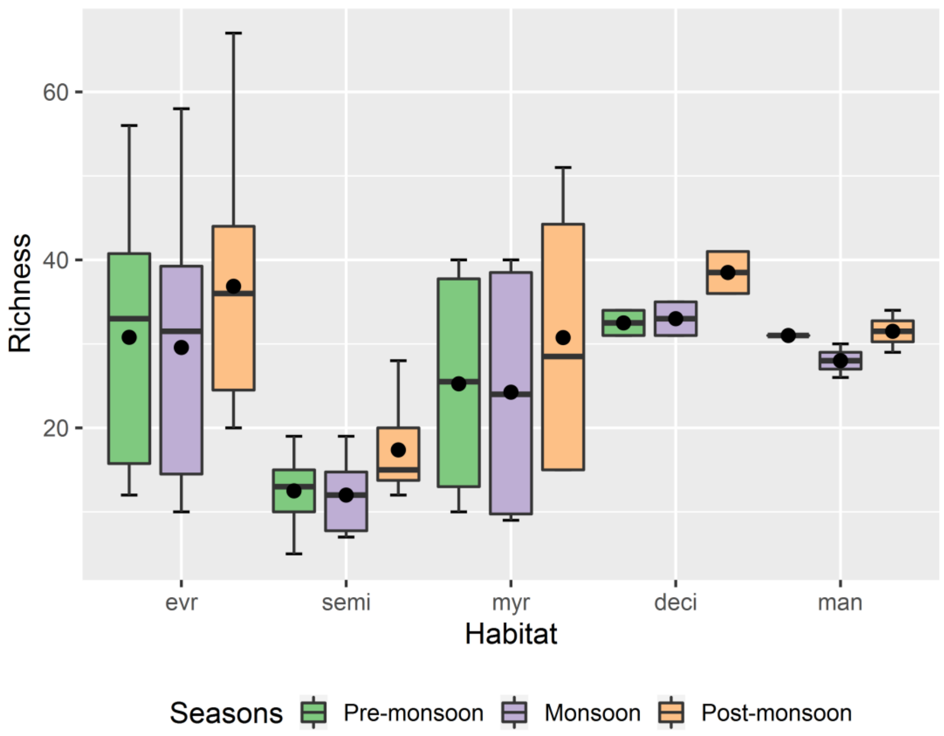


Figure 21. Box plots showing average species richness per season indifferent habitats.

4.2.11. Average species richness of spiders in different habitats per season.

The average species richness of spiders in different habitats per season shown in the Fig. 21. In EVN habitat Pre-monsoon season was 30.79 ± 14.69 with a maximum of 56 and a minimum of 12. In Monsoon season, it was 29.57 ± 15.48, 58 and 10 respectively. Followed by Post-monsoon season with a value of 36.86 ± 14.28, 67 and 20 respectively. In SEN habitat Pre - monsoon season was 12.5 ± 4.21 with a maximum of 19 and a minimum of 5. In the Monsoon season, it was 12 ± 4.66, 19 and 23. Followed by Post-monsoon season with 17.38 ± 5.58, 28 and 12 respectively. In MYA habitat Pre-monsoon season was 25.25 ± 15.44 with a maximum of 40 and a minimum of 10. In Monsoon season, it was 24.25 ± 17.06, 40 and 9 respectively. Followed by Post-monsoon season with 30.75 ± 18.55, 51 and 15 respectively. In MDS habitat Pre-monsoon season was 32.50 ± 2.12 with a maximum of 34 and a minimum of 31. In Monsoon season, it was 33 ± 2.83, 35 and 31. Followed by Post-monsoon season with a value of 38.50 ± 3.54, 41 and 36 respectively. In MGE habitat Pre-monsoon season was 31 ± 0 with a maximum of 31 and a minimum of 31. In the Monsoon season, it was 28 ± 2.83, 30 and 26. Followed by Post-monsoon season with a value of 31.50 ± 3.54, 34 and 29 respectively. Average species richness was higher in Post-monsoon season of MDS habitat with 38.50. But lower in monsoon season of SEN with 12.

4.2.12. Richness comparison between habitats

It is inevitable that differences in sample size will exist between both the historic and present surveys and between the yearly surveys, even if the sampling protocol is followed exactly. Except under certain conditions it is meaningless to compare the diversity or measure the turnover of different-sized collections. Therefore, scaled all samples to the size of the smallest sample, a procedure called rarefaction. Rarefaction is a method used to calculate *E* (S*n*), the expected number of species in a sample of *n* individuals selected at random from a collection containing *N* individuals of *S* species (Heck et al., 1975). From the list of individuals in all but the smallest of the samples, a number equal to the number of individuals in the smallest sample was randomly selected. This generates a new species list and associated abundance distribution.

The rarefaction curves showed clear differences in rarefied species richness within habitats. In the EVN habitat (Fig.22), the rarefied species richness was the highest in PK (21.56 ± 0.80, Mean ± SD) and the lowest in KS (10.57 ±1.53 species) at a sample size of 32 individuals. It varied slightly between the seasons with monsoon (16.21 ± 3.60) > Post-monsoon (15.89 ± 3.36) > Pre-monsoon (14.8 ± 3.99). In the SEN habitat (Fig. 23), the rarefied species richness was the highest in

MP (8.01± 0.66, Mean ± SD) and the lowest in PS (5.90 ± 0.62 species) at a sample size of 11 individuals. It varied slightly between the seasons with monsoon (7.65 ±1.23) > Post-monsoon (7.14 ± 0.73) > Pre-monsoon (6.45 ± 1.14). In the MYA habitat (Fig. 24), the rarefied species richness was the highest in PO (14.93 ± 0.35, Mean ± SD) and the lowest in KK (8.71 ± 0.65 species) at a sample size of 19 individuals. It varied slightly between the seasons with Monsoon (12.09 ± 3.23) > Post-monsoon (11.69 ± 3.84) > Pre-monsoon (11.67 ± 3.77). In the MDS habitat MK (Fig. 25), the rarefied species richness was (7.64 ± 0.012, Mean ± SD) at a sample size of 114 individuals. It varied slightly between the seasons with Post-monsoon (7.71 ± 0.04) > Monsoon (7.67 ± 0.09) > Pre-monsoon (7.52 ± 0.14). In the MGE habitat TK (Fig. 26), the rarefied species richness was (26.81 ±1.53, Mean ± SD) at a sample size of 132 individuals. It varied slightly between the seasons with Monsoon (27.15 ± 1.74) > Post-monsoon (26.88 ± 2.67) > Pre-monsoon (26.39 ± 0.01).

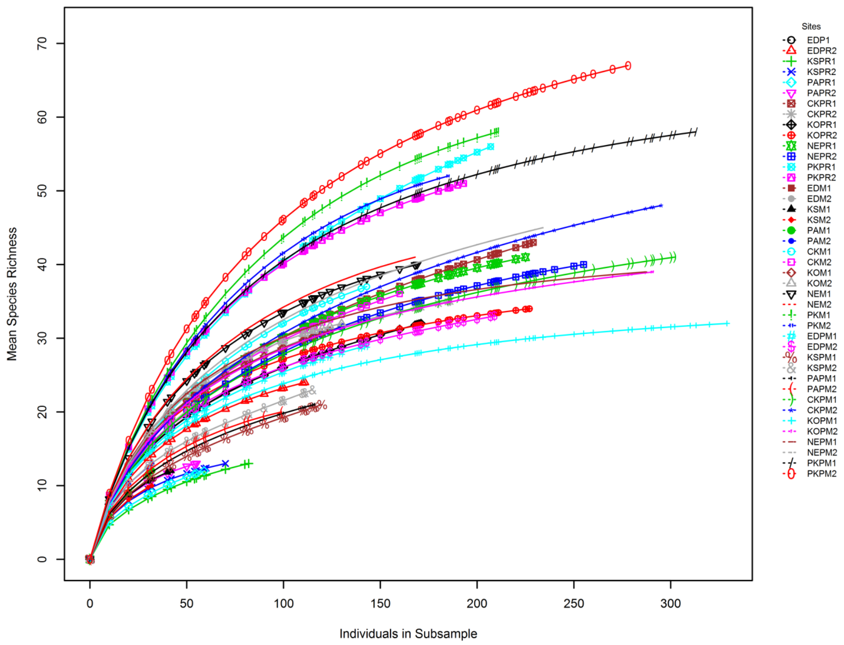


Figure 22. Standardized comparison of mean species richness for individual based rarefaction curves of sacred groves with evergreen habitat.

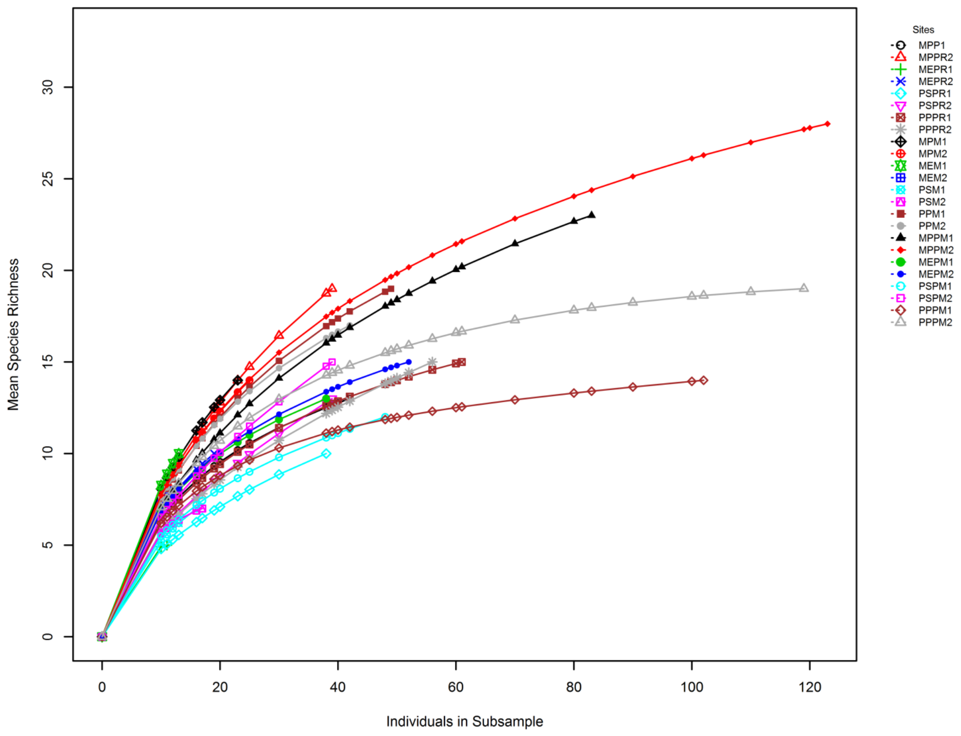


Figure 23. Standardized comparison of mean species richness for individual based rarefaction curves of sacred groves with Semi-evergreen habitat.

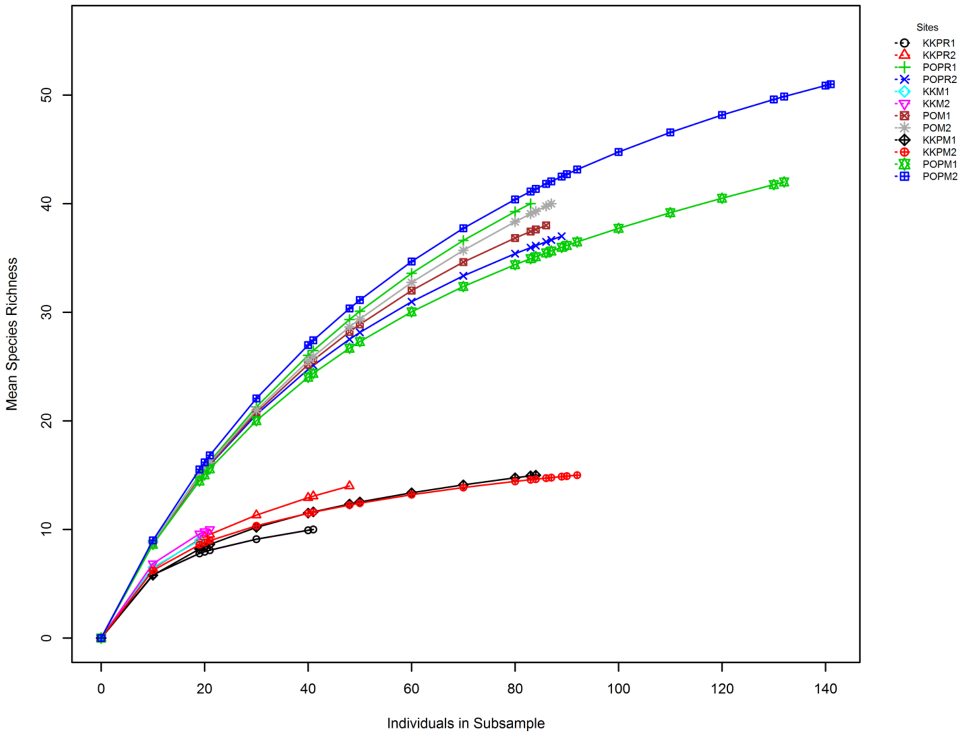


Figure 24. Standardized comparison of mean species richness for individual based rarefaction curves of sacred groves with Myristica habitat.

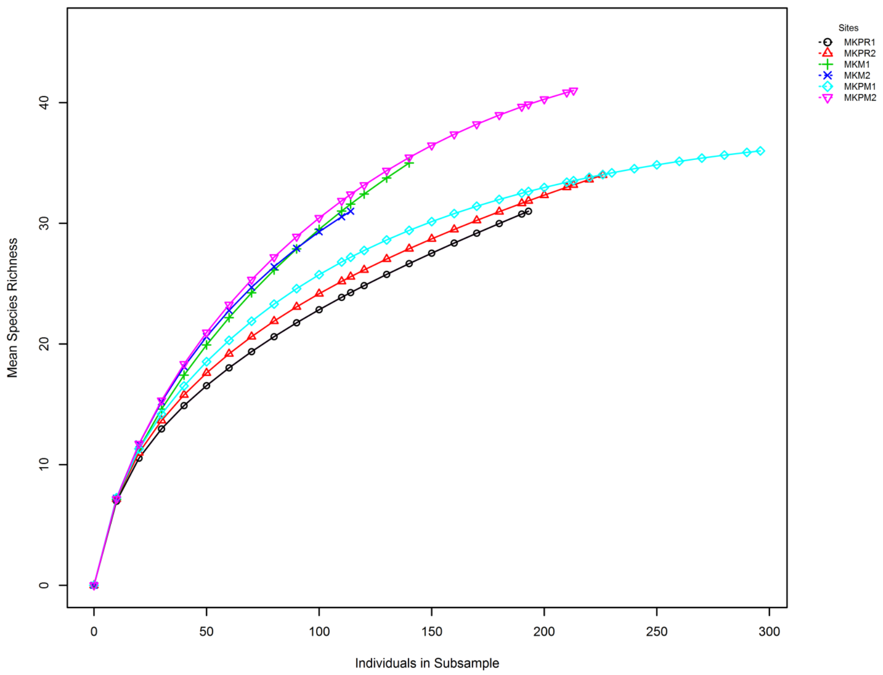


Figure 25. Standardized comparison of mean species richness for individual based rarefaction curves of sacred groves with Moist deciduous habitat.

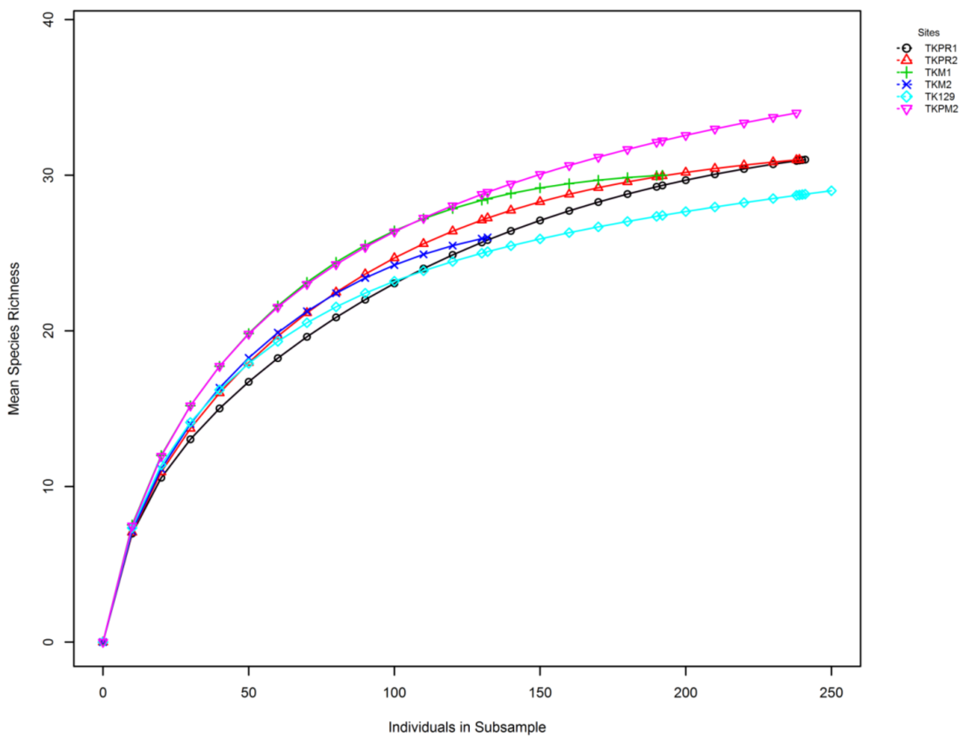


Figure 26. Standardized comparison of mean species richness for individual based rarefaction curves of sacred groves with Mangrove habitat.

4.2.13 Richness comparison between seasons

The rarefaction curves showed clear differences in species richness within Seasons. Even after standardizing sampling effort to a total of 3615 individuals in Pre-monsoon season, 2677 individuals in Monsoon season and 5181 individuals in Post-monsoon season.

Comparing the mean species richness In Pre-monsoon, with a standard value of 11 individuals per site, the rarefied species richness was higher in PO (9.52 ± 0.06, Mean ± SD, Fig. 27) and lower value in KS (5.4 ± 0.68 species). Total mean rarefied richness was 7.24 ± 1.30. For Monsoon, with a standard value of 12 individuals per site, it was higher in PO with 10.23 ± 0.04 species and lower in PS with 6.03 ±0.19 species (Fig. 28). Total mean rarefied richness was 8.4 ± 1.21. Finally in Post-monsoon season with a standard value of 38 individuals per site, found higher rarefied richness in PK (24.88 ± 1.66 species) and lower in KK (11.27 ± 0.007 species, Fig. 29). Total mean rarefied richness was 16.49 ± 4.11.

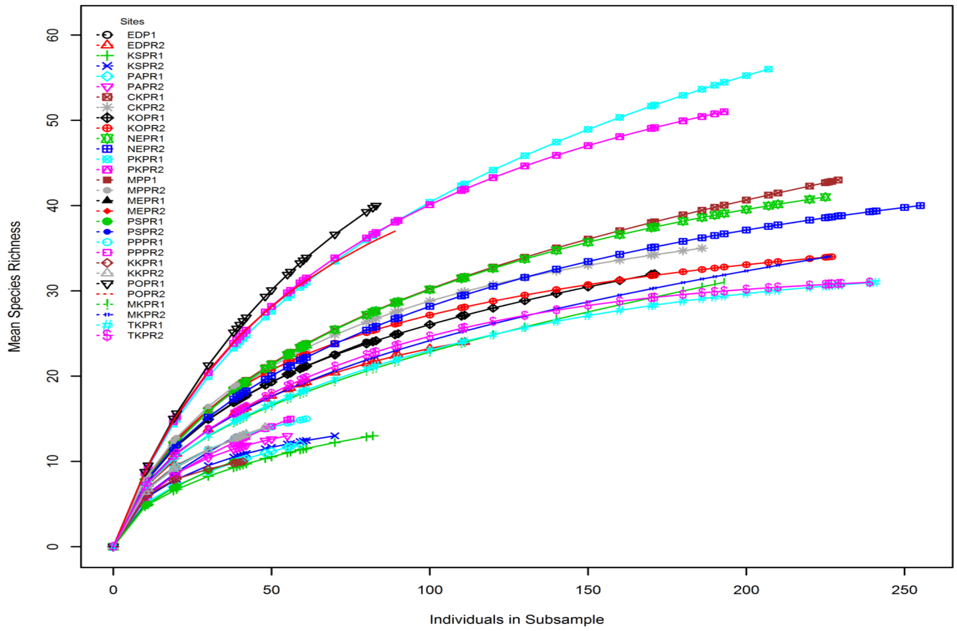


Figure 27. Standardized comparison of mean species richness for individual based rarefaction curves of Pre-monsoon season.

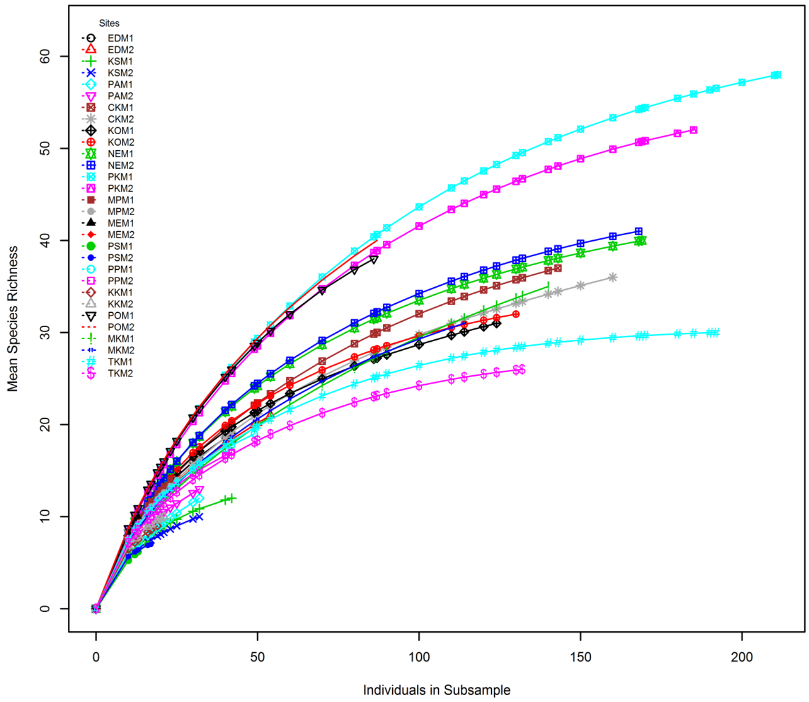


Figure 28. Standardized comparison of mean species richness for individual based rarefaction curves of Monsoon season.

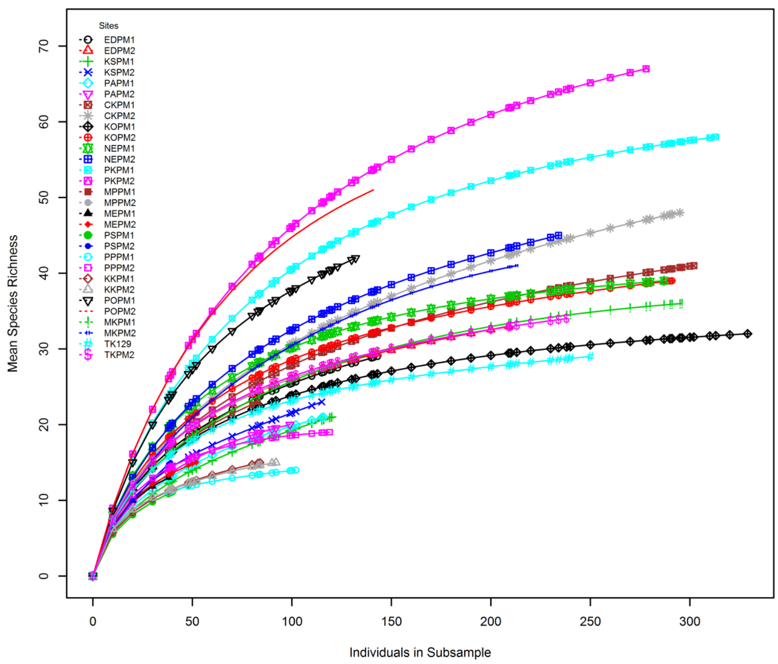


Figure 29. Standardized comparison of mean species richness for individual based rarefaction curves of Post-monsoon season.

4.2.14. Rank abundance distributions of spiders in different habitats

Species rank abundance distributions for habitats were best explained by Zipf-Mandelbrot models, as indicated by AIC (Table. 12, 13, 14, 15,16 & Fig.30-34). The main difference of the three model parameters between habitats were observed for parameter 1, which represents the fitted abundance of the most abundant species (Martinelli et al., 2006 and Wilson, 1991). This parameter had a higher value for MGE habitat (23.218). The other two model parameters (2 and 3 in Table. 12-16) can be interpreted as parameters β and γ in the original model (Wilson, 1991). β represents the potential niche diversity of the environment, and a positive β results in greater evenness among the most abundant species (Frontier, 1985; Wilson, 1991). The parameter γ represent the average probability of the appearance of a species, with values close to1 indicating greater evenness (Wilson, 1991). Differences in these parameters between the habitats indicate that the SEN habitat has greater evenness because γ (parameter 3) is lower (5.414, Table.13), and β (parameter 2) is less negative than for the EVN habitat (−1.8, Table 12).

Table 12. Model fit results from the 'radfit' function for the Evergreen habitat. The parameters for the five different fitted models are shown. Decreasing AIC values provide support to the Zipf-Mandelbrot model.

Model	Parameter 1	Parameter 2	Parameter 3	AIC
Null				5633.20
Preemption	0.049914			2922.93
Lognormal	2.2483	1.7285		1148.95
Zipf	0.19909	-1.059		1804.58
Zipf-Mandelbrot	3.8183	-1.7991	5.9502	836.60

Table 13. Model fit results from the 'radfit' function for the Semi-Evergreen habitat. The parameters for the five different fitted models are shown. Decreasing AIC values provide support to the Zipf-Mandelbrot model.

Model	Parameter 1	Parameter 2	Parameter 3	AIC
Null				583.981
Preemption	0.083945			422.628
Lognormal	1.7886	1.4347		290.620
Zipf	0.21515	-1.0212		369.862
Zipf-Mandelbrot	4.848	-1.8908	5.4147	288.747

Table 14. Model fit results from the 'radfit' function for the Myristica habitat. The parameters for the five different fitted models are shown. Decreasing AIC values provide support to the Zipf-Mandelbrot model.

Model	Parameter 1	Parameter 2	Parameter 3	AIC
Null				404.940
Preemption	0.055238			382.445
Lognormal	1.7208	1.1857		329.090
Zipf	0.14702	-0.8544		406.673
Zipf-Mandelbrot	7.9214	-1.8618	10.299	327.876

Table 15. Model fit results from the 'radfit' function for the Moist-Deciduous habitat. The parameters for the five different fitted models are shown. Decreasing AIC values provide support to the Zipf-Mandelbrot model.

Model	Parameter 1	Parameter 2	Parameter 3	AIC
Null				763.673
Preemption	0.011819			424.898
Lognormal	1.8829	1.5747		316.898
Zipf	0.26809	-1.1311		398.608
Zipf-Mandelbrot	13.996	-2.2954	5.5292	258.366

Table 16. Model fit results from the 'radfit' function for the Mangrove habitat. The parameters for the five different fitted models are shown. Decreasing AIC values provide support to the Zipf-Mandelbrot model.

Model	Parameter 1	Parameter 2	Parameter 3	AIC
Null				394.927
Preemption	0.12763			299.036
Lognormal	2.8744	1.2322		276.131
Zipf	0.23852	-0.99721		344.471
Zipf-Mandelbrot	23.218	-2.3709	6.8521	218.137

In the rank abundance plot of EVN habitat (Fig. 30), following species were comes within 10 ranks. They are *Oxytate virens* (750), *Hyllus semicupreus* (614), *Indopadilla insularis* (580), *Uloborus krishnae* (389), *Epeus triangulopalpis* (377), *Boliscus tuberculatus* (346), *Pholcus phalangioides* (279), *Araneus* sp. (267), *Tmarus histrix* (168) and *Epeus tener* (159).

In the rank abundance plot of SEN habitat (Fig. 30), following species were comes within 10 ranks. They are *Hyllus semicupreus* (183) *Phintella vittata* (105), *Stenaelurillus lesserti* (82), *Heteropoda venatoria* (70), *Indopadilla insularis* (63), *Pholcus phalangioides* (55), *Hamataliwa* sp. (53), *Uloborus krishnae* (46), *Oxytate virens* (32) and *Neoscona molemensis* (31).

In the rank abundance plot of MYA habitat (Fig. 32), following species were comes within 10 ranks. They are *Uloborus krishnae* (87), *Phintella vittata* (65), *Oxytate virens* (61), *Stenaelurillus lesserti* (60), *Indopadilla insularis* (47), *Pholcus phalangioides* (36), *Tylorida striata* (35), *Tylorida ventralis* (24), *Epeus triangulopalpis* (23) and *Tetragnatha mandibulata* (21).

In the rank abundance plot of MDS habitat (Fig. 33), following species were comes within 10 ranks. They are *Oxytate virens* (210), *Uloborus krishnae* (146), *Boliscus tuberculatus* (145), *Hyllus semicupreus* (124), *Stenaelurillus lesserti* (73), *Phintella vittata* (71), *Strigoplus netravati* (40) *Zosis geniculata* (35), *Epeus tener* (25) and *Nephila pilipes* (23).

In the rank abundance plot of MGE habitat (Fig. 34), following species were comes within 10 ranks. They are *Epeus triangulopalpis* (194), *Oxytate virens* (185), *Rhene flavigera* (151), *Tylorida ventralis* (131), *Hyllus semicupreus* (96), *Phintella vittata* (80), *Oxyopes birmanicus* (51), *Telamonia dimidiata* (31), *Indoxysticus minutus* (28), *Cyclosa hexatuberculata* (27) and *Hamataliwa* sp. I (27).

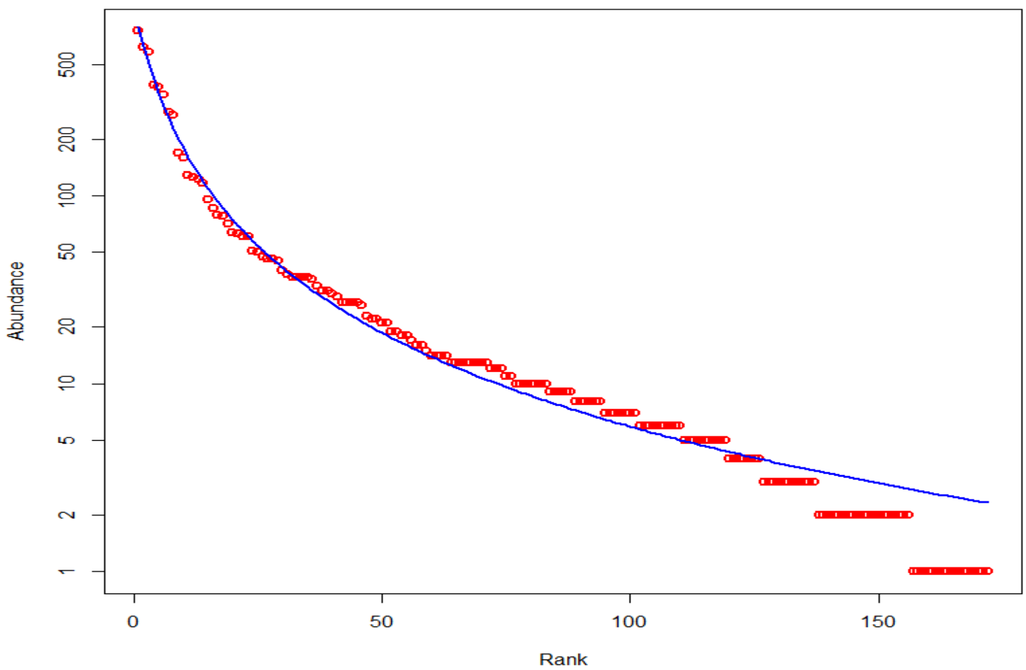


Figure 30. Rank abundance distribution for spider assemblages in Evergreen habitat. Total abundance and rank abundance distribution is plotted over in small red circles and blue lines indicated best fit abundance distribution model (Zipf-Mandelbrot).

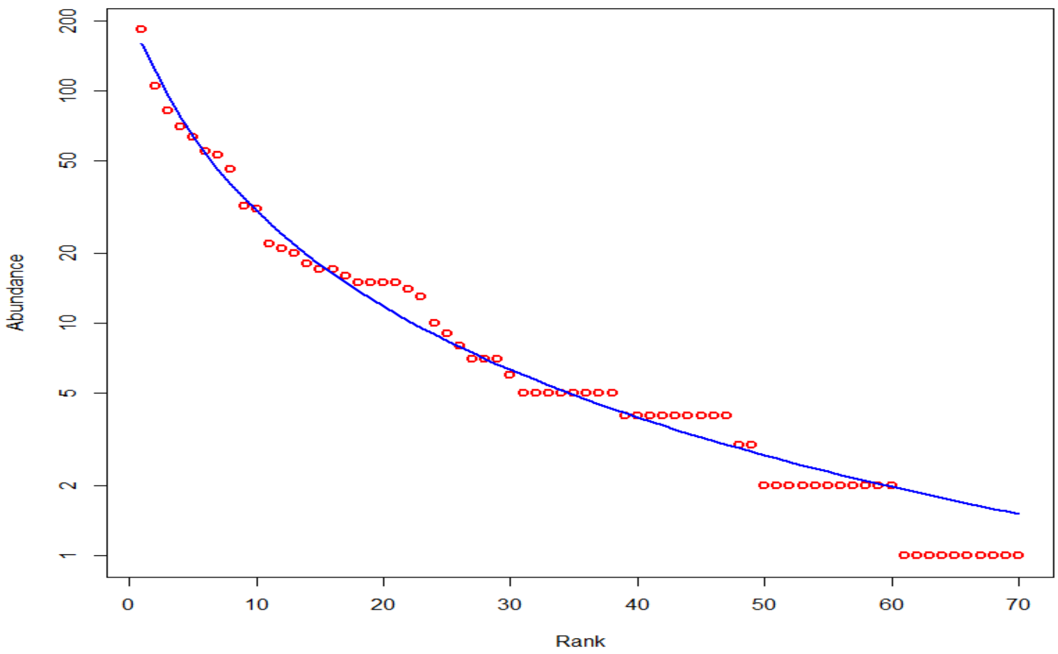


Figure 31. Rank abundance distribution for spider assemblages in Semi-evergreen habitat. Total abundance and rank abundance distribution is plotted over in small red circles and blue lines indicated best fit abundance distribution model (Zipf-Mandelbrot).

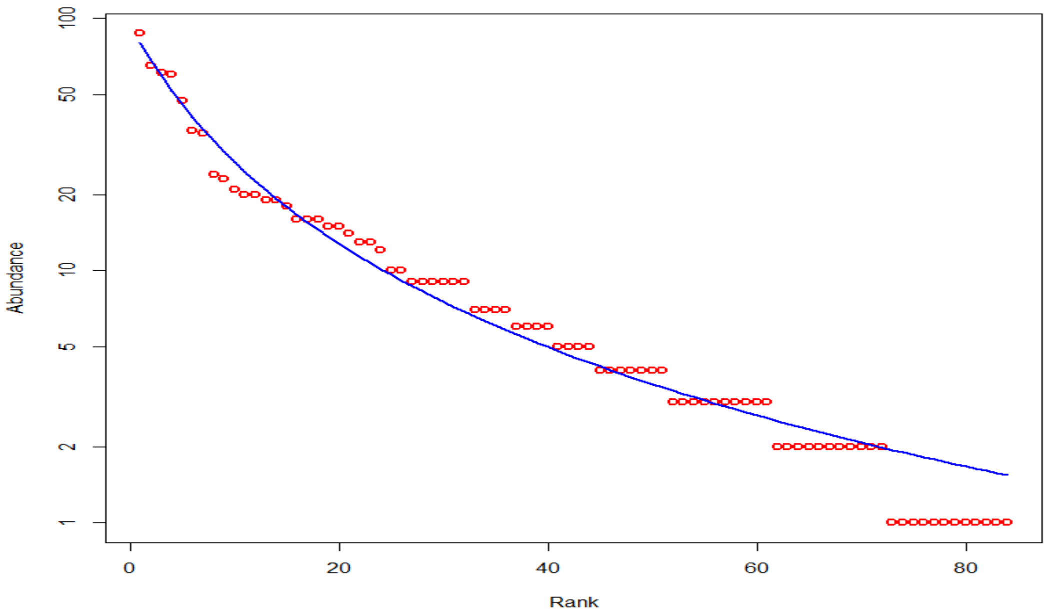
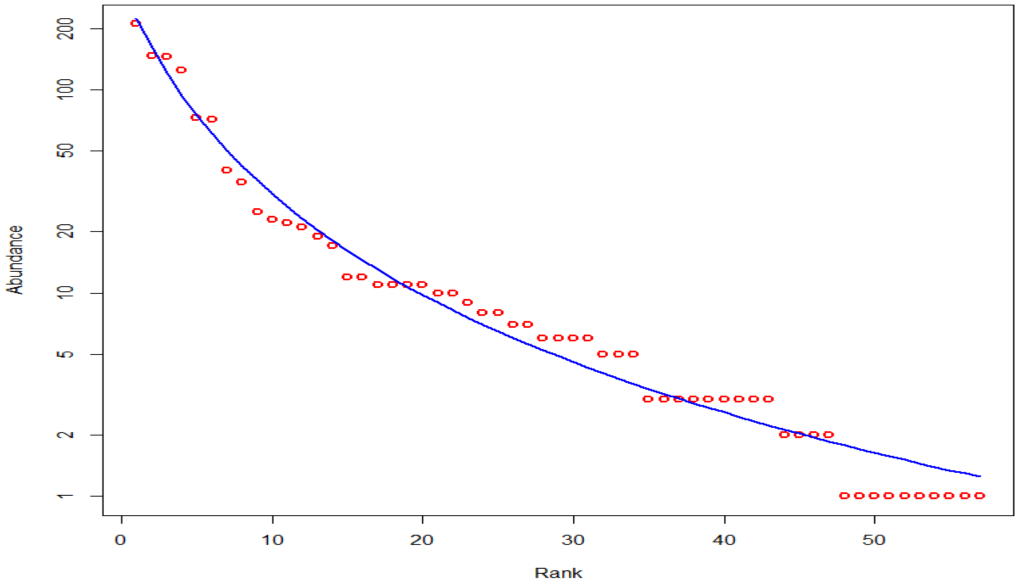


Figure 32. Rank abundance distribution for spider assemblages in Myristica habitat. Total abundance and rank abundance distribution is plotted over in small red circles and blue lines indicated best fit abundance distribution model (Zipf-Mandelbrot).



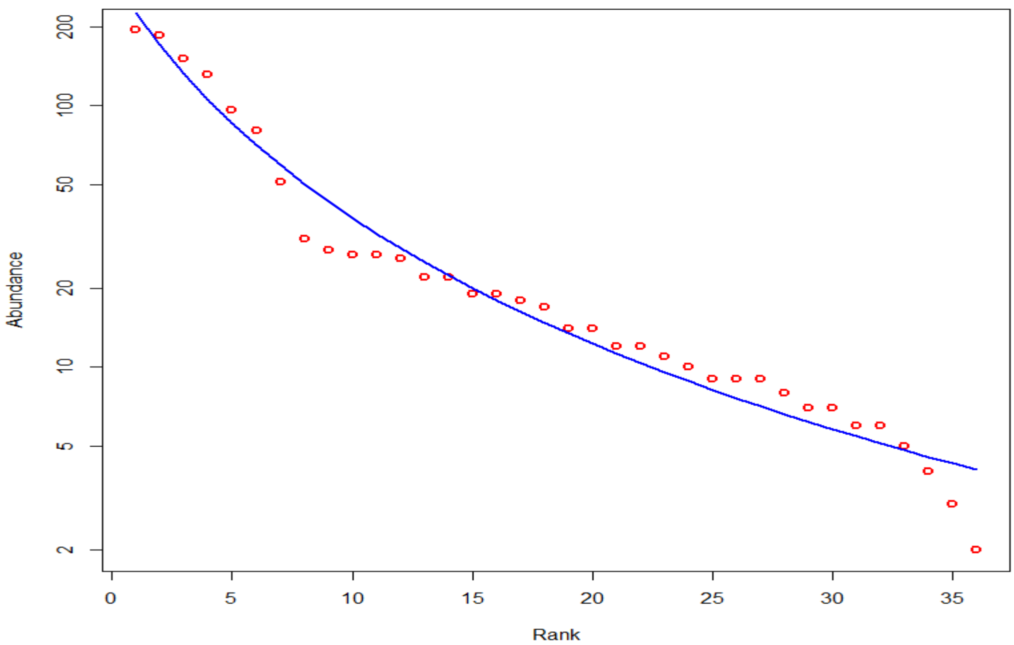


Figure 34. Rank abundance distribution for spider assemblages in Mangrove habitat. Total abundance and rank abundance distribution is plotted over in small red circles and blue lines indicated best fit abundance distribution model (Zipf-Mandelbrot).

4.3. REGIONAL DIVERSITY

This study assesses diversity in the study areas located in two districts (Kasargod and Kannur) of Northern Kerala. Analyzing different facets of local diversity (abundance, species richness, diversity), and the contribution of species differentiation (beta diversity) among localities and habitat types to the composition of regional diversity. This study found 11308 individuals of 257 spider species/ morphospecies. Local diversity differs among two sampled localities. At the habitat level, the different facets of biodiversity followed a clear pattern, where sacred grove spiders of Kannur have higher abundance, species richness and diversity than Kasargod.

4.3.1. Abundance and Diversity

Abundance and variation of species diversity (Shannon index) follow the same trend. A total of 2904 individuals with 109 species collected from Kasargod district and 8404 individuals with 220 species collected from Kannur district. Singletons and doubletons were higher in Kannur district (19,23) and other variables are represented in table 17. For testing hypothesis, we took 4 evergreen habitats from both districts to compare diversity test, whether there is any significant difference in the abundance and estimated Shannon diversity among samples from two districts. Wilcoxon rank sum test was used to test the hypothesis. Sacred groves of Kannur district have significantly higher values of abundance (Fig. 35) and diversity (Fig. 36). Result of the test was $p < 0.01$, for abundance ($w=13.5$, $p=1.594e\text{-}08$) and diversity ($w=25$, $p=6.21e\text{-}08$), so these regions show a significant variation (Fig. 35 & 36).

Table 17. Diversity parameters of the two regions.

VARIABLES	KASARGOD	KANNUR
Total individuals	2904.00	8404.00
Species richness	109.00	220.00
Estimated richness±se	122.60±8.17	227.38±4.36
Mean richness±sd	15.44±6.02	39.64±9.04
Mean abundance±sd	60.50±41.34	200.10±67.89
Average observed Shannon±sd	10.31±3.60	24.05±8.01
Average Simpson Diversity	7.85	16.64
Observed Simpson sd	2.77	6.54
Singleton	17.00	19.00
Doubleton	13.00	23.00

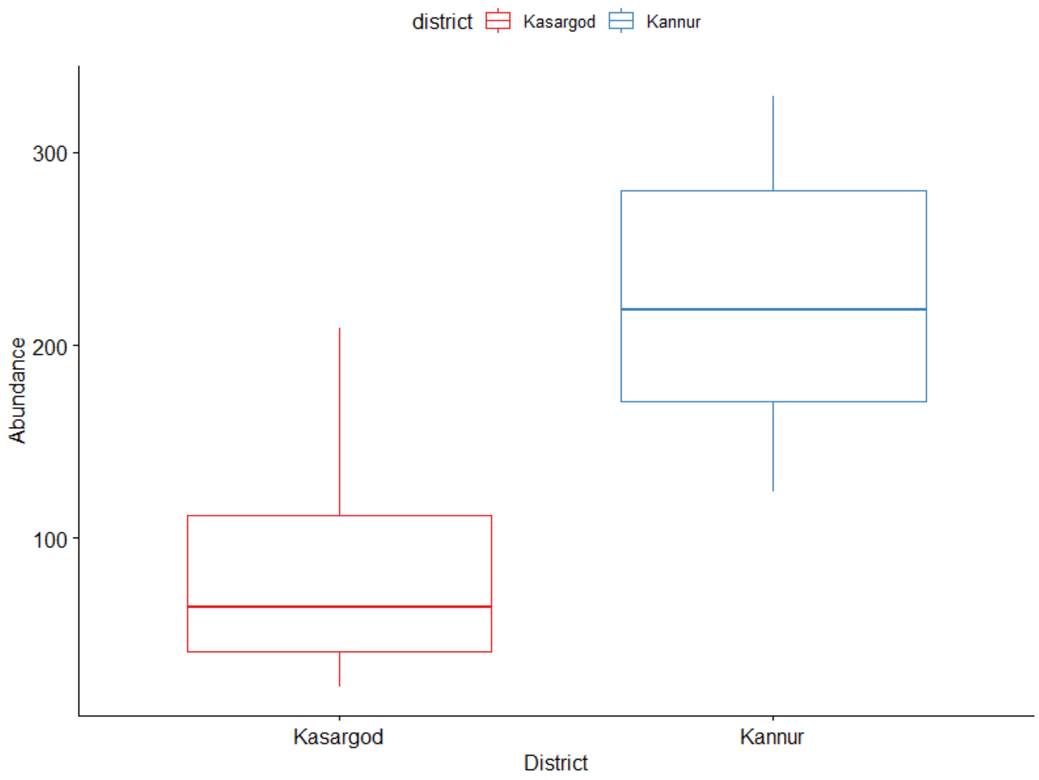


Figure 35. Box plots showing the abundance of spider assemblages in Kannur and Kasargod districts.

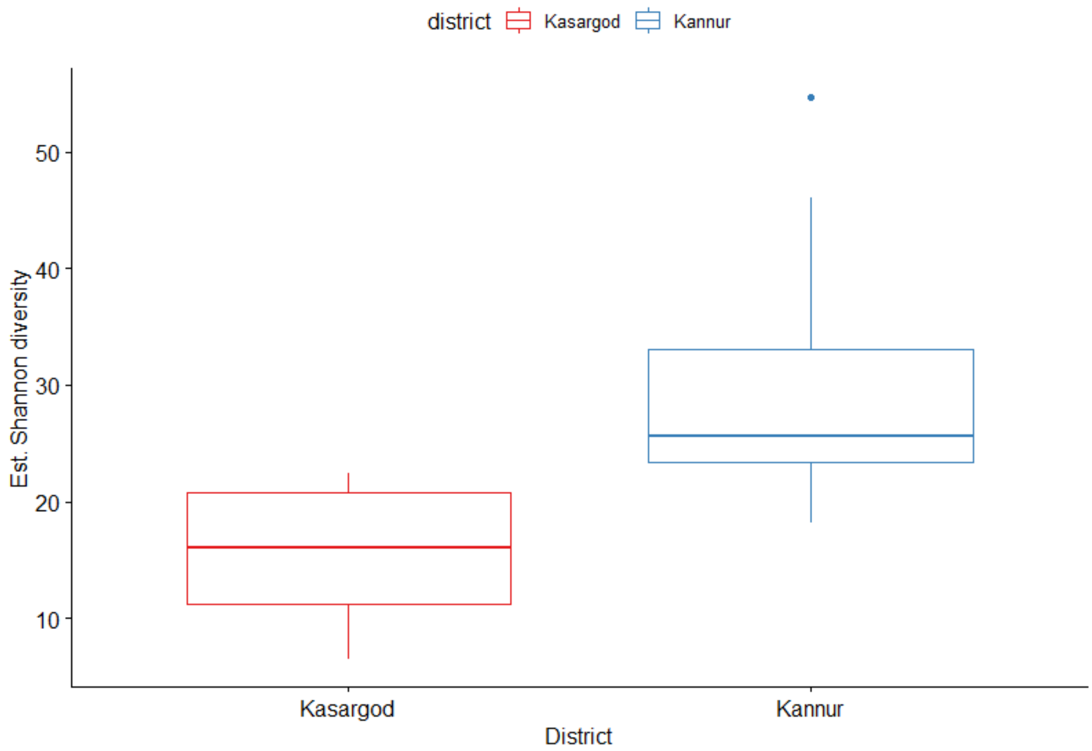


Figure 36. Box plots showing the estimated Shannon diversity of spider assemblages in Kannur and Kasargod districts.

4.3.2. Beta diversity

The overall similarity in Kannur district was 80.01%, with a 95% confidence interval of 79.25% and 80.77%. Overall similarity of Kasargod district was 79.12%, with a 95% confidence interval of 77.80% and 80.44% (Table 18 and 19). The similarity between two districts were 68.58%with a 95% confidence interval of 66.65% and 70.50%

Table 18. Overall similarity within group

Regions	Estimate	se	95%LCL	95%UCL
Horn size weighted (q=1) Kasargod	0.7912702	0.006722607	0.7780938	0.8044465
Horn size weighted (q=1) Kannur	0.8001879	0.003874392	0.7925941	0.8077817

Table 19 Similarity between groups

	Estimate	se	95%LCL	95%UCL
Horn size weighted(q=1)	0.6858151	0.009833422	0.6665416	0.7050886

4.3.3. Richness comparison between habitats and localities

For comparing the rarefied richness of Kasargod and Kannur districts, 8 sacred groves with evergreen habitats were selected for this study. The rarefaction curves showed clear differences in species richness between habitats in the two regions. Even after standardizing sampling effort to a total of 2904 individuals in Kasargod and 8404 in Kannur. Comparing the mean species richness in Kasargod district, with a standard value of 23 individuals per site, the rarefied species richness was higher in MP (13.58 ± 0.35, Mean ± SD, Fig. 37) and lower value in KS (8.67 ± 1.26 species). Total mean rarefied richness was 11.10 ± 1.95. For Kannur district, with a standard value of 124 individuals per site, it was higher in PK with 46.77 ± 3.68 species and lower in KO with 28.3 ± 2.70 species (Fig. 38). Total mean rarefied richness was 35.67 ± 6.85.

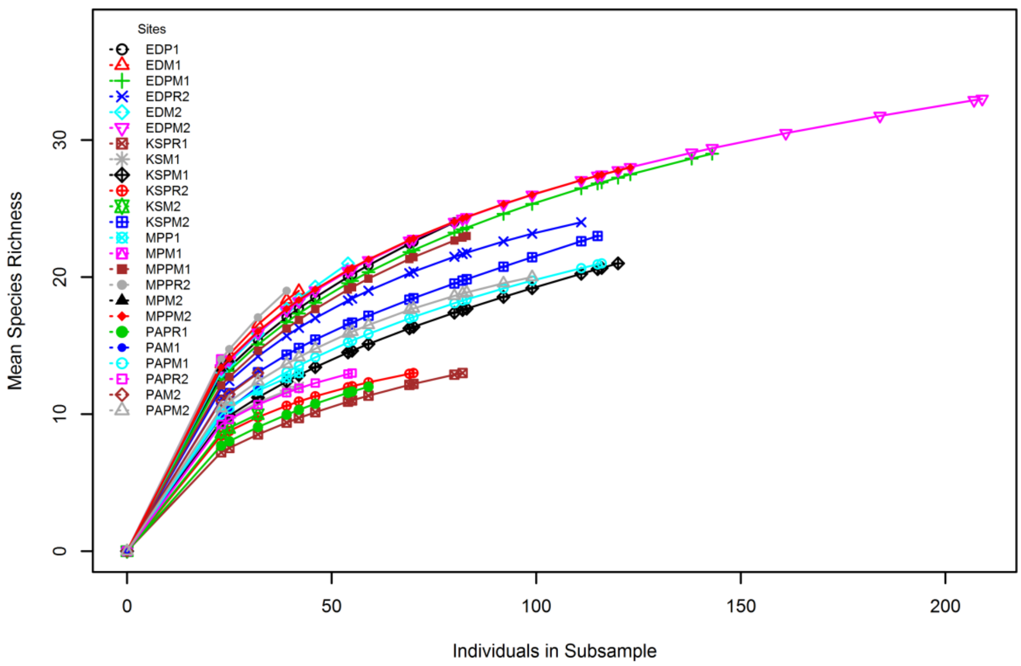


Figure 37. Rarefaction curves of scared groves for evergreen habitat in Kasargod district.

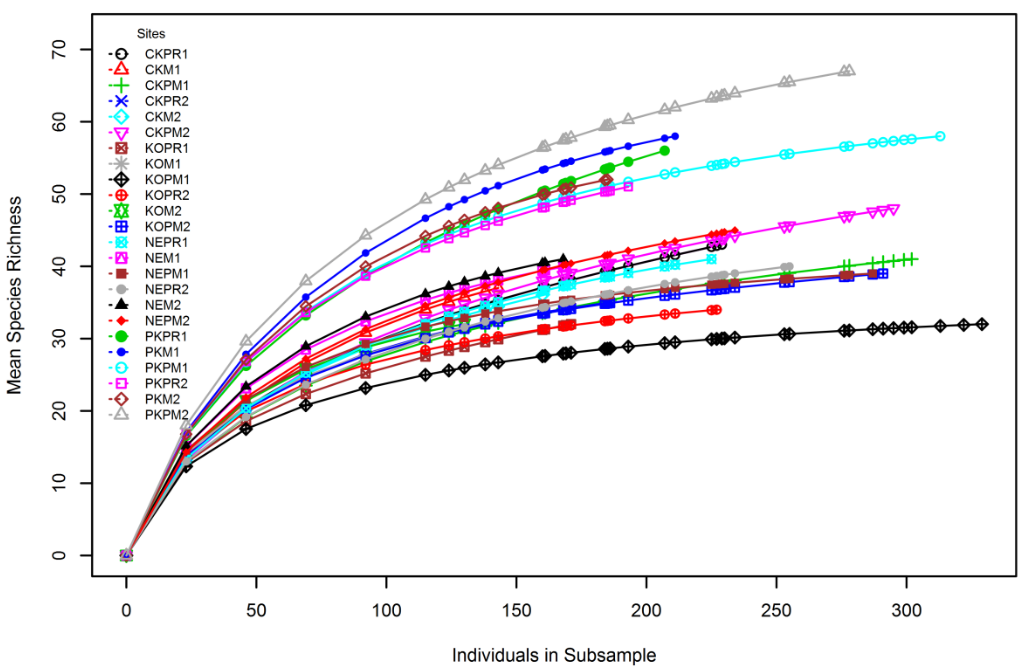


Figure 38. Rarefaction curves of scared groves for evergreen habitat in Kannur district.

4.4. GUILD STRUCTURE ANALYSIS OF SPIDERS BETWEEN HABITATS

Guilds are a group of species that exploit the same class of environmental resources in a similar way and are usually classify based on hunting strategies and predation habitats (Uetz, 1991). Spiders collected from the sacred groves with different habitats were sorted into the following eight guilds based on their foraging behaviour in the field (Cardoso et al., 2011): (1) Ambush hunters (spider family include: Thomisidae); (2) Ground hunters (Corinnidae, Gnaphosidae, Lycosidae and Oonopidae); (3) Orb webs (Araneidae, Tetragnathidae and Uloboridae); (4) Other hunters (Anyphaenidae, Cheiracanthidae, Clubionidae, Ctenidae, Linyphiidae, Miturgidae, Oxyopidae, Philodromidae, Salticidae, Scytodidae and Sparassidae); (5) Sensing web (Hersiliidae and Oecobidae); (6) Sheet web (Pisauridae); (7) Space web (Pholcidae and Theridiidae); and (8) Specialists (Mimetidae, Palpimanidae, Trachelidae and Zodariidae).

1. Ambush hunters

These spiders show a "sit-and-wait" type of behaviour for prey capture. Family Thomisidae included in this guild which contained 2570 individuals of 20 species coming under 13 genera.

2. Ground hunters

Spiders of this guild mainly feed on ground layer of the field and rarely come to the foliage or canopy of the plant for prey capture. Spiders of the family Corinnidae, Gnaphosidae, Lycosidae, and Oonopidae included in this guild. Family Corinnidae contained 133 individuals coming under 6 species of 2 genera. Gnaphosidae contained 3 species of 3 genera with a collection of 7 individuals. Family Lycosidae contained 12 species of 4 genera with a collection of 95 individuals. Majority of spiders of this category were lycosids comprising 3378 individuals of 9 species of 4 genera. Family Oonopidae constituted 3 individuals of 2 species belong to 2 genera.

3. Orb webs

Spiders of this guild construct perfect orb webs for prey capture. Spiders of the family Araneidae, Tetragnathidae and Uloboridae come under this category. Family Araneidae comprised 1138 individuals of 50 species coming under 19 genera. The long- jawed family Tetragnathidae constituted 531 individuals of 15 species coming under 5 genera. Family Uloboridae contained only 827 individuals of 6 species of 3 genera.

4. Sensing web

These spiders can catch prey by the use of sense threads found on their web. Family Hersiliidae and Oceobidae included in this guild. Tailed spider, Hersiliidae is composed of only 2 species coming under a single genus and 14 individuals collected. Family Oceobidae constituted only 3 individuals of single species coming under a single genus.

5. Sheet web

These spiders construct sheet like web for prey capture. Family Pisauridae is coming under this category. Family Pisauridae constituted only 30 individuals of 2 species of 1 genus.

6. Space web builders

These spiders construct irregular space webs for prey capture. Spiders of the family Pholcidae and Theridiidae belong to this category. Family Pholcidae contained 554 individuals of 7 species of 5 genera. Family Theridiidae constituted 349 individuals of 29 species of 17 genera.

7. Specialists

The specialists' guild is not even a true guild, but a cluster of species that, by specializing in one or very few prey, are not directly competing with any large group of species. These category shows specialist type of feeding behavior. Family Mimetidae, Palpimanidae, Trachelidae and Zodaridae come under this guild. Family Mimetidae contained 6 individuals with 2 species of 1 genus. Family Palpimanidae includes 10 individuals of 2 species coming under 2 genera. Trachelidae constituted 5 individuals of 2 species coming under a single genus. Family Zodaridae contained only 1 species of a single genus with a collection of 4 individuals.

Guild composition varied between the five habitat types. The most abundant guilds were the ambush hunters (2570 n), orb web (2496 n) and other hunters (5028 n), they together constitute more than half of the total species collected (total = 11308 n). The studied guild structure of sacred groves with different habitats as follows: 45% were other hunters, 23% were ambush hunters, 22% were orb webs, 2% were ground hunters. Sheet web, specialists and sensing web were less than 1% (Fig. 39). All guilds except sensing web, sheet web and specialists were present in all habitats. Sensing web and sheet web guilds were reported as the least guilds, and they make up less than one percentage of the total species collected. The most abundant guild in all habitats was other hunters, while the orb webs were the second abundant category.

8. Other hunters

Other hunters are considered as either foliage runners or stalkers. Families constituted in this guild are Anyphaenidae, Cheiracanthidae, Clubionidae, Ctenidae, Linyphiidae, Miturgidae, Oxyopidae, Philodromidae, Salticidae, Scytodidae and Sparassidae. Family Anyphaenidae constituted 1 individual of 1 species coming under a single genus. Clubionidae constituted 126 individuals of 11 species coming under 2 genera. Family Cheiracanthiidae constituted 56 individuals of 5 species coming under a single genus. Family Ctenidae contained a single species of one genus with a collection of 21 individuals. Family Linyphiidae contained a total of 135 individuals of 2 species coming under 2 genera. Family Miturgidae constituted 5 individuals of single species coming under a single genus. A total of 3943 individuals of 43 species coming under 35 genera were collected from the family Salticidae. Family Sparassidae was composed of 160 individuals of 7 species coming under 4 genera. Family Oxyopidae constituted 434 individuals of 17 species coming under 4 genera. Family Philodromidae contained 43 individuals of 5 species of 3 genera. Family Scytodidae contained only 2 species of a single genus with a collection of 105 individuals.

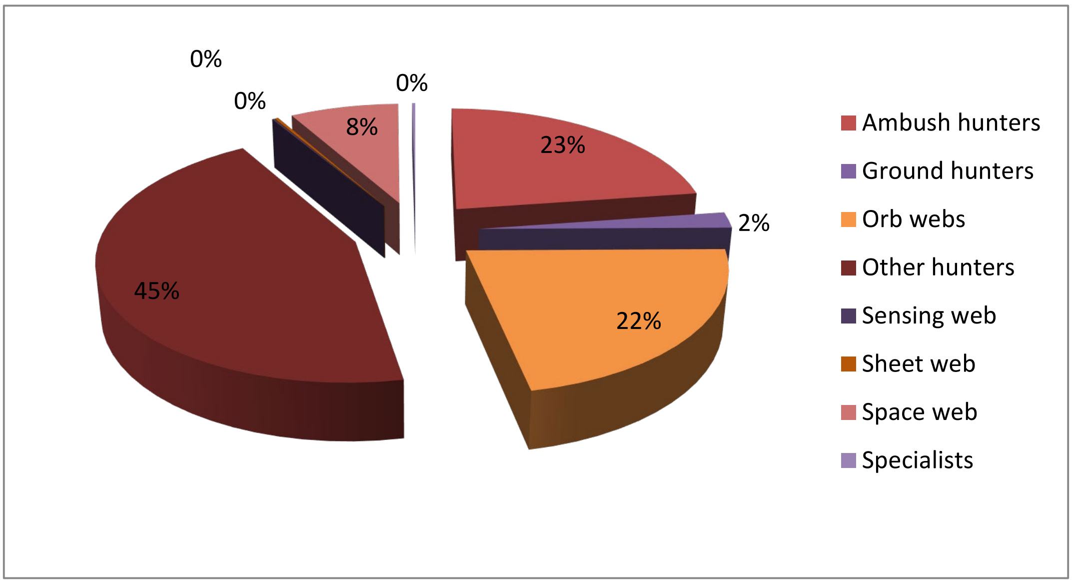
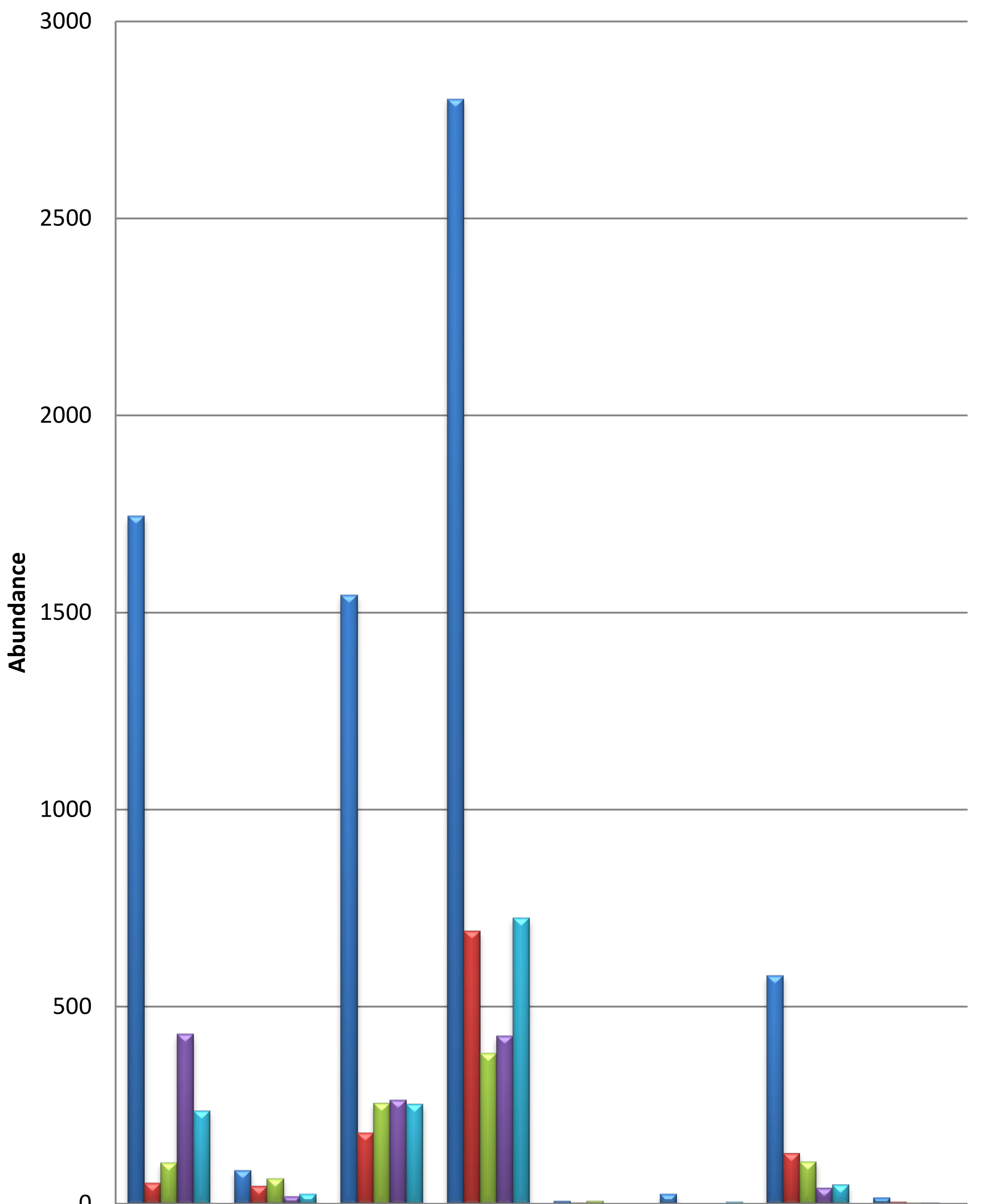


Figure 39. Total guild structure among five habitats studied.



	Ambush hunters	Ground hunters	Orb webs	Other hunters	Sensing web	Sheet web	Space web	Specialists
EVN	1745	85	1545	2803	7	25	580	15
SEN	53	45	180	692	3	0	128	5
MYA	105	64	255	382	7	0	107	3
MDS	431	19	263	426	0	0	40	3
MGE	236	25	253	725	0	5	48	0

Figure 40. Spider abundance among guilds across five habitat types.

The results of the spider abundance among guilds across five different habitats were shows that, ambush hunters, ground hunters, orb webs, other hunters and space web were found in all five habitats. The spider abundance come under sensing web, sheet web and specialists were seen some difference. Spider abundance in sensing web category were absent in MDS and MGE, abundance in sheet web category were absent in SEN, MYA and MGE and spider abundance in specialists category were found in all habitats except MGE (Fig. 40).

Spider abundance guild composition represented that in EVN (Fig. 41), there are 41% other hunters, 26% ambush hunters and 23% orb web the remaining percentage, space web, ground hunters, sheet web, specialists and sensing web. In SEN (Fig. 42), there are 63% other hunters, 16% orb web and 12% of space web, remaining percentage, ambush hunters, ground hunters, sheet web, specialists and sensing web. In MYA (Fig. 43), there are 41% other hunters, 28% orb web and 12% of space web, remaining percentage, ambush hunters, ground hunters, sheet web, specialists and sensing web. In MDS (Fig. 44), there are 37% ambush hunters, 36% other hunters, 22% orb web and 3% of space web, remaining percentage, ground hunters, sheet web, specialists and sensing web. In MGE (Fig. 45), there are 56% other hunters, 20% orb web and 18% ambush hunters, 4% of space web, remaining percentage, ground hunters, sheet web, specialists and sensing web.

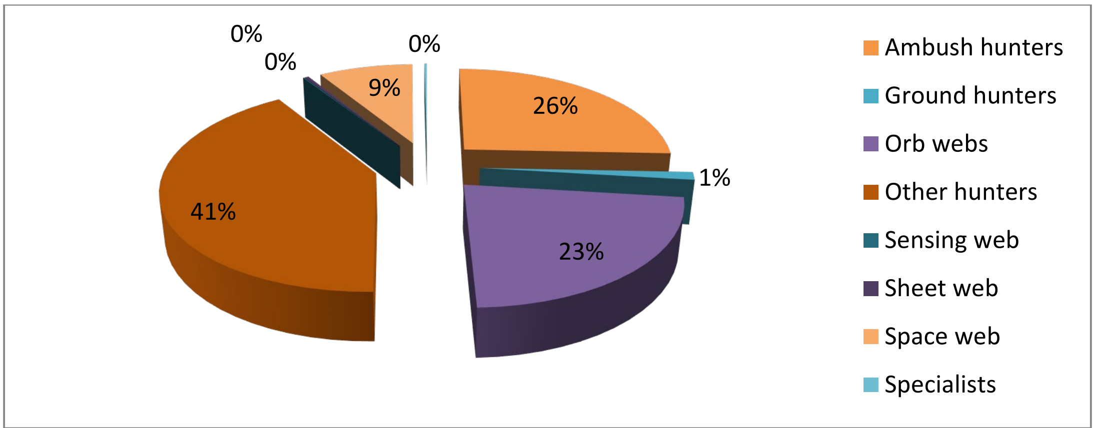


Figure 41. Spider abundance among guilds in EVN habitat.

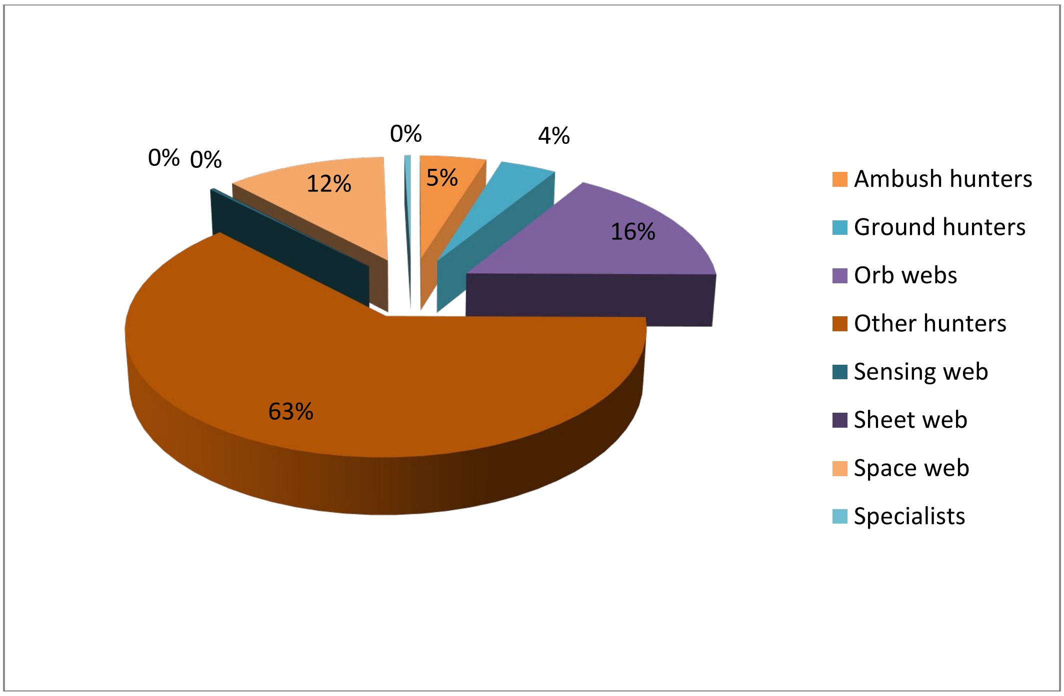


Figure 42. Spider abundance among guilds in SEN habitat.

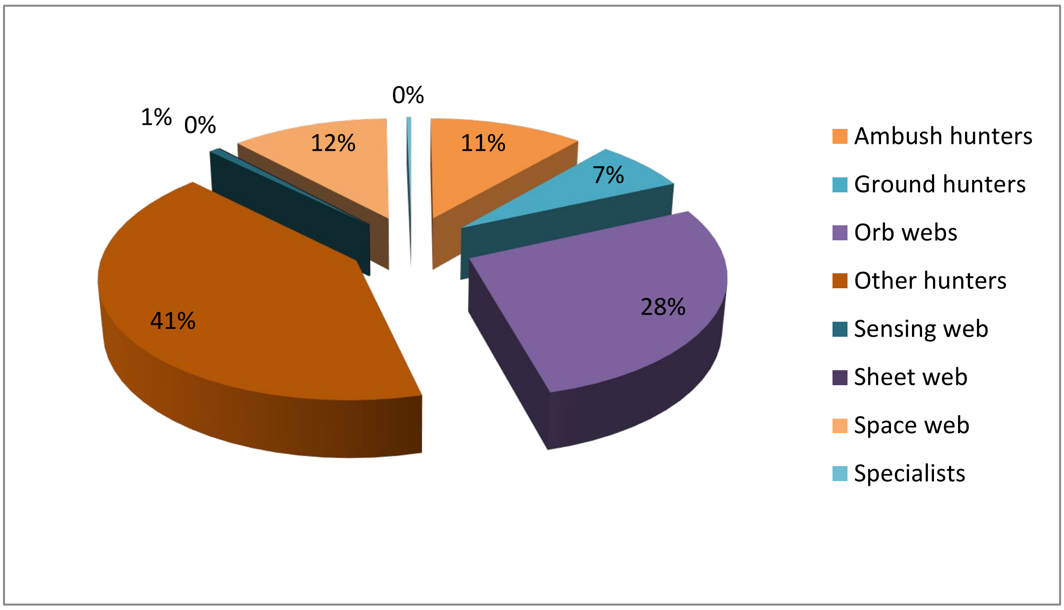


Figure 43. Spider abundance among guilds in MYA habitat

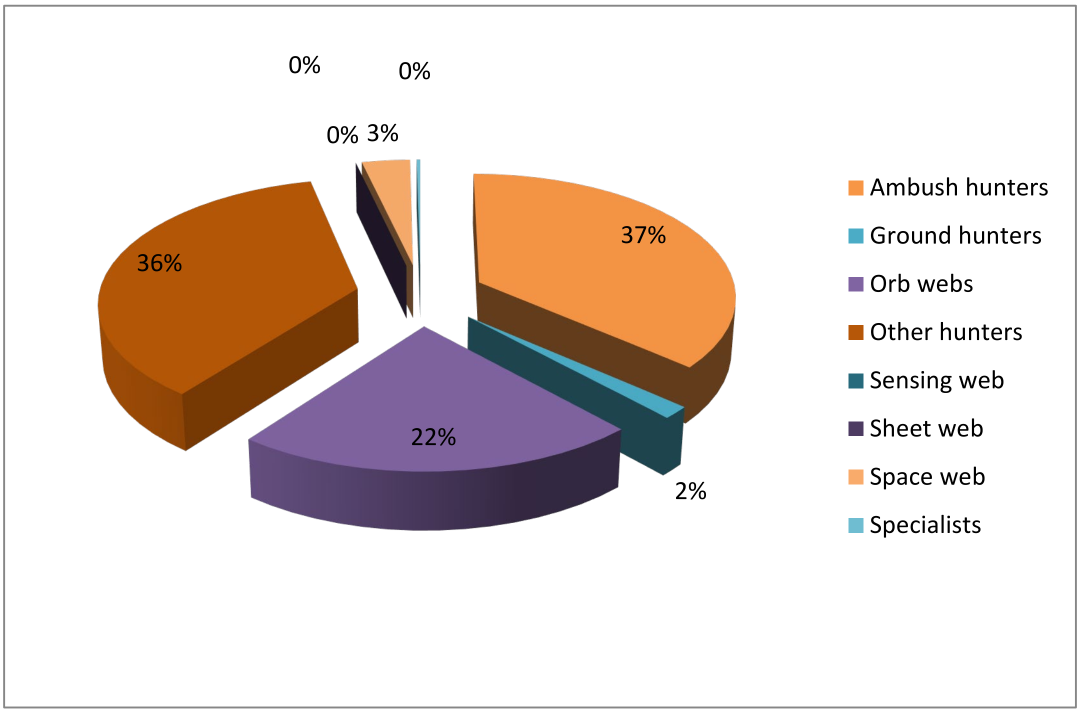


Figure 44. Spider abundance among guilds in MDS habitat.

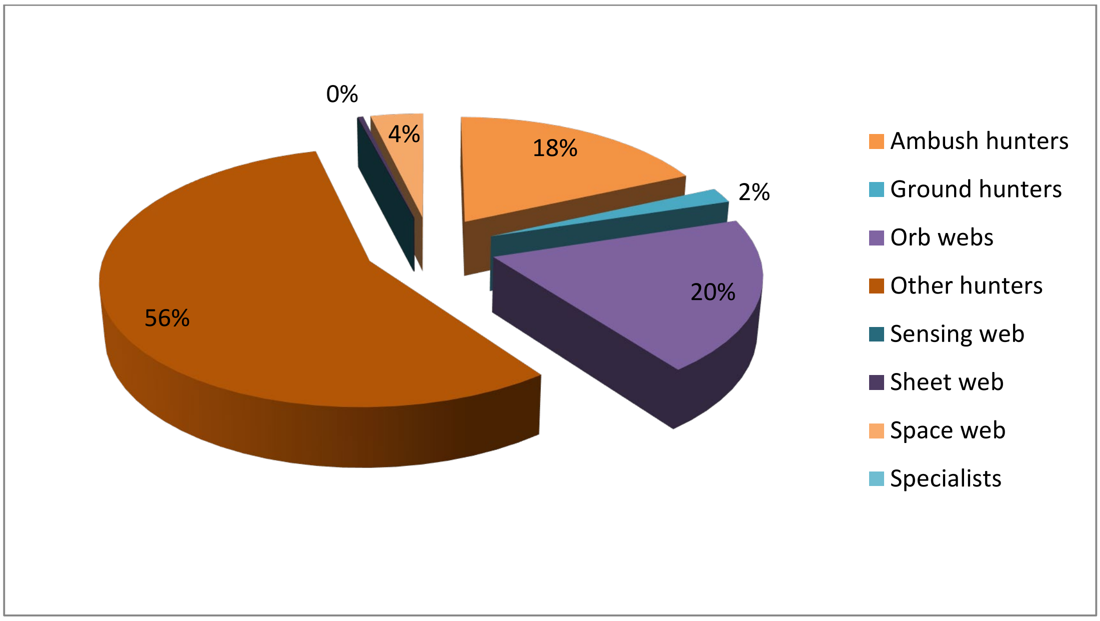


Figure 45. Spider abundance among guilds in MGE habitat.

Species richness guild composition varied between five habitat types. Other hunters category was recorded the highest species richness (169n), followed by orb web (109n), space web builders with richness of (54n), ambush hunters have (36n), ground hunters have (35n), specialists category with a species richness of (8n), sensing web category with a species richness of (5n) and sheet web category have a richness of (3n). All guilds except sensing web, sheet web and specialists were present in all habitats. Sensing web and sheet web guilds were reported as the least guilds, and they make up less than one percentage of the total species collected. The most species-rich guild in all habitats was other hunters, while the orb webs were the second species rich category (Fig. 46).

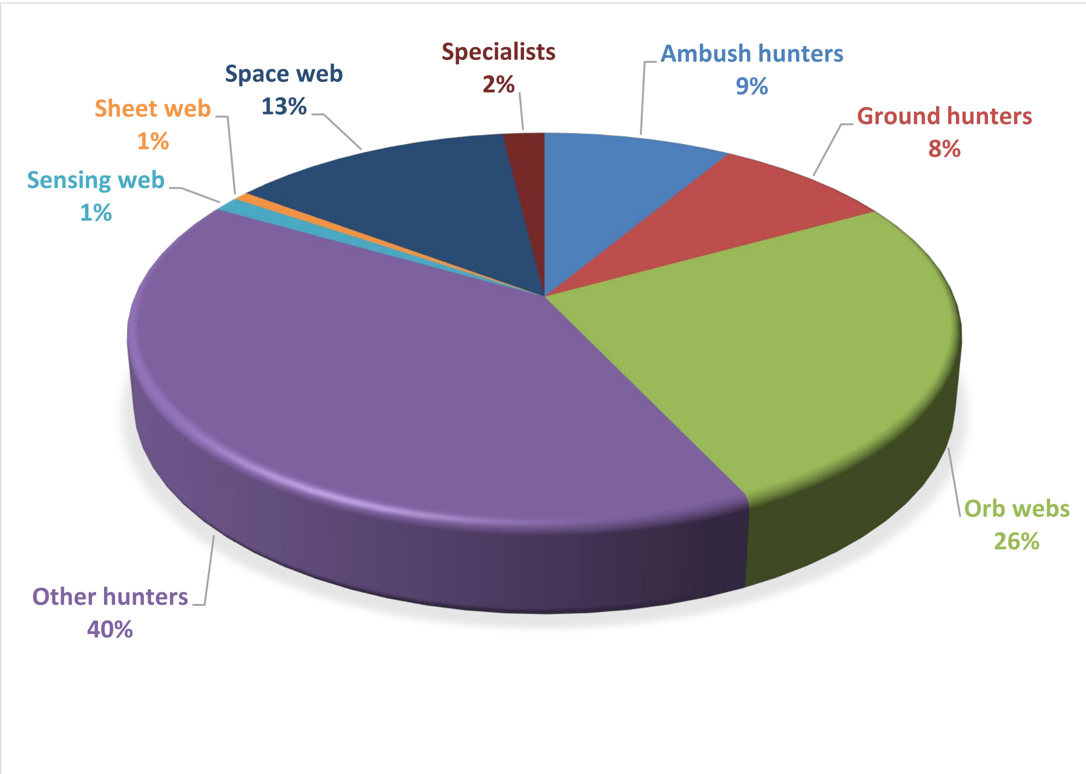
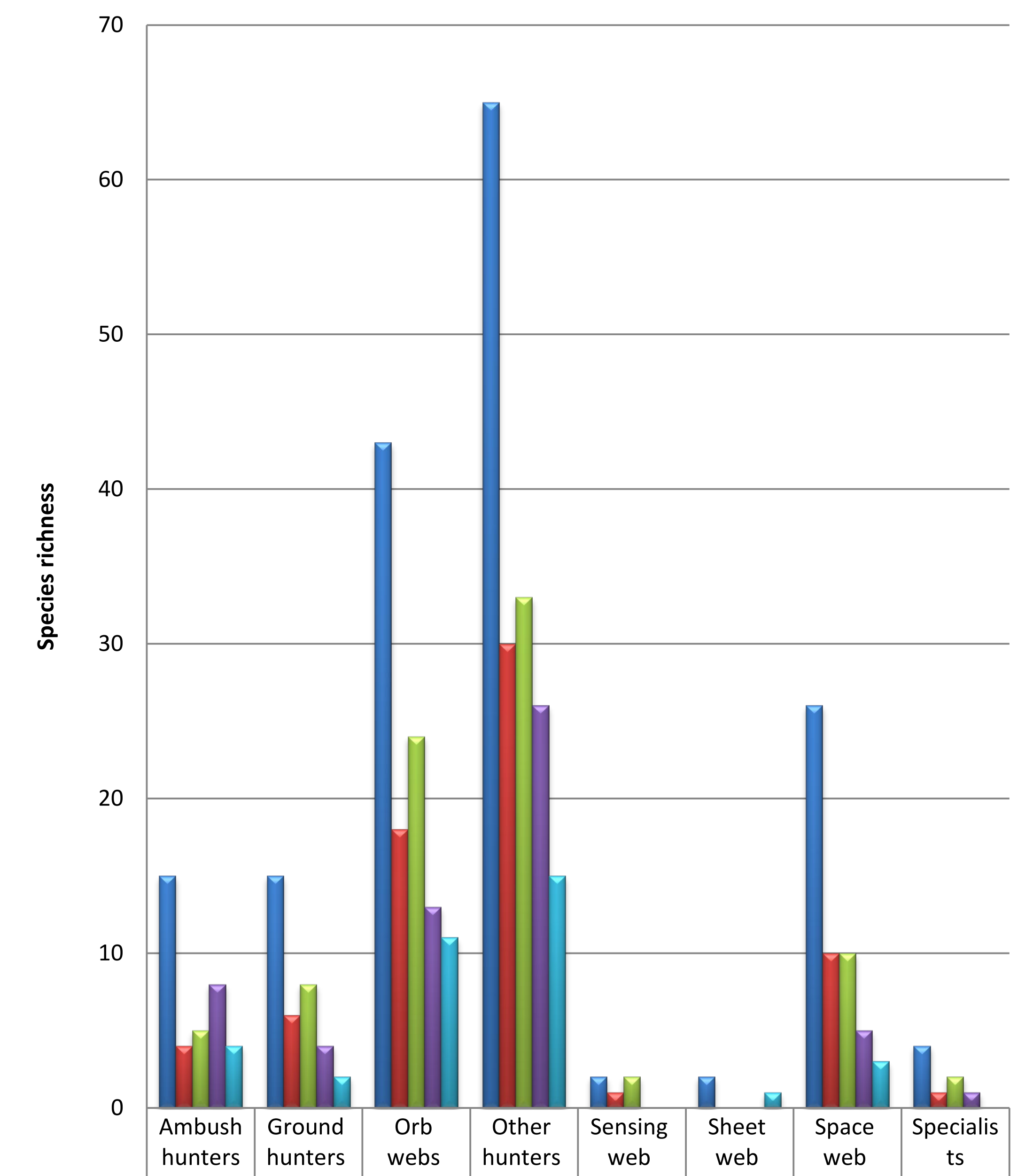


Figure 46. Total species richness among guilds in different habitats.



	Ambush hunters	Ground hunters	Orb webs	Other hunters	Sensing web	Sheet web	Space web	Specialis ts
EVN	15	15	43	65	2	2	26	4
SEN	4	6	18	30	1	0	10	1
MYA	5	8	24	33	2	0	10	2
MDS	8	4	13	26	0	0	5	1
MGE	4	2	11	15	0	1	3	0

Figure 47. Spider species richness among guilds across five different habitat types.

The results of the spider species richness among guilds across five different habitats were shows that, ambush hunters, ground hunters, orb webs, other hunters and space web were found in all five habitats. The species come under sensing web, sheet web and specialists were seen some difference. Species from sensing web category were absent in MDS and MGE, species from sheet web category were absent in SEN, MYA and MGE and specialists category were found in all habitats except MGE (Fig. 47).

Spider species richness among guild composition represented that in EVN (Fig. 48), there are 38% other hunters, 25% orb web, 15% of space web, ambush hunters and ground hunters were 9% each, 2% of specialists, 1% of sensing and sheet web category. In SEN (Fig. 49), there are 43% other hunters, 26% orb web and 14% of space web, 9% of ground hunters, 6% ambush hunters, 1% specialists and sensing web category and sheet web category were absent. In MYA (Fig. 50), there are 39% other hunters, 29% orb web and 12% of space web, 6% of ambush hunters, 10% 0f ground hunters, 2% of specialists and sensing web category, sheet web category was absent in this habitat. In MDS (Fig. 51), there are 45% of other hunters, 23% of orb web, 14% of ambush hunters,7% of ground hunters, 9% of space web, 2% of specialists, sensing and sheet web was absent in MDS. In MGE (Fig. 52), there are 42% of other hunters, 31% orb web, 11% ambush hunters, 8% of space web, 5% of ground hunters, 3% of sheet web category, sensing and specialist category was absent in MGE.

The results conclude that the vegetational complexity of the study area plays a crucial role in guild structure so the vegetation types of study area contribute to the higher abundance/richness of other hunters and orb webs.

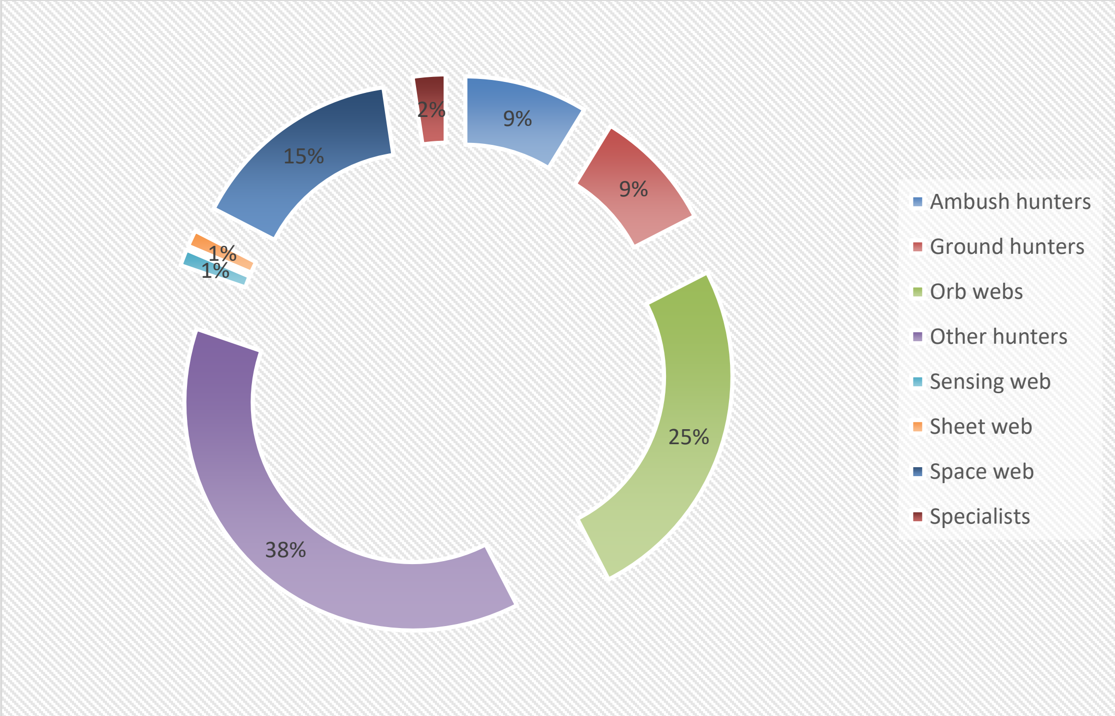


Figure 48. Spider species richness among guilds in EVN habitat.

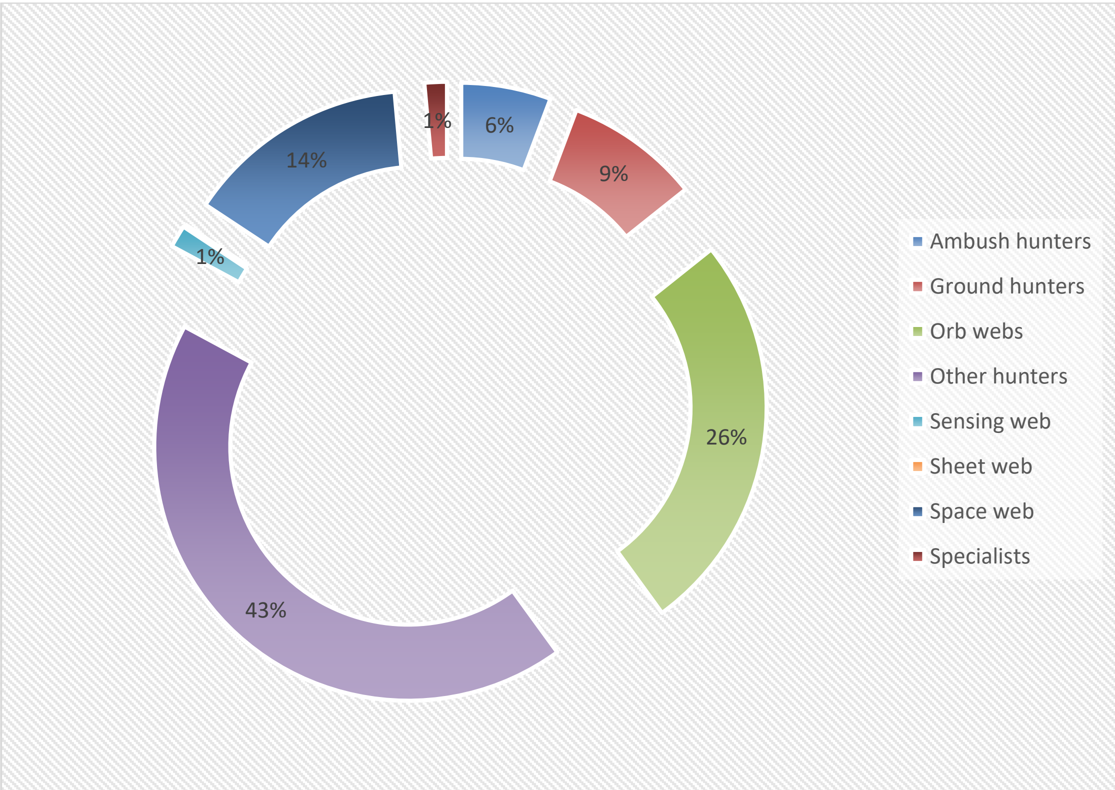


Figure 49. Spider species richness among guilds in SEN habitat.

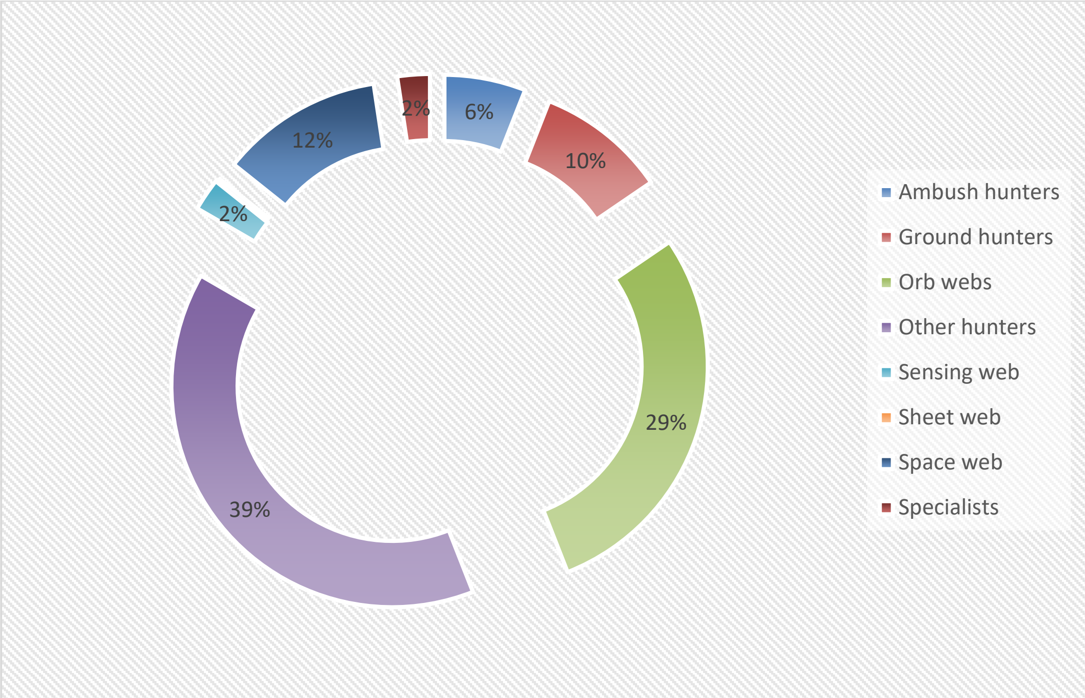


Figure 50. Spider species richness among guilds in MYA habitat.

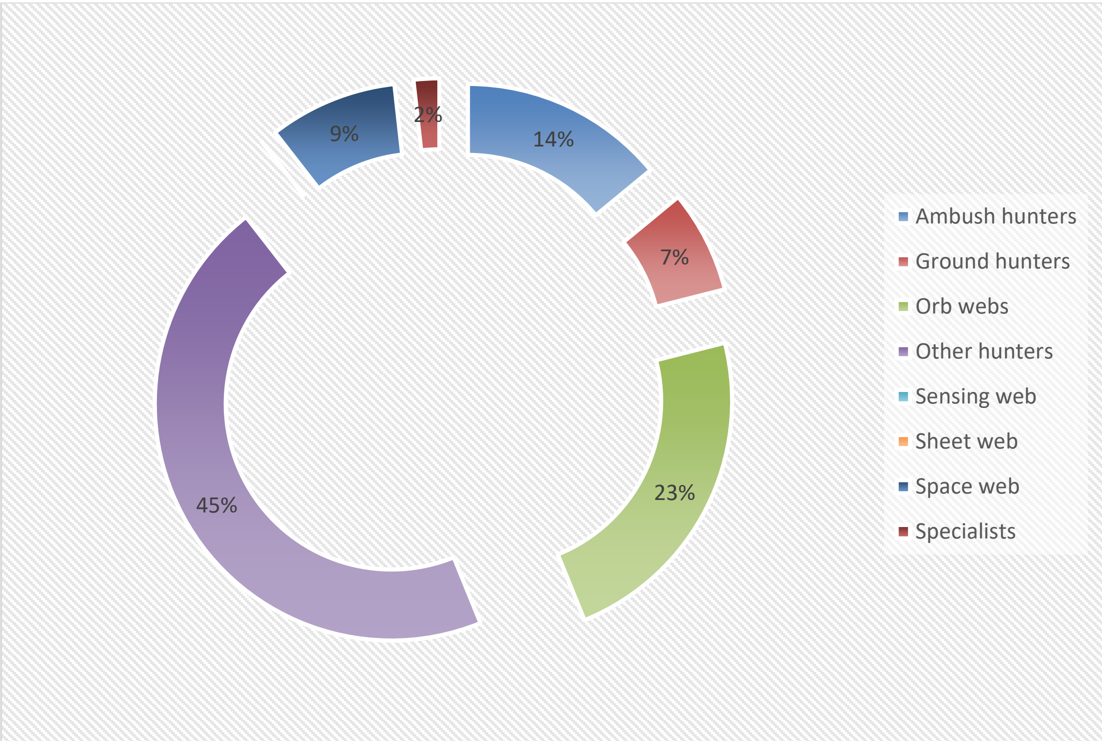


Figure 51. Spider species richness among guilds in MDS habitat.

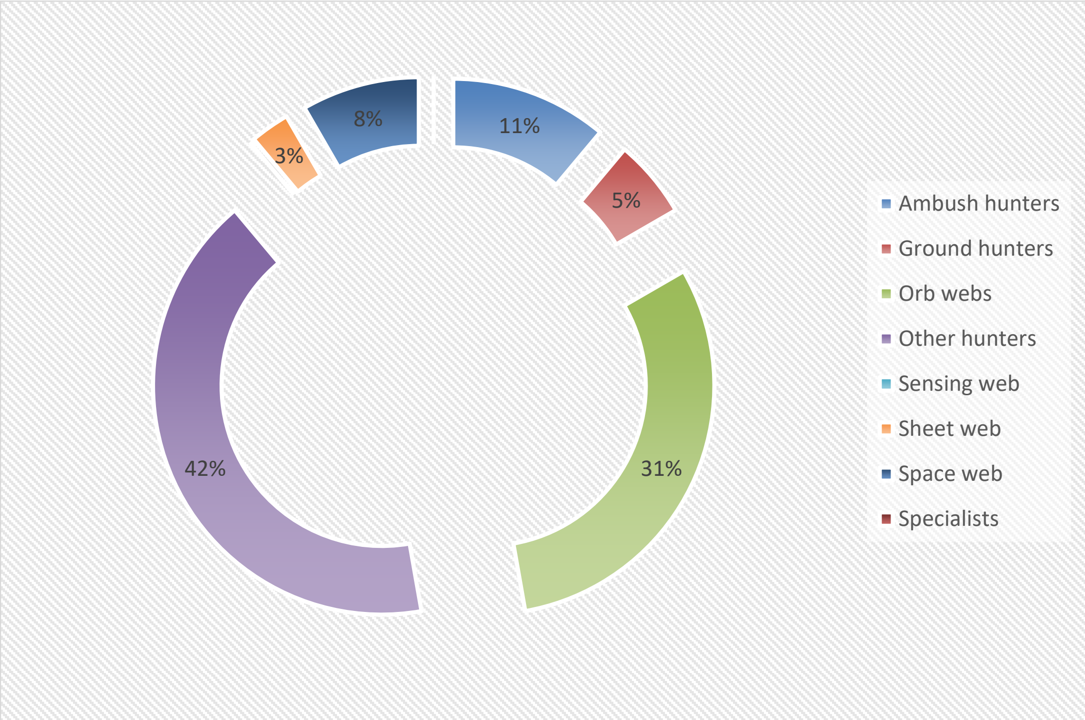


Figure 52. Spider species richness among guilds in MGE habitat.

CHAPTER 5
DISCUSSION

CHAPTER-5

DISCUSSION

The protection of biodiversity is one of the most relevant issues in global conservation, however, cannot take place if the species involved are not known (De Wet & Shoonbee, 1991). Quick inexpensive and reliable methods for estimating the species richness of taxa at particular sites (alpha diversity) could provide useful input to conservation and land management decisions (Coddington et al., 1991). Diversity patterns of arthropods are fundamental to understand and conserve its biodiversity. Spiders are one of the dominant macro-invertebrate predator groups in most terrestrial environments, playing important role in ecosystem functioning (Van Hook, 1971; Ferris et al., 2000). Spatial and temporal variations of spider communities are depending upon a range of biotic and abiotic factors, thus they are considered as ecological indicators to estimate human disturbance on ecosystem processes. Furthermore, as generalist predators, they contribute significantly in the check of insect populations in different communities. Because of their high abundance and insectivorous foraging, spiders are considered as the major agent controlling insect populations (Riechert & Lockley, 1984; Nyffeler & Benz, 1987). These characteristics make spider good indicator for comparing the biodiversity of various environments and for assessing the effects of disturbances on biodiversity. Hence, the knowledge on the diversity, distribution, foraging behaviour and taxonomy of spiders are important for implementation of integrated pest management system. This study aimed to bridge this information gap, focused on developing a spider inventory. An initial database of spider fauna was produced based on the field sampling. One of the primary objectives was to prepare a check list and explore the patterns of spider diversity. This study also intended to detect differences in changes in spider distributions at local and regional scales and guild compositions. A comprehensive documentation of the species and its diversity with appropriate baseline information on status, distribution and abundance, is crucial, for better understanding of sacred groves in Northern Kerala and incorporating such knowledge into management and conservation of sacred grove biodiversity. This study will help in assessing the conservation significance of sacred grove spiders and identifies fields for future research in indigenously protected areas.

5.1. Spider inventory

An extensive survey for a period of two years in the sacred groves indicates that the study area is occupied by 257 species of spiders belonging to 136 genera distributed in 28 families. This study, covering an area of 947 km^2 spread over two Districts in Kerala reveals that the spider fauna in the sacred groves is very rich both qualitatively and quantitatively. Results of the present study are close to 14% of the known Araneomorph spider species from India. These 257 species belong to 28 families and 136 genera which respectively come to 46 % and 29% of Araneomorph families known from India (Caleb & Sankaran, 2021). A list of species (including morphospecies) recorded is provided in Tab. 1. This result was comparable with the previous studies conducted the enlisting of spiders of groves of Rathnagiri, Maharashtra. Patil (2016) conducted a 3-year study (2013-2016) and recorded 377 species belonging to 39 families from 102 groves of Rathnagiri. De & Palita (2018) conducted 1 year study and recorded 81 species of spiders belonging to 51genera under 19 families from six sacred groves of Odisha. In South Western Maharashtra, seven sacred groves were surveyed once each for spiders among potential indicator taxa (Patil, 2011). Roy et al. (2012) conducted a study for 3 months and recorded 5 species of spiders from sacred trees of Sherampore, Hoogly, West Bengal.

In Kerala, studies about spiders of sacred groves were very less and only two authentic reports were published in connection with this topic. The reports of Jayarajan (2004) recorded 8 species of spiders from the sacred groves of Northern Kerala and this was concentrated on five sacred groves of Kasargod District. A detailed list of fauna recorded in this study which includes 110 species of butterflies, 11 species of amphibians, 2 species of reptiles, 5 species of lizards, 15 species of snakes, 179 species of birds and 13 species of mammals. Another study was by Sivaperuman (1998) in Kerala over a period of 4 months in 3 sacred groves. This study recorded only 14 species. Three sacred groves from mid Kerala were selected as the study area. 8 species of spiders were recorded from Mookuthala sacred grove, Changaramkulam, Malappuram, 7 species were recorded from Sangukulangara sacred grove, Sree Narayanapuram, Kodungallur and 6 species were recorded Iringole sacred grove, Perumbavoor, Ernakulam. These previous study reports clearly showed that results of the present study indicate a great diversity of spiders in the sacred groves of the Northern Kerala.

Araneidae is the dominant family in present study (19 genera, 50 species). This family is the third dominant family in the world (3058 species) and second in India (185 species). Other dominant families were Salticidae, Thomisidae and Theridiidae. Similarly, families Cheiracantheidae, Clubionidae, Corinnidae, Lycosidae, Oxyopidae, Philodromidae, Pholcidae, Sparassidae, Tetragnathidae and Uloboridae are represented by comparable abundances and distributed sampled strata fairly and evenly. But compositionally they may be quite different. Family

Gnaphosidae found only 3 species and families such as, Hersilidae, Linyphiidae, Mimetidae, Oonopidae, Palpimanidae, Pisauridae, Scytodidae and Trachelidae is recorded only 2 species. Similarly, only one species each from the families Anyphaenidae, Ctenidae, Miturgidae, Oecobidae and Zodariidae is present in the study area.

Araneidae is regarded as one of the most cosmopolitan families, containing a high number of genera (Coddington & Levi, 1991; Dipner Schoeman & Jocqué, 1997; Romo & Flórez, 2008). In our study, also this family reached in first position. Thus, this family may be broadly adapted to the environmental conditions of the study area, facilitating easier establishment compared to other families that have specific habitat preferences. Interestingly, the abundance and richness of Araneidae and Salticidae families did not change between wet and dry seasons. This spider community may be adapted to changes in precipitation in ecosystems. Similar results were recorded by Blanco-Vargas et al. (2003) in oak and riparian forests of the Colombian Andes. Consequently, other conditions, such as food availability or vegetation structure may be critical parameters for establishment (Borges & Brown, 2001; Jiménez-Valverde & Lobo, 2007). In similar studies of other ecosystems at different altitude, there is no clear consensus whether the spider community is influenced by climatic conditions, because statistical tests corroborating this relationship for these variables are not available (Blanco-Vargas et al., 2003; Sudhikumar et al., 2005; Dias et al., 2006; Ferreira-Ojeda et al., 2009; Escorcia et al., 2012). Two limiting factors that are influencing the abundance of Araneidae are climatic conditions and differences in plants for web construction, yet, the orb-weaver community did not show major changes in richness or abundance in relation to seasonal variation in precipitation.

This study contributed one new report and one redescription to Indian spider fauna. First one is the first report of *Amyciae albomaculata* from family Thomisidae. This specimen was collected from Koyithatta Sree Dharmasastha Kavu (KS) Kasargod District (12^{0}17’11.4” N and 075^{0}14’53.88” E) with an evergreen type habitat. This spider is remarkably similar to *Amyciae forticeps* in form, general color and structure. From this study, a checklist of spiders of the sacred groves of Northern Kerala was published (Sumesh & Sudhikumar, 2020).

A detailed redescription of *Phoroncidia septemaculeata*, including illustrations of male and female genitalia for the first time, based on fresh materials collected from the study area. Additionally, the current distributional range and new records of the species is mapped. This specimen was collected from Thrissur, Kodungallur, Sankukulangara Kavu (10º16'39.5" N and 76º09'59.6" E, 9 m alt) and it was published in Zootaxa (Nafin et al., 2019).

The study revealed a myriad of spider diversity of spiders present in the sacred groves of Northern Kerala.

5.2. Diversity, abundance and richness in different habitats and seasons

Vegetation structure could influence spiders through a variety of biotic and abiotic factors, namely web structures, temperature, humidity, level of shade cover, abundance, type of prey, refuges from natural enemies and intra guild predation (Wise, 1993; Rysptra, 1999). Different families of spiders may use separate portions of the foliage of different habitat without adversely competing for space. Quality of microhabitats for shelter and web building are strongly determined by architectural characteristics of the foliage and branches, which in turn influence family composition and individual spider diversity. The availability of great diversity of plants in the sacred groves might be the major contributing factor for the rich diversity of spiders. Other geographic features, sampling methods and time of the collection have a great influence on the difference in quality and quantity of spider fauna. The size of the sacred grove is a matter of concern either it is large or small (Patil, 2016). In this study the size of the sacred groves ranges from 1- 24.00 ha. Bodin et al. (2006) have proved that even small fragmented patches are capable of providing landscape-scale ecosystem services like pollination and seed dispersal by enhancing the habitat connectivity for the agents responsible for the services. Therefore, it is necessary to recognize the importance of isolated sacred groves.

For rapid assessment of spider diversity Coddington et al. (1991) developed a sampling protocol and estimation procedure. This and similar protocols can be structured to provide replicated data sets that reflect the relative abundance of species in the study area and may therefore provide comparable views of species richness, taxonomic composition, and guild structure across diverse communities and regions (Coddington et al., 1996; Silva & Coddington, 1996; Dobyns, 1997). Major objectives of species richness studies should be helped to predict how many samples are required for a complete (observed species accumulation curve reaches asymptote) or adequate (accurate estimate of true richness) survey (Sudhikumar, 2008).

Among the five habitats surveyed, EVN and MYA recorded the highest species richness and diversity of spiders. In the case of singleton, doubleton, unique species and rare species also were higher in EVN. The spider fauna differs between habitats (Luczak, 1963; Duffey, 1968; Bultman et al., 1982). Physical and biological features of each habitat might be related to difference in species richness in various habitats (Uetz, 1975; Muma, 1980; Rodríguez-Rodríguez et al., 2015). The high species richness and diversity together with high number of unique species in EVN may be due to awide spectrum of microhabitats available in these habitats like high litter content. Unlike semi-evergreen forests, evergreen forest retains most of its leaves throughout the seasons, the deciduous forests drop its entire leaves, particularly during the dry seasons as an adaptation of drought avoidance (Ackerly, 2004; Kursar et al., 2009). Consequently, the thick and complex leaf litter found, almost throughout the year. Spider species richness and diversity increased with both litter depth and complexity (Jocqué, 1973; Uetz, 1979; Clarke & Grant, 1968). The Shannon and Simpson index were higher in EVN. Edwards (1993) has suggested that the ratio of species to genera can provide some indication of the ecological 'breadth' of the communities being compared. Factors such as litter complexity, microclimate, microhabitats and prey species richness, all positively allied with increased litter depth (Uetz, 1979) in forests made the spiders to make strong association with these habitats. Uetz (1991) suggests that structurally shrubs that are more complex can support a more diverse spider community. Thus, the physical structure of environments has a significant influence on the habitat preferences of spider species, especially on web-building species (Uetz, 1991; Hurd & Fagon, 1992). Downie et al. (1999) and New (1999a) have verified that spiders are very sensitive to minor changes in the habitat structure; including habitat intricacy, microclimate characteristics and litter depth. Species richness and Chao 1 species prediction of different habitats studied and it was higher in EVN. Generally, as disturbance increases the spider species richness decreases. Each habitat types have its own families and species emphasizing that the importance of habitats and spider diversity conservation. Hence, any habitat cannot be considered as insignificant and attempts should be taken to sustain all the habitat types among sacred groves. spider composition at the family level is linked to the habitat type because similar families clump together within a similar habitat type. However, for species, the habitat type does not seem to affect the community composition. Thus, not only the habitat type but also the seasonal variation may be an important determinant of spider diversity. This offers important information regarding sampling methods and some species may dominate at different times of the year. In order to get a true representation of the species present, sampling should be conducted in all seasons. Sampling throughout the year is essential since, certain species mature at different times of the year. For the species level taxonomic identification adult specimens are important. Factors at the microhabitat level are important in influencing the diversity (Whitmore et al., 2002).

There have been significant differences in diversity, abundance and richness indices between seasons. Post-monsoon season recorded the highest diversity and abundance. Singleton, doubleton, unique and rare species were higher in monsoon season. The results indicate that the three seasons show different species composition. It might be expected that climatic changes through seasons would influence the abundance of spiders (Kato et al., 1995). The influence of rainfall on the regional spider diversity was explained by Russell-Smith (2002). In the tropics, a continuum of species with extended seasonal ranges has been found (Basset, 1991), that would give rise to variable samples at different times of the year. Assemblage of spiders are limited to certain environmental conditions. Variation in humidity and temperature preferences of species offer a microclimate within the range of their physiological tolerances in different seasons. So, the difference in species diversity between the three seasons is likely to be due to the difference in the number of climatic factors in the three seasons. Nevertheless, since the members of the order Araneae show diverse habits and tolerances, it is likely that species representatives can inhabit most areas in similar densities to prey species present. Exceptions comprise severe or marginal habitats where a limited supply of suitable web sites may influence the number of web-building spiders supported by the habitat. Other habitats may influence the number of spiders present by offering a limited supply of the structural features necessary for web building. According to Turnbull (1973), most webs have specific attachment and space requirements. Other researchers have also found the availability of specific structural features to limit the habitats occupied by various web-builders (Young & Edwards, 1990). These resources might also limit the number of individuals supported within a given habitat. Lubin (1986) suggested that the examined temporal abundance variation might result from seasonal changes in humidity and prey availability. In addition, the difference in the seasonal abundance of spiders may be due to the variation in patterns of activity of individual spiders and the phenology of total spider community (Corey et al., 1998).

The species richness is one of the major criteria in recognizing the importance of an area for conservation. In general, species richness in Post-monsoon season is greater than the other two seasons. In case of Chao 1 predictor species richness of spiders was again set highest in Post-monsoon season. Difference in species diversity between communities generally results from variations in site quality (Denslow, 1980).

This research supports the idea that to measure the diversity of the spider community properly we need to use complementary tools that provide a more realistic measurement of biodiversity for understanding the impact of human activities on natural communities (Moreno et al., 2017). Ecological biodiversity during species richness inventories is the most common of the dimensions considered for conservation decisions, but our research shows the importance of considering different biodiversity metrics concurrently in order to follow the different trends of the biological community patterns caused by fragmentation and disturbance. Nevertheless, further replication of habitat types is needed to strengthen the conclusion that sacred grove fragmentation and disturbance differently affects diversity metrics of spider assemblages associated with it.

5.3. Morisita-Horn similarity

Here, the relative abundance of Morisita-Horn index was higher in MGE with a similarity of 95.78% and lower in MYA habitat with a similarity of 67.86% compare than that of other habitats. The similarity percentage is greater than 50 in five studied habitats; this indicates that the habitats of this present study have high similarity percentage. However, pair wise similarity was higher in EVN-MDS with 76.25% and lower in the MYA–MGE with 36.47%. Among these 10 pair 4 of them have highest pair wise similarity more than 50% and 6 of them have least similarity less than 50%. Relatively low similarity can be explained by the difference in the type of habitat.

The relative abundance of spiders between seasons also found some differences. Morisita-Horn index was higher in Post-monsoon season with a similarity of 68.93% and pair- wise similarity was higher in Monsoon and Post-monsoon seasons with 98.13%. Similarity percentage was higher in all three seasons with more than 50%. Pair-wise similarities between seasons also have greater similarity.

The distance between the habitats is likely to be too low to play a major role in the difference of spider species assemblages. These results indicate that there are the most differences between spider assemblages that spider communities follow a pattern depending on the humidity of the habitat, which might be correlated to the plant distribution pattern varying also with the quantity of water on the soil. This finding confirms the probable link between the humidity and the associated vegetation and the spider communities' distribution (Vincent & Hadrien, 2013). Although significant changes in community composition were observed, they were apparently too small to significantly affect arthropod community variability, except for spider communities when analysed with the Morisita-Horn dissimilarity index. However, it must be stressed that this index is strongly influenced by the most abundant species, which could lead to overestimation of the dissimilarity between communities (Chao et al., 2006). Such an index, being biased towards abundant species, might be more appropriate for ecosystem service assessments, where the abundance of a few common species matters more than species diversity to provide the related service (Winfree et al., 2018). The different habitats of sacred groves that we used for our studies were differed in elevation, soil type, exposition and productivity. The reason for these diverging taxon-specific patterns may lie in the different dispersal capacities of predatory invertebrates (Hendrickx et al., 2009). Small-sized and young spiders are highly mobile, relying mostly on aerial ballooning for dispersal (Bell et al., 2005). This mobility gives spiders the flexibility to vacate a locally disturbed or no longer suitable area, and to colonise a habitat patch that becomes suitable again (Lessard-Therrien et al., 2018). So the study area shows a great similarity in between habitats and seasons.

5.4 Hill Numbers

In biodiversity studies, ecologists are interested in measuring not only diversity, but also evenness and inequality (Ricotta & Avena, 2003). Jost et al (2010) used partitioning theory to derive Hill's useful class of evenness measures, the ratios of Hill numbers and species richness. These two classes of measures have been difficult to accurately estimate statistically from samples due to their strong dependence on species richness, and thus on sample size. Jost et al (2010) suggested estimating both S and Hill numbers at fixed coverage to obtain meaningful estimates of evenness and inequality indices and able to analytically estimate evenness and inequality indices at fixed sample size or sample coverage.

Important remarks of diversity profile curve of present study among habitats, q=0 (species richness), q=1 (Shannon diversity) and q=2 (Simpson index) were higher in MYA habitat. In seasonal diversity profile curve q=0 (species richness) was higher in Post-monsoon season, q=1 (Shannon diversity) and q=2 (Simpson index) were higher in monsoon season.

Generally, in swampy ecosystems similar to the study area, the plant family Myristicaceae is remarkably dominant over in Myristica habitat, which are believed to be the vital elements to consider an ecosystem as Myristica swamps. But could not find out any strong reason for such a categorization since the species composition is determined by many factors such as microclimate, soil characteristics, dispersal mechanisms, fragmentation etc. Since the study sites comes under this category are fragmented sacred grove in a rural area, we may not expect all dominant species characteristic to Myristica swamp ecosystem. The values of floristic diversity indices were comparatively less, when compared to diversity indices of semi-evergreen and evergreen forests according to the observations of Sreejith et al. (2016). In their observation, any minute change in abiotic or biotic factors may influence swampy system and results in change in the structure and composition of tree community. In a Myristica swamp, specific conditions such as water content in the soil, presence of knee roots etc. are the reason for few number species and over dominance. Selected members of Myristicaceae, which could survive in swampy system. Most of the Myristica swamps in Western Ghats including the present one are highly fragmented to disjunct patches, where the gene flow and seed dispersal is restricted by geographical barriers. The species richness, Shannon diversity and Simpson index shows high value when comparing to the other habitats. The ecotone area between the swamps and the adjacent matrix had relatively a greater number of species, except where the ecotone had been disturbed (Joyce et al., 2015).

Myristica swamps are tropical swamp forests first reported from Kulathupuzha Reserve Forests and adjoining regions of Anchal, Thenmalai and Shendurney Wildlife Sanctuary (WS) in Kollam and Thiruvananthapuram districts of Kerala (Krishnamoorthy, 1960). Besides Kerala, they are also known to occur in Karnataka and Goa (Joyce et al. 2014). These are highly fragmented ecosystems with restricted distribution (Rodgers & Panwar 1988). The insect diversity in these swamps were studied by Sinu & Sharma (2013); spiders by Joyce et al. (2007a); animal diversity by Joyce (2007b). The general insect diversity of Shendurney WS was covered by Mathew et al. (2004), the butterflies list can be seen in Sujitha et al. (2019).

Observation from present study is sacred groves present higher degree of disturbance and fragmentation, these factors are adversely affected inhabiting spider communities. Continuous forest did not hold greater taxonomic or functional diversity than fragments. Only ecological diversity was greater in continuous forest than in forest fragments, while forest fragments had higher functional diversity. Patterns of abundance varied between habitat types but not species diversity. The mobility of the spider species found in the present study may explain these findings because most of the recorded spiders were other hunters and orb webs used webs to catch their prey. More recently, ecological diversity can be estimated by using Hill numbers (Chao et al., 2014, Jost, 2006, Murillo-Pacheco et al., 2016). The use of Hill numbers permits comparing the magnitude of the differences of plant and animal communities between natural and perturbed habitats, but it does not always detect all changes in biodiversity.

Taxonomic diversity gives a neutral perspective when compared with ecological and functional diversity. Results for the spider community suggest that according to ecological diversity the conservation of sacred groves are relevant because of their high taxonomic diversity. On the other hand, based on functional diversity, sacred groves held a novel variety of spiders' traits not present in other habitat. Based on this information, habitat fragmentation and disturbance affected the spider communities associated with sacred groves (Benítez-Malvido et al., 2020).

5.5. Beta Diversity

Many ecologists also now use β diversity to describe measures that incorporate additional information, such as the relative abundances of species (Legendre et al., 2005), or the taxonomic, phylogenetic or functional relationships among species (Izsak & Price, 2001; Clarke & Gaston, 2006; Graham & Fine, 2008; Swenson et al., 2013). The use of different measures or analytical approaches on a single set of data can naturally result in quite different outcomes and interpretations (Smith & Lundholm, 2010). In addition, most measures of β diversity are applied without incorporating statistical null models, even though they might be appropriate, given known interrelationships between α, β and γ diversity. Pair wise dissimilarities form the basis of multivariate analyses of β diversity. Different measures have different properties. They emphasize different aspects of community data and therefore can yield very different results. Abundance information is, however, an important aspect of community structure and there is no reason not to include it in analyses of variation in communities (Anderson et al., 2011). Indeed, comparing analyses of β diversity that emphasize species identities alone (with a strong role for rare species) to those that emphasize differences in relative abundances (where common and numerically dominant species play a strong role) can yield useful insights into the specific nature of community-level changes (Olsgard et al., 1997; Anderson et al., 2006).

β diversity analysis of different habitat of sacred groves in present study indicates that no significant difference was found between the centroids of each habitat. Species composition does not vary among habitats. However, some observable separation found between EVN and SEN habitat, others seem to overlap. ANOVA results of the difference in abundance among seasons between EVN and SEN recorded some significant difference. Post-monsoon - monsoon season of EVN and SEN shows significant difference in abundance. The same was done for checking the significant difference in Shannon diversity. There was no difference found in EVN and SEN.

Factors influencing beta diversity are usually a combination of environmental and geographic variables (Borcard et al., 1992) although the relative importance of each set of variables varies with taxonomic group, taxonomic level, spatial scale and geographic region (Qian & Ricklefs, 2007; Qian et al., 2009). Two basic mechanisms have been proposed to explain the origin of beta diversity patterns (Legendre et al., 2005). First, the variation in environmental characteristics may be responsible for the species composition variation through differentiation of species' niches. If the environmental variables are spatially structured, their structure will induce spatial dependence in the beta diversity patterns (Gilbert & Lechowicz, 2004;

Veech & Crist, 2007; Novotny et al., 2007). Second, spatial structure may arise by neutral mechanisms (Bell, 2001; Hubbell, 2001; He, 2005). In this case, beta diversity patterns are created by limited dispersal of species, which produce aggregated patterns, inducing spatial auto correlation in species distributions. Recent evidences suggested that niche and neutral processes are not mutually exclusive and can affect community composition in a scale-dependent manner (Laliberte´ et al., 2009; Lindo & Winchester, 2009; Legendre et al., 2009). Therefore, our understanding of the origins of beta diversity patterns depends on our ability to disentangle the relative importance of different processes, acting at different spatial scales on communities. In a previous study, Jime´nez-Valverde et al. (2009) reported a lack of significant correlation between spider assemblage composition and geographic distance. In conclusion, this study revealed that environmental factors influenced spider assemblages' variation in a scale-dependent way, highlighting the need of considering the scale-specific influence of niche and neutral processes on beta diversity patterns (Carvalho, 2012).

5.6. Overall Diversity

Gamma diversity was computed as the cumulative number of species collected across the entire habitat. The study resulted in the documentation of a total of 11308 individuals of spiders belonging to 257 species, 136 genera and 28 families. Of all the species collected 74% of were identified to species level and the remaining 26 % were identified to genus level. The sample coverage was 99.8. Observed species richness, Shannon Diversity and Simpson Diversity (Hill numbers for q=0, 1, 2) for this sample were 269.018, 55.413 and 25.079 respectively.

The present study was conducted to determine the multi-habitat gamma diversity of spiders in sacred groves of Northern Kerala. 0.947 km^2 area of sacred groves were covered in the present study. Data from 15 sampling sites representing EVN, SEN, MYA, MDS and MGE habitats were pooled to obtain the total multi-habitat gamma diversity. Results showed that different habitat composition and configuration influenced spider communities.

An additional issue in measuring the effect of habitat structure on biodiversity is the spatial scale at which biodiversity is measured. Most studies have evaluated local biodiversity, following the focal-patch approach (Thornton et al., 2011). In doing so, they measured the effect of the surrounding landscape on the biodiversity of individual patches or sample sites of a given cover type (Bennett et al., 2006; Ernoult & Alard, 2011; Thornton et al., 2011). However, it is also important, in a conservation perspective, to look at the overall diversity at the landscape scale, i.e. the gamma diversity (Bennett et al., 2006). Although, several studies have assessed gamma diversity, in most cases it was assessed only in a single habitat type within the landscape (Grasslands - Dauber et al., 2003, Forests - Radford et al., 2005, Hedgerows – Ernoult & Alard , 2011; Millan-Pena et al., 2003, Crops - Concepción et al., 2012). Since species composition varies among habitat types, these approaches only partially reflect the total biodiversity in the landscape (Duflot et al., 2017). To evaluate the effect of landscape pattern on biodiversity over the whole landscape, diversity needs to be measured in all habitat types. Hence, the relative effects of landscape composition and configuration on landscape-scale gamma diversity remain largely unknown. Assessing multi-habitat gamma diversity at the landscape scale requires a hierarchically stratified sampling design (Bennett et al., 2006; Diekotter et al., 2008). Data from the 15 sampled sites in each habitat were pooled to obtain the total multi-habitat gamma diversity of sacred groves. Two measures of diversity were used to reflect different aspects of diversity: species richness for each habitat (species number), and Morisita-Horn index between habitat pairs.

The study aims to throw light on the urgent need for conservation of sacred groves by generating a crucial baseline data on these neglected repositories of biodiversity in North Malabar. It highlights the ecological importance of sacred groves. The previous studies provide information projecting some aspects of the richness of the sacred groves in this area. Hence, this study is an attempt to stress on the importance of groves as refugia and as biodiversity inocula, to describe the ecological and cultural services provided by the groves, and to explain the socio-economic aspects of degradation of groves. More natural vegetation loss in the human inhabited areas, the remaining patches of forests in the form of sacred groves come to acquire a crucial role in buffering biodiversity. Sacred groves acquire importance from the point of view of ecology and conservation of biological diversity. Cultural practices always have their impact on environment. They determine the community use and disuse of natural resources and management of the resources. They modify the fragile ecological balance and diversity of our plant and animal life, and sometimes destroy it, leading to the loss of biota. The present study establishes the biological richness of the sacred groves of northern Kerala. Species diversity is more in these selected groves and each grove represents a different forest type. Each forest type harbours typical forest species. Endemism is also a notable phenomenon in these groves. Therefore, from the conservation point of view, these groves are most useful for *in situ* conservation of biodiversity (Jayarajan, 2004).

5.7. Species Accumulation Curve

Species accumulation curves are a classic, but informal way to assess the completeness of an inventory (Pielou, 1975; Soberon & Llorente, 1993). As individuals of a population are sampled, new species are encountered rapidly at first, but subsequently appear less frequently as the asymptote of species accumulation is approached (Miller & Wiegert, 1989). If the richness estimators do attain a stable plateau, even if the observed curve is still rising by the last sample, the inventory may be adequate to estimate richness of the fauna (Colwell & Coddington, 1994). On the other hand, if the estimators are still climbing by the end of the inventory, richness estimates may still be subject to under sampling bias.

The species accumulation curve depends upon different factors like, effects of method, time of day and collector, number of adults, number of species and taxonomic composition of the samples. Method, collector and method-time of day interaction significantly affected the numbers of adults and species per sample (Coddington et al.,1996).

The species accumulation curve for entire spider assemblage of sacred groves depicts the observed species richness. As recommended by Gotelli & Colewell (2001) to compare the sample based abundance data, the accumulation curve rescaled to numbers of individuals rather than numbers of samples. The curve reached in a plateau represents that the sampling effort was almost complete and collected majority of specimens from the study area. Total sample coverage was 99.8% and only 0.2% remaining.

The fluctuations in richness and abundance during the course of the sampling may be due to the weather conditions of the study area. Probably more favourable conditions for many species may have caused the rise in numbers, although other unperceived factors can also be involved. Confirming all the previously published studies (Coddington & Levi., 1991, Coddington et al.,1996; Dobyns 1997; Sørensen et al., 2002; Scharff et al., 2003), the methods employed are the most important factor to be taken into account when replicating sampling in different areas. Another pattern that confirmed by many studies is that all the most commonly employed methods are able to capture a close overall number of species, independently of their productivity per sample. The more productive methods in terms of number of specimens, in this case hand picking, beating method, aerial sampling, litter collection and visual search however do show accurate estimates of richness. Even if an analysis by time of day or period does not differentiate differences in productivity or taxonomic composition, the analysis of method and period combined does show significant differences, especially concerning the latter. Although the productivity is similar, sampling with the same method by day or night is so different that each combination may be regarded as a different method in itself. Differences in productivity and sample composition between collectors could not be found. Cardoso et al. (2007) provide the explanation for such differences. The high canopy density of some habitats provides a shelter against extreme temperatures, wind, rain, or other meteorological factors for the lower layers. Consequently, the microclimatic conditions are relatively constant throughout the year. This possibly allows the coexistence of many species as adults during longer periods, with longer optimum conditions for breeding. Without such protection, like in the open habitat studied, the optimum window for species' reproduction is much shorter and a lower percentage of overall annual adult richness is found during any season throughout the year (Cardoso et al., 2007).

In the observations Cardoso et al. (2009) pointed out three important things taking into consideration for this type of studies are:

1) Method and time of day are the most important factors to take into account in sampling protocols.
2) Populations in structurally simple habitats present narrower peaks of adult abundance, which implies higher percentages of juveniles in samples.
3) Structurally simple habitats may require as much sampling effort as more complex habitats in order to reach the same completeness levels.

5.8. Diversity of spiders in different habitats per season

Analysis of the diversity pattern revealed that diversity varied between seasons in different habitats. Among three seasons studied the Post- monsoon season recorded the highest abundance in all habitats. Species abundance was higher in Post-monsoon season of EVN habitat with 3131 individuals. 20 species of spiders were recorded as most abundant species with more than100 individuals, some of them are *Oxytate vierens* (1238), *Hyllus semicupreus* (1017), *Indopadilla insularis* (712), *Epeus triangulopalpis* (631) and *Uloborus krishnae* (668).

The average species abundance of spiders in different habitats per seasons shows highest in Post-monsoon season of each habitat. Among studied habitat, it was higher in Post-monsoon season of MDS habitat. The average estimated Shannon diversity of spiders in different habitats per seasons as follows: in EVN, SEN, MDS had a higher estimated Shannon diversity in Monsoon season and in MYA and MGE it was higher in Post - monsoon season. Among these sites, average estimated Shannon index was higher in Post-monsoon season of MYA habitat. The average species richness of spiders in different habitats per season as; in EVN habitat Pre-monsoon season shows higher average species richness and in SEN, MYA, MDS and MGE habitat, it was higher in Post- monsoon season. Among these habitats, average species richness was higher in Post-monsoon season of MDS habitat.

The differences detected for species diversity among habitats in this complex landscape clearly suggest a marked spatial pattern for the distribution and diversity of spiders. These results lead to the conclusion that the structural complexity of the habitat might determine diversity and spider species composition, a result that has been demonstrated by other studies (Hatley & MacMahon, 1980; Raizer & Amaral, 2001).

Evidence for other insect groups suggests that key habitats might render species to be secure when adverse conditions are present (Bennett, 1991; Dennis & Fry, 1992). However, when favourable conditions are re-established, species recolonization may be possible, depending on species dispersal capabilities and on the spatial structure of the landscape. Therefore, habitat grouping could be determined by the type of plant architecture and by the similarity between physical variables.

Landscape changes affect particularly rare or spatially restricted species. Despite this widespread habitat loss and fragmentation, some natural and semi natural habitats might play an important role for the persistence of several key populations (Lawton et al., 1998; Perfecto & Vandermeer, 2002). A consistent feature among these habitat types could be that they maintain relatively stable conditions for tree cover, humidity and prey abundance. Nonetheless, having recognized the spatial structure of the spider community in these sacred groves, it would be desirable to assess the relative importance of several key landscape elements, which may enhance connectivity over a number of generations among local populations over relatively large areas. Overall, spiders respond rapidly to environmental changes, and the knowledge of how landscape composition and structure affect their distribution and diversity levels can reveal important features of the landscape and identify important aspects of the ecosystem (Pinkus-Rendón, 2006).

As suspected, the results revealed that the community structure and diversity of sacred grove spiders changed with seasons. Seasonal community structure and diversity of arboreal spiders and some insect communities in temperate forests also contain species that are aggregated due to host plant phenology (Summerville & Crist, 2003; Veech et al., 2003; Summerville & Crist, 2005). However, the distribution of spiders is mostly governed by microclimate, vegetation architecture and prey availability (Halaj et al., 2000).

Based on the results claim that the composition and diversity of spider communities in sacred groves is strongly influenced by seasonal variables. Should not only focus on the partitioning of spatial components of community structure (Hsieh & Linsenmair 2011, 2012), but also take into consideration temporal factors when studying biodiversity. In this way, current estimates of the number of arthropod species may increase, or even double as shown here, thus enabling us to gain a more accurate image of diversity in the study area.

5.9. Richness Comparison between habitats and seasons

Aim of rarefaction is to make fair comparisons among incomplete samples. Sample -size based rarefaction, in which the samples are all standardized to an equal size provide useful sampling information for a range of sizes. Rarefaction curves allow us to make more robust and detailed inferences about the sampled assemblages. Curves for species richness always give the same qualitative ordering of species richness. If crossing occurs, then the sample-size and coverage-based curves have exactly the same number of crossing points. However, for species richness, the coverage-based method is always more efficient (requiring smaller sample sizes in each assemblage) than the traditional method for detecting any specific crossing point (Chao & Jost, 2012).

Rarefaction was performed for sample size and sample coverage. The former is the traditional method of applying rarefaction and extrapolation, but using sample coverage has recently been shown to be more reliable (Chao & Jost, 2012). While sample size is simply the number of individuals in a sample, sample coverage is the proportion of individuals in a community that belong to the species represented in the sample (Cherrill, 2017). While an additional scarce or abundant species will contribute equally to species richness, the former will have much less influence on indices of diversity that incorporate proportional abundance (Magurran, 1988).

The rarefaction curves showed clear differences in rarefied species richness within habitats of sacred groves. In EVN habitat the rarefied species richness was the highest in PK and lowest in KS at a sample size of 32 individuals. It varied slightly between the seasons with Monsoon > Post-monsoon > Pre-monsoon. In the SEN habitat it was the highest in MP and the lowest in PS at a sample size of 11 individuals. It varied slightly between the seasons with Monsoon > Post-monsoon> Pre-monsoon. In the MYA habitat it was the highest in PO and the lowest in KK at a sample size of 19 individuals. It varied slightly between the seasons with Monsoon > Post-monsoon > Pre-monsoon. In the MDS habitat MK, the rarefied species richness was at a sample size of 114 individuals. It varied slightly between the seasons with Post-monsoon > Monsoon > Pre-monsoon. In the MGE habitat TK, the rarefied species richness was at a sample size of 132 individuals. It varied slightly between the seasons with Monsoon > Post-monsoon >Pre-monsoon.

Comparing the mean species richness in Pre-monsoon, with a standard value of 11 individuals per site, the rarefied species richness was higher in PO and lower value in KS. For Monsoon, with a standard value of 12 individuals per site, it was higher in PO lower in PS. Finally in Post-monsoon season with a standard value of 38 individuals per site, found higher rarefied richness in PK and lower in KK.

The slope of a sample-size-based expected species accumulation curve or a rarefaction/extrapolation curve also provides important information. The slope at the base point in the species accumulation curve or rarefaction curve is closely related to the Simpson diversity and to Hurlbert's (1971) Probability of an Interspecific Encounter (PIE) measure (Olszewski, 2004). The slope at any other point is closely related to the complement of coverage (Chao & Jost, 2012). For coverage-based curves, consider different sampling schemes and discuss the relationship between the expected species accumulation curve, Simpson diversity, and PIE. For Hill numbers, only species relative abundances are involved. Species absolute abundances play no role in traditional diversities. From the perspective of measuring ecosystem function, Ricotta (2003) argued that if two assemblages have the same relative abundances, the one with larger absolute abundances should be considered more diverse (Chao et al., 2014).

5.10. Rank abundance

Most plant and animal assemblages are characterized by a few common species and many uncommon and rare species. A major aim of research in ecology is to understand the mechanism and process that generate and shape the differences among species abundance (McGill et al., 2007). The dominance of the species explains the differences between rank abundance plots of different habitats, where the native sites could favour higher activity of densities of certain species (Bell et al., 1997). In fact species assemblages of different habitats were clearly separated and shared half of their species. These significant, as different habitats are nevertheless very closely related habitat types. But these differences in species composition confirm the assumptions that micro-scale habitat relations are important for some highly specialized spider species (Finch, 2008; Muff et al., 2009).

The rank abundance curves showed a main set of species that dominates the sacred grove spider communities. Members of family Araneidae and Salticidae are active and dominant spiders in the study area. These spider families were the most common in all studied habitat types. Records were limited to spiders suggesting that this tropical habitatis important for sustaining some spider species in the study region.

Most of the tropical spider communities are generally fitted to the Log-Normal distribution (Coddington et al., 2009), in different strata of spider assemblages (Moring & Stewart, 1994; Ferreira-Ojeda et al., 2009). For present data, Zipf- Mandelbrot model explained the abundance distribution in the sacred groves. Zipf-Mandelbrot models are associated to many factors acting sequentially in small, unstable and less diverse communities, whereas the Log-Normal model can be seen as the result of many factors acting simultaneously on the species, and it is frequently reported for large, stable and diverse communities (Wilson, 1991; Magurran, 2004). In the present study, sacred groves were divided in to five habitats and sampling was done for a period of two years. Different habitats were present different number of samples which means it was not uniform. So this may be the reason the rank abundance curve fitted as Zipf - Mandelbrot model. Fails in predictions for some of these models (mainly Log-Normal) also have been mentioned by other authors (Nummelin, 1998; Basset et al., 1998; McGill et al., 2007), it is possible that these models might not be universal indicators for the species-abundance distributions in complex habitats, small scales or short-terms conditions as the ones considered in this study. However, this model has been applied in a number of studies and continues to have application in both terrestrial and aquatic ecosystems. It has also been used to test the performance of various diversity estimators (Magurran, 2004). Unexpectedly, the relative abundance of all dominant species for these habitats had significant seasonal changes, promoting the high variation observed for this spider assemblage (Campuzano, 2020).

5.11. Regional Diversity

The correct estimation of local and regional species richness has been considered critical for determining the shape of the relationship between local and regional species richness (Srivastava, 1999). The ecological interpretation of diversity is not straightforward. It might be expected that diversity should increase with habitat heterogeneity. In fact, more structurally complex habitat harbour more spider species per plot, probably due to more niches being available. The probability of species interactions is higher and the interpretation of patterns more easily related to processes operating at the local scale, such as vegetation heterogeneity and diversity (Collins et al., 2002). In previous studies suggesting that species assemblages are random samples drawn from a pool of potential colonists, and also that spider communities may be largely structured by interspecific competition or local features of the habitat (Wise, 1993). Spider assemblages, in a particular small patch, probably correspond to a collection of individuals of the species present, under the constraints of habitat structure and limited niche space. Habitat management may also have intense effects on local spider assemblages, since local spider richness seems to be related to well-developed and complex vegetation. It is also important to consider the potential utility of measures of species richness in habitat management and conservation-management of sacred groves. If saturation occurs at the local scale, then diversity could be of limited value in identifying levels of mean species richness at the local scale. An investment in standardized sampling within regions, to obtain measures of diversity, would greatly enhance the understanding of processes operating at local and regional scales (Borges & Brown, 2004).

The geographical and climatic patterns have a crucial role in spider assemblages. Analysis of different facets of regional diversity in sacred groves of Kannur and Kasargod District shows significant difference. A clear difference present in between climate, geographical features and elevation pattern in both Districts. Kannur experiences a rare humid tropical monsoon climate and has an elevation of 1.02 metres (2.98 ft). Kasargod has a tropical climate and has an average elevation of 19 meters (62 ft).

Analyzing different facets of local diversity (abundance, species richness, diversity), and the contribution of species differentiation (β - diversity) among localities and habitat types is very important to deteremine the composition of regional diversity. At the habitat level, the different facets of biodiversity followed a clear pattern, where sacred grove spiders of Kannur have higher abundance, species richness and diversity than Kasargod.

Abundance and variation of species diversity (Shannon index) follow the same trend. A total of 2904 individuals with 109 species collected from Kasargod District and 8404 individuals with 220 species collected from Kannur District.

Singletons and doubletons were higher in Kannur District. For testing hypothesis, took 4 evergreen habitats from both Districts to compare diversity - to test whether there is any significant difference in the abundance and estimated Shannon diversity among samples from two Districts. Wilcoxon rank sum test was used to test the hypothesis. Sacred groves of Kannur District have significantly higher values of abundance and diversity. The overall similarity in Kannur District was 80.01% and Kasargod District was 79.12%. The similarity between two Districts were 68.58%.

Comparing the rarefied richness of Kasargod and Kannur Districts of 8 sacred groves with evergreen habitats were selected for this study. The rarefaction curves showed clear differences in species richness between habitats in the two regions. Even after standardizing sampling effort to a total of 2904 individuals in Kasargod and 8404 in Kannur. Comparing the mean species richness in Kasargod District, with a standard value of 23 individuals per site, the rarefied species richness was higher in MP and lower value in KS. For Kannur District, with a standard value of 124 individuals per site, it was higher in PK and lower in KO.

Land management strategy design incorporating patterns of spider diversity at an appropriate regional scale is essential for the spider biodiversity conservation (New, 1999b). It is feasible starting from the local knowledge of the diversity considering that this has a high correlation with the vegetation complexity that appears as a powerful predictor of the local spider species richness on a regional scale (Jiménez-Valverde & Lobo, 2007).

In sacred groves the presence of contrasting habitats and the variation between localities have a great influence in orb-weaving spider communities, leading to an important contribution of beta diversity to the regional spider species richness. Management for conservation in the sacred groves should be directed towards promoting natural spatial heterogeneity, giving special emphasis to habitat mosaics in different localities (Rubio & Moreno, 2010). However, to provide a better framework for conservation management, other biological groups should be studied. Moreover, microhabitat variables and disturbance effects should also be investigated because they may stand for important factors influencing diversity, especially in order to assess the potential anthropogenic activities in this type of protected areas.

Many more habitats will have to study until the relationship between local and regional species pool of spiders can be understood. This study has considered diversity in spider assemblages with respect to sample size and habitat heterogeneity. However, other factors such as productivity, latitudinal gradient and size of the regional species pool have been suggested to influence species richness (Huston & Huston, 1994; Koleff & Gaston (2002). It was not possible to assess the impact of these factors quantitatively only limited sites per habitat type were sampled. But with its emphasis on the diversity patterns at small scale the present study may help to outline ideas for design of monitoring programmes and future inventories (Hore, 2009).

This study revealed that the value of different habitats will depend on their size and location. The amount of under story vegetation has a strong influence on spider abundance and diversity, thus affecting the amount of habitat available to spider occurrence. Therefore, diversity can be maintained as far as suitable habitat structure is provided. So that spiders can perceive the connectivity of different habitats. Studies revealed that optimum species richness influence habitat heterogeneity (Uniyal & Hore, 2008). This allows a narrow niche separation (Bonn & Klienwachter, 1999), hence benefiting the persistence of species with divergent habitat preferences and interrelated sets of species traits. This study recommends that the spider fauna of sacred groves is rich and useful for monitoring work, and that support for the conservation of this area should be continued. More individual spider species need to be studied in order to evaluate their indicator values that would help in establishment of a longer list of indicator species for sacred grove management. Thus, it might be wise to extend this survey to other parts of Kerala, since it might increase the number of known species in this ecosystem.

5.12 Guild Structure

Species are limited to ecological niche boundaries by competing species (Hutchingson, 1959; Colwell & Futuyama, 1971). Groups of competitors, or ‘‘a group of species that exploit the same class of environmental resources in a similar way’’, were later called guilds by Root (1967). The currently most accepted definition characterizes ecological guilds as non-phylogenetic groups of species that share one or a series of important resources (Blondel, 2003). The definition and study of guilds is especially useful if they respond in roughly the same way to similar changes in the environment, independently of the specific taxonomic composition. Studying ecological guilds or functional groups can be helpful to examine assemblage response to climate change, habitat disturbance, and management among many other areas.

The study of guild structure implies its quantification. Functional diversity is one of the most important parameters used to explain how ecosystems work and adapt to change (Tilman et al., 2001; Petchery & Gaston, 2002). In order to evaluate guild and functional group diversity, a number of complex and precise measures have been developed during the latter decade. Petchey & Gaston (2002) first proposed using total dendrogram branch length to measure functional diversity as a more useful measure than simply counting the number of guilds or functional groups (Tilman et al., 2001). Separating species into guilds can be as simple as grouping taxa according to trophic level (Wilson, 1999) or as complex as studying all the relationships between taxa in a multidimensional matrix (Inger & Colwell, 1977). The approach taken depends on different factors (1) the objectives of the study, (2) the spatial scale of the study, (3) the taxonomic scale, (4) the data reasonably available.

This study attempted to characterize a mega diverse group at a global scale, the approach was designed to test questions at this level. In the case of tropical spider species, most of them are undescribed and discriminated only as morphospecies. Besides, ecological characteristics (foraging strategy, prey range, vertical stratification and circadian activity) for those species, which are recognized at specific or generic levels, are usually unknown. In such cases, family or even genus characteristics are available to aid in guild assignment (Cardoso et al., 2011). At a global level for spiders, families, and occasionally groups within families, are the most practical basis for guild classification. As expected, the most significant characteristic for defining guild placement was foraging strategy. Web type or hunting methods mainly determine the division of spider families into guilds, as was previously recognized by different authors dealing with this taxon (Utez et al., 1999).

Spiders collected from the sacred groves with different habitats were sorted into the following eight guilds based on their foraging behaviour in the field (Cardoso et al., 2011). Ambush hunters (Thomisidae): the members of this family do not construct webs to trap their prey, but they ambush unsuspecting prey that comes in proximity, grasping them with their strong, spiky, curved front legs, similar to

Venus flytrap plant, but sit-and-wait for their prey. The most abundant guilds in this environment are likely those with families and species able to adequately occupy niches, given structural and spatial characteristics of the environment. A lack of preferred hunting and sit-and-wait points within the forest, such as flowers or open spots, could affect the abundance of these kind of guild,

Ground hunters (Corinnidae, Gnaphosidae, Lycosidae and Oonopidae): they predominantly hunt on vegetation in the tropics. Ground hunting spiders do spin silk, but never construct web to capture prey instead they hunt and chase prey along the ground. The members of this families include species with different lifestyles, but these spiders can be also found wandering on the ground. This guild joined the "sedentary nocturnal ground hunters" and the "litter stalkers", both proposed by Höfer & Brescovit (2001).

Orb webs (Araneidae, Tetragnathidae and Uloboridae): the typical orb-weavers are the most prominent group of spiral wheel-shaped web builders frequently found in gardens, fields and forests. Since they construct round shaped webs they are commonly known as orb weavers (Araneidae and Tetragnathidae). Most of species of this guild make an orb web, usually a two-dimensional structure, but some species construct a highly modified structure, ranging from a tridimensional web to only one silk line.

Other hunters (Anyphaenidae, Cheiracanthidae, Clubionidae, Ctenidae, Linyphiidae, Miturgidae, Oxyopidae, Philodromidae, Salticidae, Scytodidae and Sparassidae): Uetz et al. (1999) proposed eight guilds as per the studies of crops in the USA. These authors, though, included Linyphiids in their own wandering sheet or tangle weavers guild and many families that (Cardoso et al., 2011) denominate as ''other hunters'' were considered as either foliage runners or stalkers.

Sensing web (Hersiliidae and Oecobidae): special structures are used in a characteristic hunting behaviour in which the spider holds the spinnerets over the prey, and then rotates at great speed around the prey, fixing it to the substratum (Murphy & Murphy, 2000).

Sheet web (Pisauridae): construct tridimensional web, this guild comprises species that produce sheet, funnel or other tri-dimensional webs, hunt during the day on the web. The representatives of this guild were divided in “sedentary sheet web-weavers”and “aerial space web-weaver” in previous studies (Höfer & Brescovit, 2001; Silva & Coddington, 1996; Uetz et al., 1999).

Space web (Pholcidae and Theridiidae): the abundance of thin and ramified branches in shrubs and small trees generating a complex three-dimensional spatial structure in riparian forests could possibly explain this occupation of space web spiders in these strata. Unlike orb web, the web of space builders does not have adhesive properties. The uneven structure of the web entraps insects, making their escape difficult. The spider rapidly encapsulates its prey with silk and then imposes the fatal bite. They either eat the prey immediately or stored for later.

Specialists (Mimetidae, Palpimanidae, Trachelidae and Zodariidae): after the studies of Dias et al. (2009), Neotropical spiders further refined many of the guilds in diurnal and nocturnal. In this study, circadian activity was not decisive for guild placement. Circadian activity, phenology and body size were used in smaller-scale or species-based studies. Species, which are hunting in different times of day or seasons or having different body sizes probably are not sharing resources. No previous study considered the problem of stenophagy and specialization of prey. It may be important to recognize in guild placement that specialist taxa have little overlap in resource sharing with other species. In that sense, the specialists’ guild is not even a true guild, but a cluster of species that, by specializing in one or very few prey, are not directly competing with any large group of species.

In present study, guild composition varied between the five habitat types. The most abundant guilds were the ambush hunters (2570 n), orb web (2496 n) and other hunters (5028 n), they together constitute more than half of the total species collected (total =11308n). The studied guild structure of sacred groves with different habitats, 45% were other hunters, 23% were ambush hunters, 22% were orb webs, 2% were ground hunters, sheet web, specialists and sensing web percentage was less than 1%. All guilds except sensing web, sheet web and specialists were present in all habitats. Sensing web and sheet web guilds were reported as the least guilds. The most species-rich guild in all habitats was other hunters, while the orb webs were the second species rich category. Spider guild composition represented that in EVN, SEN, MYA, MGE shows highest percentage of other hunters and in MDS represented highest percentage of ambush hunters.

The results of the spider species richness among guilds across five different habitats were shows that, ambush hunters, ground hunters, orb webs, other hunters and space web were found in all five habitats. Species from sensing web category were absent in MDS and MGE, species from sheet web category were absent in SEN, MYA and MGE and specialists category were found in all habitats except MGE.

The results of the spider abundance among guilds across five different habitats were shows that, ambush hunters, ground hunters, orb webs, other hunters and space web were found in all five habitats. Spider abundance in sensing web category were absent in MDS and MGE, abundance in sheet web category were absent in SEN, MYA and MGE and spider abundance in specialists category were found in all habitats except MGE.

These results suggest a consistent guild classification can promote future comparison between different geographic regions and habitats. Also, suggest that different families may have similar ecological roles, with replacement of some taxa by other within the same guild according to the region. Guild structure may therefore be predictable and independent of taxonomic structure. This study also indicates that tropical regions may have higher redundancy of functional roles or finer resource partitioning than temperate regions. If the diversity-stability relation is confirmed, this may be an indication of higher resistance to disturbance in high-diversity in sacred groves. Finally, functional diversity may correlate with habitat structure and vegetation complexity. Vegetation structure influences family level spider composition because similar families tend to associate within similar habitat type. The result also reveals the presence of similar species at specific time of the season. Thus, proving seasonal variation has a significant impact on spider diversity than vegetation structure.

Finally, it is concluded that these findings can be utilized for conducting further refinement studies and also directly for incorporation into spider-inventory based conservation processes.

CHAPTER 6
SUMMARY AND CONCLUSION

CHAPTER-6

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6.1. Summary

A total of 15 sacred groves were selected for the present study. They were located in Kannur and Kasargod districts. Out of 15 sacred groves, 7 of them comes under evergreen habitat (EVN), 4 of them are in semi-evergreen habitat (SEN), 2 of them are in myristica habitat (MYA) and one each in moist-deciduous (MDS) and mangrove habitat (MGE). The study was made during the period of 2015 to 2020. Study area identification, selection and pilot study were done in 2015 to 2016. Spider sampling was carried out from February 2016 till January 2018. Taxonomic identification and further data analysis were done in 2018 to 2020. The study periods were divided into Pre-monsoon, Monsoon and Post-monsoon seasons and samples collected during each season. Spiders were collected in the morning (7.00 am to 10.00 am) and evening (4.00 pm to 7.00 pm). Line transect method was adopted in this study. Collection by hand, beating method, aerial sampling, ground hand collection and visual search method were used for sample collection. Collected specimens were kept in separate vials and preserved in 70% ethyl alcohol. Proper labelling and other notes of taxonomic importance were recorded. Specimens collected were transported to the laboratory and identified up to species level with the help of available literature. Statistical analysis of the data was carried out using Vegan package 2.4-3 (Oksanen et al., 2017). One-way ANOVA, Tukey honest significant differences test, Rarefaction curves and Rank abundance plot analysed by using R package (Vegan package 2.5-7). Regional diversity analysis was done by using a non-parametrical test called Wilcoxon rank sum test. Designation of spider guild was based on ecological characteristics known for the family (Cardoso et al., 2011).

Inventory of spiders from the sacred groves: Rich spider diversity has been documented in the present study with 257 species belong to 28 families and 136 genera. The dominant families were Araneidae, Salticidae and Theridiidae. A paper published from this inventory, which provided a detailed redescription of *Phoroncidia septemaculeata*, and also a new report of species *Amyciae albomaculata* (first report from India) from family Thomisidae.

Abundance and diversity in different habitats: Among five habitats studied, the EVN habitat shows the maximum number recorded with 6805 individuals and MYA ecosystem was minimum with 923 individuals. Maximum singleton and doubleton were higher in EVN habitat and minimum in mangrove habitat. Coming to the unique species and rare species percentage, maximum number of unique species was recorded in EVN and rare species percentage was maximum in MYA habitat.

Seasonal species richness: The local diversity or alpha diversity of Post-monsoon season in terms of species richness was 232. The species richness of monsoon was 214 and Pre-monsoon was 198. The species richness estimator Chao 1 estimator (Chao, 1984), predicted 263 species of spiders in monsoon season, 253 species in Post-monsoon season and 226 species in Pre-monsoon season. It is evident from the standardized reference sample that Post-monsoon season appears to have higher observed species richness than others seasons.

Beta diversity of spiders in sacred groves: The variation of diversity among the different habitats were analysed using the PERMANOVA test (Anderson et al., 2011), done using adonis function of vegan with 999 permutations and was visualized using the nMDS plot. But no significant difference was found between the centroids of each habitat in Adonis. In EVN it was 0.28365, SEN it was 0.47798, in MYA it was 0.47523, in MDS it was 0.12801 and MGE 0.06237. That means the species composition does not vary among the habitats. However, there is some observable separation between the evergreen and semi evergreen habitats. Others seem to overlap.

Overall diversity: The study resulted in the documentation of a total of 11308 individuals of spiders belonging to 257 species, 136 genera and 28 families. Among this 74 % of were identified to species level and the remaining 26 % were identified to genus level. The sample coverage was 99.8%. Observed species richness, Shannon diversity and Simpson diversity (Hill numbers for $q = 0, 1, 2$) for this reference sample were 269.018, 55.413 and 25.079 respectively.

Species accumulation curve: The curve reached in a plateau represents that the sampling effort was almost complete and collected majority of specimens from the study area. Total sample coverage was 99.8% and only 0.2% remaining.

Rank abundance distributions of spiders in different habitats: Species rank abundance distributions for habitats were best explained by Zipf-Mandelbrot models, as indicated by AIC. The main difference between the three model parameters between habitats were observed for parameter 1, this parameter had a higher value for MGE habitat (23.218). The other two model parameters can be interpreted as parameters β and γ. Differences in these parameters between the habitats indicate that the SEN has greater evenness because γ (parameter 3) is lower (5.414,), and β (parameter 2) is less negative than for the EVN habitat (−1.8).

Richness comparison between habitats: The rarefaction curves showed clear differences in rarefied species richness within habitats. In the Evergreen habitat the rarefied species richness was the highest in PK (21.56 ± 0.80, Mean ± SD) at a sample size of 32 individuals. It varied slightly between the seasons with Monsoon (16.21 ± 3.60) > Post-monsoon (15.89 ± 3.36) > Pre-monsoon (14.8 ± 3.99). In the Semi-evergreen habitat, the rarefied species richness was the highest in MP (8.01 ± 0.66, Mean ± SD) at a sample size of 11 individuals. It varied slightly between the seasons with Monsoon (7.65 ± 1.23) > Post-monsoon (7.14 ± 0.73) > Pre-monsoon (6.45 ± 1.14). In the Myristica habitat the rarefied species richness was the highest in PO (14.93 ± 0.35, Mean ± SD) at a sample size of 19 individuals. It varied slightly between the seasons with Monsoon (12.09 ± 3.23) > Post-monsoon (11.69 ± 3.84) > Pre-monsoon (11.67 ± 3.77). In the Moist-deciduous habitat the rarefied species richness was (7.64 ± 0.012, Mean ± SD) at a sample size of 114 individuals. It varied slightly between the seasons with Post-monsoon (7.71 ± 0.04) > Monsoon (7.67 ± 0.09) > Pre-monsoon (7.52 ± 0.14). In the Mangrove habitat the rarefied species richness was (26.81 ± 1.53, Mean ± SD) at a sample size of 132 individuals. It varied slightly between the seasons with monsoon (27.15 ± 1.74) > Post-monsoon (26.88 ± 2.67) > Pre-monsoon (26.39 ± 0.01).

Richness comparison between seasons: The rarefaction curves showed clear differences in species richness within seasons. Even after standardizing sampling effort to a total of 3615 individuals in Pre-monsoon season, 2677 individuals in Monsoon season and 5181 individuals in Post-monsoon season. Comparing the mean species richness In Pre-monsoon, with a standard value of 11 individuals per site, the rarefied species richness was higher in PO (9.52 ± 0.06, Mean ± SD). Total mean rarefied richness was 7.24 ± 1.30. For Monsoon, with a standard value of 12 individuals per site, it was higher in PO with 10.23 ± 0.04 species. Total mean rarefied richness was 8.4 ± 1.21. Finally, in Post-monsoon season with a standard value of 38 individuals per site, found higher rarefied richness in PK (24.88 ± 1.66 species). Total mean rarefied richness was 16.49 ± 4.11.

Regional diversity: Assessment of spider diversity in the study areas located in two districts (Kasargod and Kannur) of Northern Kerala was carried out in this study. Different facets of local diversity (abundance, species richness, diversity), and the contribution of species differentiation (beta diversity) among localities and habitat types to the composition of regional diversity were analysed. This study resulted in a total of 11308 individuals of 257 spider species/morphospecies. Local diversity differs among two sampled localities. At the habitat level, the different facets of biodiversity followed a clear pattern, where sacred grove spiders of Kannur have higher abundance, species richness and diversity than Kasargod.

Guild structure: Guild composition varied between the five habitat types. The most abundant guilds were the ambush hunters (2570n), orb web (2496n) and other hunters (5028n), they together constitute more than half of the total species collected (total =11308n). The composition of the guild structure as follows: 45% other hunters, 23% ambush hunters, 22% orb webs, 2% ground hunters, sheet web, specialists and less than 1% sensing web.

6.2 Conclusion

Worshiping nature is an expression of the special relationship between people and the rest of nature. It offers us an opportunity to remind ourselves of the deep and meaningful relationships that many religions and faith communities have with nature, demonstrated by their devotion to sacred natural sites. The nurturing of these sacred groves, in diverse settings - both cultural and natural - helps give meaning to our lives. At the same time, we need to be aware about how we are treating such areas. Why are many of them being abandoned, degraded or lost completely? So we can put forth most appropriate kinds of land use and resource management practices. IUCN is working with local communities, faith groups, scientists and resources managers (including from the private sector) in all parts of the world to answer such questions. IUCN will continue to strongly support sacred natural sites and contribute to these discussions by facilitating dialogues and partnerships, and drawing the attention of our members, decision-makers and the general public to the many values of these sacred sites that give nature its special meaning for human well-being. For the improved understanding and importance of sacred groves grab the attention of a wider audience in many ways by making an awareness about the different aspects of sacred groves like, high biodiversity values of SG'S, documentation of losses of SG'S, threats and pressure that may still face, multi-faceted and complex cultural dimensions of SG'S, differences and the commonalities of SG'S, inter disciplinary approach of people are collaborating on understanding and protecting these special places and make recommendations to decision makers at local, national and international levels in support of conserving sacred sites (Verschuuren et al., 2010).

Global development brought the significant changes in these indigenously protected areas, many of which affects sacred natural sites and their custodian communities. They are, population increase, modernity and erosion of traditional culture, biodiversity loss, habitat and species decline, species extinction and ecosystem damage, industrialization of agriculture, forestry, fisheries or other types of land and sea use, extractive and energy industries, growth of cities, urbanization and transport networks, increased conflict over resources, weakened livelihood systems and poverty, social and political changes and conflicts in the geopolitical realm, globalization of the dominant economic model based on continual growth, detached from ecological realities, decline in spiritual values and climate change.

Many of the drivers of these global changes are mutually reinforcing and affect cultural and biological diversity and the many services that SG'S provide to human well- being. Generating a greater recognition of the sacred dimensions of nature focused on SG'S is expected to be an important means of building public support for the policies that conserve biodiversity, ecosystem services and the diversity of human adaptations to a changing environment.

Preservation in the form of declaration of protected areas has been a key conservation reaction of the 20^{th} century. On the other hand, sustainable use in the form of sacred groves is an ancient practice, especially in India. Both approaches have contributed to conservation of biodiversity and both face daunting challenges (Gadgil & Chandran, 1992; Rodgers, 1994). The major challenges or threats faced by the sacred groves are as follows - decline of traditional institutions, decrease of traditional basic education, insufficient transmission of knowledge to the coming generations, changing attitudes and lifestyle, development of individualism, administrative territory subdivision by the state, mixing of cultures, ignorance of the importance of sacred sites, human population growth, clearing for agriculture, encroachment by neighbours and urban development.

In the present context, this study suggest the principal measures to community members for following the sustainable management and conservation of sacred groves are: raising public awareness of values of sacred groves at national and international levels, map and demarcate the boundaries of sacred groves, improve knowledge of sacred groves, defining a legal status for sacred groves while recognizing them as the property of the entire community, developing guidelines for the management of sacred groves, reviving traditional knowledge while encouraging parents to transmit their conservation knowledge, involving all stake holders especially women, young people, elites, state institutions, religious institutions and NGOs in all reflections related to the management of sacred groves in a participatory way and clearly defining the role of each.

The present study indicates that sacred groves of Northern Kerala are community conserved biodiversity area with varied degree of socio-cultural and ecological dimensions. In the present scenario, the sacred groves are facing threats of differing intensity and thus location-specific conservation and protection activities have to be under taken. Data obtained from the inventory of spiders conducted through this study would be used as a database for future studies. Furthermore, to promote the value of sacred grove for biodiversity conservation, there would be a need for proper scientific assessment of sacred groves to demonstrate their relevance to habitat and species protection. This should include state-wide inventories and the documentation of biodiversity status of sacred groves.

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PUBLICATIONS

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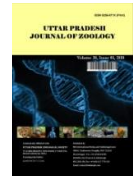

CHECKLIST OF SPIDERS FROM THE SACRED GROVES OF NORTHERN KERALA, INDIA

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AUTHORS' CONTRIBUTIONS
This work was carried out in collaboration between both authors. Author NVS designed the study, wrote the protocol and first draft of the manuscript. Author AVS managed the literature searches and analyses of the study. Both authors read and approved the final manuscript.

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ABSTRACT

Sacred groves are important gene pools and the first major effort of the society to recognize and conserve biodiversity. In addition to preserving the biodiversity, they help in soil and water conservation. At present, the area covered by sacred groves in India is gradually declining owing to various socioeconomic factors. Like other groves of Kerala, Sacred groves of North Malabar region are also facing the threat of extinction from increasing anthropogenic activities. Sacred groves of Northern Kerala have rich and diverse flora that supports an important array of fauna. This study presents a checklist of the spider fauna in 15 the sacred groves. It is a pioneering study and no other studies done in this area. The sampling methods such as line transect method; handpicking in ground and strata, and beating were used to catch specimens. The caught specimens were preserved and identified to species and genus level using available literature. A total of 257 species of spiders belonging to 130 genera and 28 families were identified from the study area. The dominant family was Araneidae followed by Salticidae, Theridiidae, and Thomisidae, these families represent roughly the 47% of the total abundance. Five families were observed as rare in the study area with less than 2 individuals.

Keywords: Araneofauna; India; richness; sacred natural sites.

1. INTRODUCTION

Appropriate documentation of biodiversity is vital for its sustainable management and conservation by the timely monitoring of the rate of species loss. Checklists form a fundamental part of systematic documentation. Species identified from different parts of the world are added to global databases and catalogues, which form a core of taxonomy and indirectly contribute to the conservation of

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biodiversity. Taking into consideration the rising level of anthropogenic threats to biodiversity, an inventory and proper documentation of biodiversity is indeed urgently [1]. The World Spider Catalog [2] documented a total of 48,624 species belonging to 4,172 genera and 128 families. India has around [3] 60 of the 128 spider families and 1,842 of the 48,624 species known worldwide. More number of species undoubtedly await discovery. A world without spiders would have serious problems affecting the whole food chain and cause an imbalance in the ecosystem [4] however; their study has always remained neglected in sacred groves.

India is exceptionally rich in sacred groves with around 13,720 sacred groves spread across 19 States [5]. The state of Kerala harbours 1500 to 2000 sacred groves, the extent of which varies from 0.004ha to >20 ha [6]. As reported by Induchoodan [7] 361 sacred groves in Kerala having an area of more than 0.02ha. Many small sacred groves have been lost in recent years and no recent data are available to assess their status [8]. Sacred groves are supposed to be relics of ancient vegetation and remnants of larger forest tracts [9]. Documenting and understanding spider assemblages in tropical forests in the present context of rapid loss is an important task [10].

Certain spiders have the ability to indicate habitat alteration in rain forest fragments of the Western Ghats [10]. Spider guilds specific to microhabitats like bark, foliage and ground did also show strong association levels with potential to indicate changes in these micro habitats [11].

Sacred groves play an important role in ensuring smooth ecosystem services such as clean environment that is, air, soil and water conservation, flora and fauna conservation, temperature control and conservation of traditional knowledge. Microclimatic features, soil cover, litter cover, water resources, highly diverse flora of these areas supports varied array of fauna. So that they are of central importance as far as ecological conservation and policy regarding conservation and management of forest at state and national levels are concerned [9].

The reports of Jayarajan [12] recorded 8 species of spiders from the sacred groves of northern Kerala. Sivaperuman [13] conducted a study in Kerala during 1997-1998 over a period of 4 months in 3 sacred groves. This study was recorded only 14 species by visual search method. A correlation between size of the sacred grove and spider species richness was expected but not found. Another studies conducted in the South Western Maharashtra [14] seven sacred groves were surveyed once each for spiders among potential indicator taxa. The enlisting of spiders of groves of Rathnagiri, Maharashtra [15] recorded 377 species belonging to 39 families from 102 groves. Sarmistha [16] recorded 5 species of spiders from sacred trees of Sherampore, Hoogly, and West Bengal. Report of Palita [17] recorded 81 species of spiders from six sacred groves of Odisha.

The sacred groves in Kerala are known as in different names depending upon the ownership and deities to whom these groves are dedicated. They are Ayyappan kavu or Sasthan kavu, Bhagavathy kavu or Amman kavu, Vanadevatha and Cheema or Cheerumba depending upon the ownership and deities to whom these groves are dedicated. The kavu's are two kinds - some are in the midst of human habitation and in most cases attached to households or not far away from them. In Kerala, based on management systems, sacred groves can be categorised into three types [18]. They are, managed by individual families, by groups of families and by the statutory agencies for temple management (Devaswom Board). The key question is how habitat of sacred groves influences spider diversity. The aim of the present study is to provide data on the spider assemblages in sacred groves of Kannur and Kasargod Districts of Kerala, India; to produce a checklist of spiders of from sacred groves of Northern Kerala.

2. MATERIALS AND METHODS

The study areas were located in Kasargod and Kannur districts of northern Kerala. Kannur is one of the 14 districts along the west coast in the state of Kerala, it is located between is 11°52′8.04′′ North latitude and 075° 21′19.66′′ East longitude and an area of 2,966 km^2. Kasargod district is one of the 14 districts in the Southern Indian state of Kerala. It is located between is 12°30′0′′ North latitude and 075° 0′0′′ East longitude and an area of 1,992 km^2. The following 15 sacred groves were selected for the study according to the area and habitat type. Details are given in Fig. 1 and Table 1.

The general floristic composition and physiognomy of vegetation of the sacred grove are typically like the low level evergreen forest. The vegetation in undisturbed groves is luxuriant and comprises several stories of trees mixed with shrubs, lianas, herbs, macro fungi, algae and water plants. The soil is rich in humus and covered with thick litter. Floristic variations have occurred in many sacred groves exposed to human and animal interferences and climatic and edaphic changes [18].

Table 1. Details of sites covered for spider inventory in sacred groves of Kasargod and Kannur Districts

Sl. no	Name of sacred groves	Location	Co-ordinates	Area of sacred grove (ha)	Vegetation	Diety	District
1	Edaylakadu	Thrikkarippoor	12°08'10.72'' N 75°09'23.88'' E	6.40	Evergreen type	Bhagavathynagam	Kasrgod
2	Kammadom Kavu	West elery	12°18'41.0''N 75°18'55.8'' E	24.00	Evergreen with fresh water myristica swamp	ThayyiParadevatha	Kasrgod
3	Koyithatta Sree Dharma Sastha Kavu	Koyithatta	12°17'11.4'' N 075°14'53.88'' E	3.00	Evergreen type	Sasthavu	Kasrgod
4	Mannam Purathukavu	Neeleswaram	12°15'27.6'' N 75°07'59.4'' E	2.83	Semi ever green type	Thaipardhevatha,Nagam	Kasrgod
5	Malliyodan Kavu	Konnakkad	12°22'1.24'' N 75°19'22.8'' E	3.00	Semi ever green type	Malliyodandevasthanam	Kasrgod
6	Payyamkulam Kavu	Kinaur,Karinthalam	12°17'41.7' N 75°12'18.96'' E	5.00	Evergreen type	Poomalabhagavthy	Kasrgod
7	Periyanganam Sree Dharma Sastha Kavu	Periyanganm	12°18'36.0'' N 75°15'52.56'' E	2.00	Semi ever green type	Sasthavu	Kasrgod
8	Puthiya Parambathukavu	Puthukky, Neeleswaram	12°15'34.56'' N 75°07'41.16.'' E	3.00	Semi ever green type	Bhagavathy	Kasrgod
9	Chama Kavu	Vellur, Payyannur	12°09'07.03'' N 75°12'35.5'' E	3.640	Evergreen type	ThayyiParadevatha	Kannur
10	Konginichal Kavu	Thulluvadakkam, Alappadambu	12°8'36.41'' N 75°14'18.76'' E	3.320	Evergreen type	NarambilBhagavathy	Kannur
11	Madayi Kavu	Eripuram, madayi	12°02'05.5'' N 75°21'50.0'' E	6.06	Moist deciduous	ThayyiParadevatha	Kannur
12	Neeliar Kottam	Morazha, Anthoor	11°56'03.8'' N 75°21'50.0'' E	8.7	Evergreen type	Neeliamma	Kannur
13	Palathara Kavu	Karivellur	12°10'07.0'' N 75°12'07.9'' E	1.00	Evergreen type	Bhagavathy	Kannur
14	Poongottu Kavu	Mattannur, Poongottu	11°55'14.7'' N 75°36'58.9'' E	14.60	Fresh water myristica swamp	Sasthavu	Kannur
15	Thazhe Kavu	Thekkumbadam, Mattul	11°57'59.3'' N 75°17'50.9'' E	7.52	Mangrove	Bhagavathy	Kannur

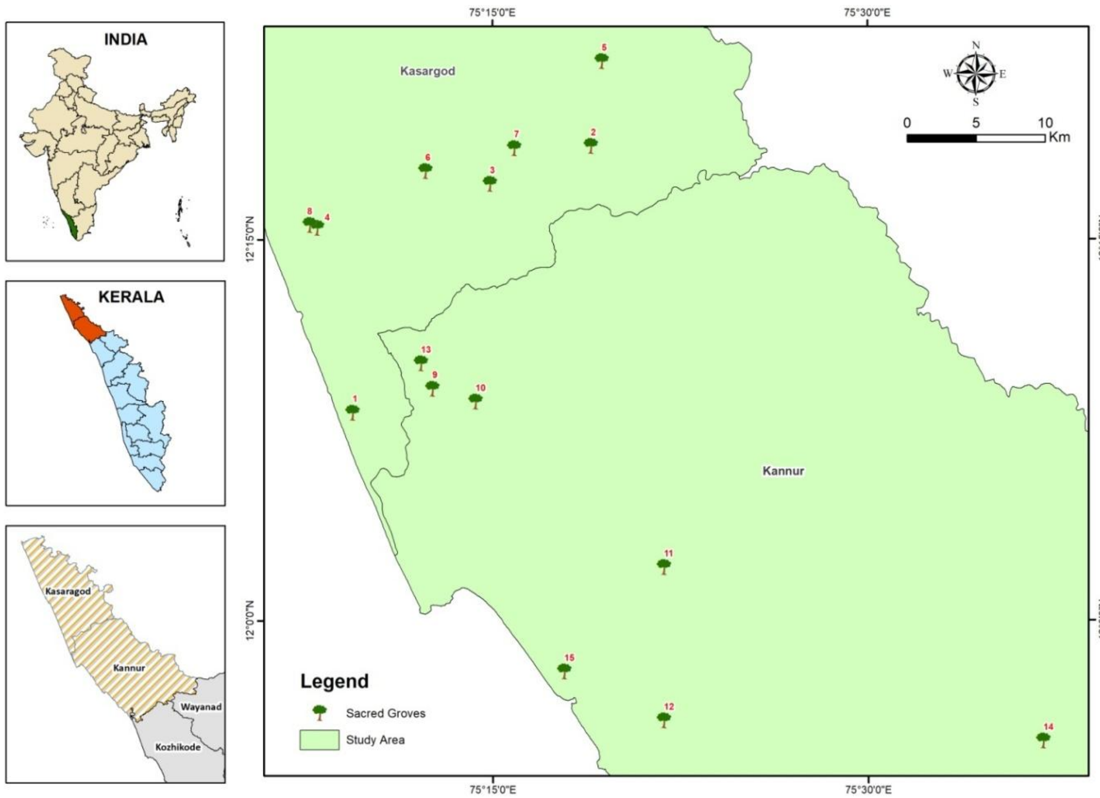

Fig. 1. Map showing the study area

Generally vegetation of the study area divided into evergreen, semi-evergreen, freshwater myristica swamp, moist deciduous and mangroves. General climatological factors in sacred groves like average annual rainfall is in between 2500 and 2680 mm. May and October are the wet months while November to April is relatively dry, Relative humidity is always greater than 55% and attain 100% during rainy season. Mean maximum temperature is between 25°C and 30°C while mean minimum temperature is about 18°C. The soil is sandy loam to laterite and acidic with pH value ranging from 4.8 to 5.2.

Spider sampling was carried out from 2016 February till 2018 January. The study period is divided into Pre-monsoon, Monsoon and Post monsoon seasons and samples collected from each season. A total of 90 samples collected during the study from 15 sacred groves. Spiders were collected in the morning from 7.00 am to 10 .00 am and evening from 4.00 pm to 7.00 pm. Line transect method [19] were adopted in this study. A total of 30 fixed transects (100 m in length) were established across the 15 sacred groves. Spiders were collected along 100 m transect length of two transects per habitat. Each transect was sampled 1 hour, thus adding up to 1-2 hours for a study area. Standard sampling techniques such vegetation beating, litter sampling, ground hand collection, aerial hand collection and sweep netting were employed to collect the spiders from their own habitats. To avoid the edge effect transects were fixed 25 m inside from the boundary.

All specimens were kept in separate vials with proper labeling and other notes of taxonomic importance. They were sorted and an effort was made to identify live specimen using reference books like Sebastian [20] up to at least family or genus level and recorded from the field itself. They were preserved in 70% ethyl alcohol. Some adults of each species or morphospecies were preserved as voucher specimen with proper cataloguing. They were subjected to detailed taxonomic examination. Adult specimens identified by the detailed examination of genital structures like epigyne and palp. Juveniles also identified by morphological examination. Other methods like standard taxonomic keys, standard literatures [20,21,22,23] and expert advice. (Mrs. Sarah J. Kariko, Associate of the Department of Organismic and Evolutionary Biology, Harvard University and John Caleb, Reasearch Associate, Zoological Survey of India, Kolkata) also used. They will be retained at Centre for Animal Taxonomy and

Ecology, Department of Zoology, Christ College (Autonomous) Irinjalakuda, Thrissur, Kerala. For future reference it will be deposited in appropriate collections.

Collected specimens were transported to Centre for Animal Taxonomy and Ecology, Department of Zoology, Christ College (Autonomous) Irinjalakuda, Thrissur, Kerala, India. Comparatively large specimens were photographed in the field itself before collection with the help of special digital camera and lens (Canon EOS 5D digital SLR and Canon 180 mm macro lens). Preserved specimens were examined under a stereo zoom microscope (Leica-M205C) in the laboratory for taxonomic identification. Identification and classification was also done on the basis of morphometric characters of various body parts. Most of the literature for this purpose was sourced from [2] which have an almost complete global repository of taxonomic literature on spiders. Similarly, websites such as spiders of Europe [24]. Aranea of India [3] etc. were helpful for the study.

3. RESULTS

Present study shows richness of 257 species, consist of 130 genera belonged to 28 families, including morphospecies. Details of family and genus richness represented in Fig. 2 & Table 2. It was observed that 19% species comes under family

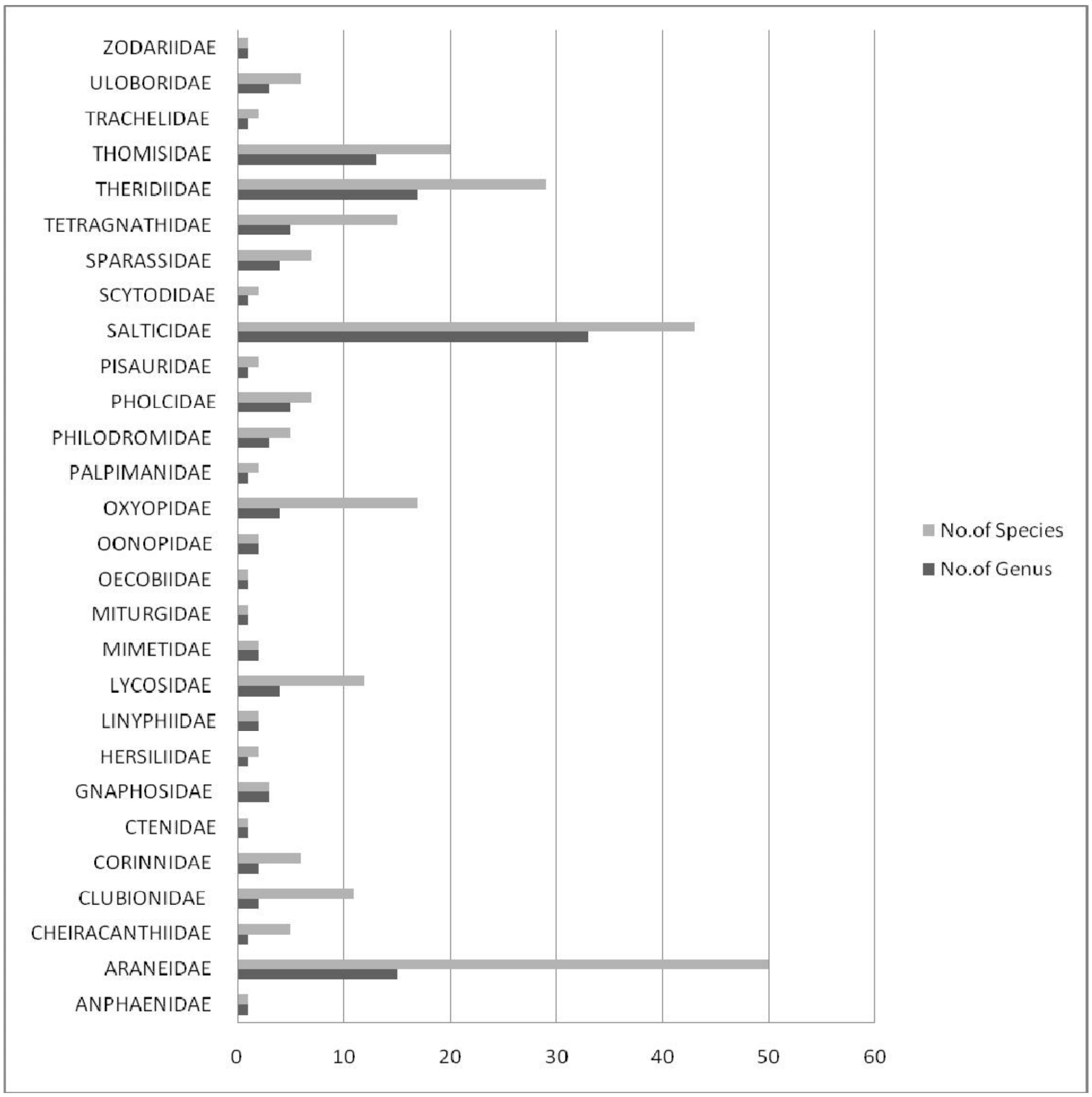

Fig. 2. Representation of genera and species in different spider families of the entire spider assemblage recorded in the study area

Araneidae was dominant in terms of taxonomic richness with 15 genera, 50 species. 16% species comes under family Salticidae with 33 genera, 43 species. Followed by 7% comes under family Theridiidae with 17 genera, 29 species and 5% Thomisidae with 13 genera, 20 species. Families like, Anphaenidae, Ctenidae, Miturgidae, Oceobidae and Zodariidae were least dominant with a single genus and species. Most abundant species in these study areas were *Nephila pilipes*, *Oxyopes birmanicus, Pholcus phalangioides, Epeus indicus, Epeus tener, Indopadilla insularis, Hyllus semicupreus, Phintella vittata, Rhene flavigera, Stenaelurillus lesserti, Telamonia dimidiata, Tylorida striata. Tylorida ventralis, Oxytate virens, Strigoplus netravati, Tmarus kotigeharus, Xysticus audax, Xysticus minutus.*

Table 2. Checklist of spiders collected from the study area

	I) ANYPHAENIDAE (Bertkau, 1878)
1	*Anyphaena* sp.(Sundewall, 1833)
	II) ARANEIDAE (Clerck, 1757)
2	*Anepsion maritatum* (O. Pickard-Cambridge, 1877)
3	*Arachnura* sp. (Vinson, 1863)
4	*Araneus* sp. I (Clerck, 1757)
5	*Araneus* sp. II (Clerck, 1757)
6	*Araneus sp.* III (Clerck, 1757)
7	*Araneus* sp. IV(Clerck, 1757)
8	*Araneus* sp. V (Clerck, 1757)
9	*Argiope aemula* (Walckenaer, 1841)
10	*Argiope catenulata* (Doleschall, 1859)
11	*Argiope pulchella* (Thorell, 1881)
12	*Porcataraneus bengalensis* (Tikader, 1975)
13	*Chorizopes* sp. (O. P. Cambridge, 1870)
14	*Chorizopes quadrituberculata* (Roy et al., 2014)
15	*Cyclosa argenteoalba* (Bösenberg & Strand, 1906)
16	*Cyclosa confraga* (Thorell,1892)
17	*Cyclosa hexatuberculata* (Tikader, 1982)
18	*Cyclosa spirifera* (Simon, 1889)
19	*Cyclosa* sp. (Menge, 1866)
20	*Cyrtarachne* sp. (Thorell, 1868)
21	*Cryptaranea* sp. (Court & Forster, 1988)
22	*Cyrtophora cicatrosa* (Stoliczka, 1869)
23	*Cyrtophora citricola* (Forsskal, 1775)
24	*Eriovixia excelsa* (Simon, 1889)
25	*Eriovixia laglaizei* (Simon, 1877)
26	*Eriovixia palawanesis* (Barrion&Litsinger, 1995)
27	*Eriovixia sakiedaorum* (Tanikawa, 1999)
28	*Eriovixia* sp. I (Archer, 1951)
29	*Eriovixia* sp. II (Archer, 1951)
30	*Eriovixia* sp. III (Archer, 1951)
31	*Gasteracantha dahli* (Sundevall, 1833)
32	*Gasteracantha geminata* (Fabricius, 1798)
33	*Gasteracantha hasselti* (C. L. Koch, 1837)
34	*Gasteracantha kuhli* (C. L. Koch, 1837)
35	*Gea subarmata* (Thorell, 1890)
36	*Gea* sp. (C. L. Koch, 1843)
37	*Herennia multipuncta* (Doleschall, 1859)
38	*Nephila pilipes* (Fabricius, 1793)
39	*Neoscona crucifera* (Lucas, 1838)
40	*Neoscona molemensis* (Tikader & Bal, 1980)
41	*Neoscona mukerjei* (Tikader, 1980)
42	*Neoscona* sp. I (Simon, 1864)
43	*Neoscona* sp. II (Simon, 1864)
44	*Neoscona* sp. III (Simon, 1864)

45	*Neoscona theisi* (Walckenaer, 1841)
46	*Neoscona vigilans* (Blackwall, 1865)
47	*Parawixia dehaani* (Doleschau, 1859)
48	*Parawixia* sp. (F.O Pickard-Cambridge ,1904)
49	*Paraplectana* sp. (BritoCapello, 1867)
50	*Poltys* sp. (C. L. Koch, 1843)
51	*Zygiella indica* (Tikader & Bal, 1980)
	III) CLUBIONIDAE (Wagner, 1887)
52	*Clubiona bilobata* (Dhali et al., 2016)
53	*Clubiona drassodes* (O. Pickard-Cambridge, 1874)
54	*Clubiona hexadentata* (Dhali et al., 2016)
55	*Clubiona modesta* (L. Koch, 1873)
56	*Clubiona pila* (Dhali et al., 2016)
57	*Clubiona tridentata* (Dhali et al., 2016)
58	*Clubiona* sp. I (Latreille, 1804)
59	*Clubiona* sp. II (Latreille, 1804)
60	*Clubiona* sp. III (Latreille, 1804)
61	*Clubiona* sp. IV (Latreille, 1804)
62	*Pristidia* sp. (Deeleman-Reinhold, 2001)
	IV) CORINNIDAE (Karsch, 1880)
63	*Castianeria zetes* (Simon, 1897)
64	*Castianeira* sp. I (Keyserling, 1879)
65	*Castianeira* sp. II (Keyserling, 1879)
66	*Castianeira* sp. III (Keyserling, 1879)
67	*Castianeira* sp. IV (Keyserling, 1879)
68	*Corinna* sp. (C. L. Koch, 1841)
	V) CTENIDAE (Keyserling, 1877)
69	*Ctenus cochinensis* (Gravely, 1931)
	VI) CHEIRACANTHIIDAE (Wagner,1887)
70	*Cheiracanthium danieli* (Tikader, 1975)
71	*Cheiracanthium melanostomum* (Thorell, 1895)
72	*Cheiracanthium punctorium* (Villers, 1789)
73	*Cheiracanthium* sp. I (C. L. Koch, 1839)
74	*Cheiracanthium* sp. II (C. L. Koch, 1839)
	VII) GNAPHOSIDAE (Pocock, 1898)
75	*Drassodes* sp. (Westring, 1851)
76	*Scotophaeus blackwalli* (Thorell, 1871)
77	*Zelotes* sp.(Gistel, 1848)
	VIII) HERSILIIDAE (Thorell, 1870)
78	*Hersilia savignyi* (Lucas, 1836)
79	*Hersilia* sp.(Audouin, 1826)
	IX) LINYPHIIDAE (Blackwall, 1859)
80	*Linyphia striata* (Laterile, 1804)
81	*Neriene sundaica* (Simon, 1905)
	X) LYCOSIDAE (Sundevall, 1833)
82	*Hippasa agelenoides* (Simon, 1884)
83	*Hippasa greenalliae* (Blackwall,1867)
84	*Hippasa* sp. (Simon, 1855)
85	*Lycosa phipsoni* (Pocock, 1899)
86	*Lycosa mackenziei* (Gravely, 1924)
87	*Pardosa birmanica* (Simon, 1884)
88	*Pardosa chambaensis* (Tikader & Malhotra, 1976)
89	*Pardosa kupupa* (Tikader, 1970)
90	*Pardosa pseudoannulata* (Bosenberg& Strand, 1906)
91	*Pardosa sumatrana* (Thorell, 1890)
92	*Paradosa* sp. (C. L. Koch, 1847)

93	*Trochosa* sp. (C. L. Koch)
	XI) MIMETIDAE (Simon, 1881)
94	*Ero* sp. (C. L. Koch, 1836)
95	*Mimetus* sp. (Hentz, 1832)
	XII) MITURGIDAE (Simon, 1886)
96	*Systaria* sp. (Simon, 1897)
	XIII) OECOBIIDAE (Blackwall, 1862)
97	*Oecobius* sp. (Lucas, 1846)
	XIV) OONOPIDAE (Simon,1890)
98	*Gamasomorpha* sp. (Karsch, 1881)
99	*Opopaea* sp. (Simon, 1892)
	XV) OXYOPIDAE (Thorell, 1870)
100	*Hamadruas sikkimensis* (Tikader,1970)
101	*Hamadruas* sp. I (Deeleman-Reinhold, 2009)
102	*Hamadruas* sp. II (Deeleman-Reinhold, 2009)
103	*Hamataliwa* sp. I (Keyserling, 1887)
104	*Hamataliwa* sp. II (Keyserling, 1887)
105	*Oxyopes birmanicus* (Thorell, 1887)
106	*Oxyopes javanus* (Thorell, 1887)
107	*Oxyopes lineatipes* (C. L. Koch, 1847)
108	*Oxyopes pandae* (Tikader, 1969)
109	*Oxyopes salticus* (Hentz, 1845)
110	*Oxyopes shweta* (Tikader, 1970)
111	*Oxyopes sikkimensis* (Tikader, 1970)
112	*Oxyopes* sp.I (Latreille, 1804)
113	*Oxyopes* sp. II (Latreille, 1804)
114	*Oxyopes* sp. III (Latreille, 1804)
115	*Peucetia ananthakrishnani* (Murugesan et al., 2006)
116	*Peucetia viridana* (Stoliczka, 1869)
	XVI) PALPIMANIDAE (Thorell, 1870)
117	*Palpimanus* sp. I (Dufour, 1820)
118	*Palpimanus* sp. II (Dufour, 1820)
	XVII) PHILODROMIDAE (Thorell, 1870)
119	*Philodromus* sp. I (Walckenaer, 1826)
120	*Philodromus* sp. II (Walckenaer, 1826)
121	*Thanatus parangvulgaris* (Barrion & Litsinger, 1995)
122	*Thanatus* sp. (C. L. Koch, 1837)
123	*Tibellus elongatus* (Tikader, 1960)
	XVIII) PHOLCIDAE C. L. Koch, 1850
124	*Artema atlanta* (Walckenaer, 1837)
125	*Crossopriza lyoni* (Blackwall, 1867)
126	*Pholcus phalangioides* (Fuesslin, 1775)
127	*Pholcus* sp. *I* (Walckenaer, 1805)
128	*Pholcus* sp. II (Walckenaer, 1805)
129	*Smeringopus pallidus* (Blackwall, 1858)
130	*Uthina* sp.(Simon,1893)
	XIX) PISAURIDAE (Simon, 1890)
131	*Dendrolycosa gitae* (Tikader, 1970)
132	*Dendrolycosa* sp. (Doleschall, 1859)
	XX) SALTICIDAE (Blackwall, 1841)
133	*Acragas* sp. (Simon, 1900)
134	*Ajaraneola* sp.(Wesolowska & A. Russell-Smith, 2011)
135	*Asemonea tenuipes* (O. P. Cambridge, 1869)
136	*Attulus* sp. (Simon, 1889)
137	*Bianor narmadaensis* (Tikader, 1975)
138	*Brettus albolimbatus* (Simon, 1900)

139	*Brettus anchorum* (Wanless, 1979)
140	*Brettus* sp. I (Thorell,1895)
141	*Brettus* sp. II (Thorell,1895)
142	*Carrhotus viduus* (C. L. Koch, 1846)
143	*Chalcotropis pennata* (Simon, 1902)
144	*Chrysilla volupe* (Karsch, 1879)
145	*Epeus indicus* (Proszynski, 1992)
146	*Epeus tener* (Simon, 1877)
147	*Epocilla aurantiaca* (Simon, 1885)
148	*Euophrys omnisuperstes* (Wanless, 1975)
149	*Eupoa* sp. (Zabka, 1985)
150	*Evarcha* sp. (Simon, 1902)
151	*Habrocestum* sp.(Simon, 1902)
152	*Hasarius adansoni* (Audouin, 1826)
153	*Hyllus semicupreus* (Simon, 1885)
154	*Indopadilla insularis* (Malamel et al., 2015)
155	*Langona* sp. (Simon, 1901)
156	*Lyssomanes* sp. (Hentz, 1845)
157	*Marpissa decoratedecorata* (Tikader,1974)
158	*Marengo sachintendulkar* (Malamel et al., 2019)
159	*Menemermus bivittatus* (Dufour,1831)
160	*Myrmaplata plataleoides* (O. P. Cambridge, 1869)
161	*Neon reticulatus* (Blackwall, 1853)
162	*Phintella vittata* (C. L. Koch, 1846)
163	*Plexippus paykulli* (Audouin, 1826)
164	*Portia fimbriata* (Doleschall, 1859)
165	*Portia* sp.I (Doleschall, 1859)
166	*Ptocasius yashodharae* (Tikader,1977)
167	*Rhene daitarensis* (Proszynski, 1992)
168	*Rhene flavigera* (C. L. Koch, 1846)
169	*Siler semiglaucus* (Simon, 1901)
170	*Siler* sp. (Simon, 1889)
171	*Stenaelurillus lesserti* (Reimoser, 1934)
172	*Stenaelurillus* sp. (Simon, 1885)
173	*Telamonia dimidiata* (Simon, 1899)
174	*Thiania bhamoensis* (Thorell, 1887)
175	*Thyene* sp. (Simon, 1885)
	XXI) SCYTODIDAE (Blackwall, 1864)
176	*Scytodes fusca* (Walckenaer, 1837)
177	*Scytodes thoracica* (Latreille, 1802)
	XXII) SPARASSIDAE (Bertkau, 1872)
178	*Heteropoda nilgirina* (Pocock, 1901)
179	*Heteropoda venatoria* (Linnaeus, 1767)
180	*Heteropoda* sp. I (Latreille, 1804)
181	*Heteropoda* sp. II (Latreille, 1804)
182	*Pseudopoda straminiosa* (Kundu et al., 1999)
183	*Sinopoda* sp. (Jäger, 1999)
184	*Olios milleti* (Pocock, 1901)
	XXIII) TETRAGNATHIDAE (Menge, 1866)
185	*Guizygiella nadleri* (Heimer, 1984)
186	*Leucauge decorata* (Blackwall, 1864)
187	*Leucauge dorsotuberculata* (Tikader, 1982)
188	*Leucauge pondae* (Tikader, 1970)
189	*Leucauge tessellata* (Thorell, 1887)
190	*Leucauge* sp. (White, 1841)
191	*Opadometa fastigata* (Simon, 1877)
192	*Tetragnatha bituberculata* (L. Koch, 1867)

193	*Tetragnatha cochinensis* (Gravely, 1921)
194	*Tetragnatha elongata* (Walckenaer,1841)
195	*Tetragnatha javana* (Thorell, 1890)
196	*Tetragnatha mandibulata* (Walckenaer,1842)
197	*Tetragnatha* sp.(Latreille,1804)
198	*Tylorida striata* (Thorell, 1877)
199	*Tylorida ventralis* (Thorell, 1877)
	XXIV) THERIDIIDAE (Sundevall, 1833)
200	*Achaearanea durgae* (Tikader,1970)
201	*Achaearanea* sp. (Strand, 1929)
202	*Argyrodes ambalikae* (Tikader, 1970)
203	*Argyrodes amboinensis* (Thorell, 1878)
204	*Argyrodes flavescens* (O. Pickard-Cambridge, 1880)
205	*Argyrodes gracilis* (L. Koch, 1872)
206	*Argyrodes gazedes* (Tiader, 1970)
207	*Argyrodes kumadai* (Chida et al., 1999)
208	*Argyrodes* sp.(Simon, 1864)
209	*Asagena* sp. (Sundevall, 1833)
210	*Chrysso argyrodiforms* (O. Pickard-Cambridge,1882)
211	*Chrysso* sp. (O. Pickard-Cambridge,1882)
212	*Enoplognatha sp*. (Pavesi, 1880)
213	*Episinus* sp. (Walckenaer, 1809)
214	*Meotipa argyrodiformis* (Yaginuma, 1952)
215	*Meotipa multuma* (Murthappa et al.,2017)
216	*Meotipa picturata* (Simon, 1895)
217	*Molione triacantha* (Thorell, 1892)
218	*Neospintharus trigonum* (Hentz, 1850)
219	*Nesticodes rufipes* (Lucas, 1846)
220	*Nihonhimea mundula* (L. Koch, 1872)
221	*Parasteatoda tepidariorum* (C. L. Koch, 1841)
222	*Phycosoma martinae* (Roberts, 1983)
223	*Phycosoma* sp. I (O.Pickard – Cambridge)
224	*Phycosoma* sp. II (O.Pickard – Cambridge)
225	*Phoroncidia septemaculeata* (O. Pickard-Cambridge, 1873)
226	*Rhomphaea projiciens* (O. Pickard-Cambridge, 1896)
227	*Theridula angula* (Emerton,1882)
228	*Thwaitesia margaritifera* (O. Pickard-Cambridge, 1881)
	XXV) THOMISIDAE (Sundevall, 1833)
229	*Amyciaea albomaculata* (O. Pickard-Cambridge, 1874)
230	*Amyciaea forticeps* (O. P. Cambridge, 1873)
231	*Camaricus formosus* (Thorell, 1887)
232	*Camaricus* sp. (Thorell, 1887)
233	*Ebrechtella* sp.(Dahl, 1907)
234	*Indoxysticus minutus* (Tikader, 1960)
235	*Mastira* sp. (Thorell, 1891)
236	*Misumena* sp.(Latreille, 1804)
237	*Oxytate greenae* (Tikader, 1980)
238	*Oxytate virens* (Thorell, 1891)
239	*Ozyptila* sp. (Simon, 1864)
240	*Runcinia roonwali* (Tikader, 1965)
241	*Strigoplus netravati* (Tikader,1963)
242	*Thomisus projectus* (Tikader, 1960)
243	*Thomisus viveki* (Gajbe, 2004)
244	*Tmarus kotigeharus* (Tikader, 1963)
245	*Xysticus audax* (Schrank, 1803)
246	*Xysticus cristatus* (Clerck, 1757)
247	*Xysticus minor* (Charitonov, 1946)

248	*Xysticus minutus* (Tikader, 1960)
	XXVI) TRACHELIDAE (Simon, 1897)
249	*Utivarachna* sp. I (Kishida, 1940)
250	*Utivarachna* sp. II (Kishida, 1940)
	XXVII) ULOBORIDAE (Thorell, 1869)
251	*Miagrammopes* sp. I (O. P. Cambridge, 1870)
252	*Miagrammopes* sp. II (O. P. Cambridge, 1870)
253	*Uloborus danolius* (Tikader, 1969)
254	*Uloborus glomosus* (Walckenaer, 1841)
255	*Uloborus krishnae* (Tikader, 1970)
256	*Zosis geniculata* (Olivier, 1789)
	XXVIII) ZODARIIDAE (Thorell,1881)
257	*Suffasia* sp. (Jocqué, 1991)

4. DISCUSSION

Results of the present study are close to 14% of the known Araneomorph spider species from India [3]. These 257 species belong to 28 families and 130 genera which come to 46.6% and 27.6% of Araneomorph families and species known from India [3]. A list of species (including morphospecies) recorded.

As discussed by Patil [15] conducted study for 4 years in 102 sacred groves of Maharashtra region and recorded 377 species. Whereas our study, which was conducted in 15 sacred groves of Northern Kerala documented 257 species in two years. This may indicates more rich in diversity of spiders in sacred groves of Kerala.

Vegetation structure could influence spiders through a variety of biotic and abiotic factors, temperature, humidity, level of shade cover, abundance, type of prey, refuges from natural enemies and intra guild predation [25,26]. Different families of spiders may use separate portions of the foliage of different habitat without adversely competing for space, quality of microhabitats for shelter and web building are strongly determined by architectural characteristics of the foliage and branches, which in turn influence family composition and individual spider diversity. The availability of great diversity of plants in the sacred groves might be the major contributing factor for the rich diversity of spiders.

Sacred groves are now facing severe threats due to encroachment, improper management, pollution etc., So, proper silvicultural and horticultural practices should be undertaken to improve the plant diversity in the sacred groves and thereby the faunal diversity. It is very vital to recognize that sacred groves are the 'LUNGS AND RESERVOIRS' of a locality. About 75% of groves are facing the threat of extinction. Considering the limitation of short-term studies and that too in very few selected areas, it will be premature to arrive at any conclusion on the correlation between size of the area and the diversity of species. So, a comprehensive long term study would yield further information to help arrive at conclusive results and to understand the role of sacred groves in biodiversity conservation completely.

5. CONCLUSION

A checklist on the spiders of sacred groves of Northern Kerala is given in this paper with 257 species belonged to130 genera from 28 families. Sacred groves with different habitat show significant variation of spider diversity and family composition. Present study indicates a great diversity of spiders was found in the sacred groves. This is the first ever documentation of the spiders of sacred groves from Kerala. However, this by no means is comprehensive and it only suggests the great diversity of the spider fauna of sacred groves and thus warranting future exploration of the spiders of this indigenously protected areas.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Redescription and new records of *Phoroncidia septemaculeata* O. Pickard Cambridge 1873 from India (Araneae: Theridiidae)

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The genus *Phoroncidia* Westwood 1835 is currently represented by 81 species and is cosmopolitan in distribution. Currently, four species are known from India, namely *Phoroncidia aculeata* Westwood 1835, *Phoroncidia maindroni* (Simon 1905), *Phoroncidia septemaculeata* O. Pickard-Cambridge 1873 and *Phoroncidia testudo* (O. Pickard-Cambridge 1873) (World Spider Catalog 2019). *P. septemaculeata* O. Pickard-Cambridge 1873 was described based on a few specimens collected by Mr G. H. K. Thwaites in 1871 from Sri Lanka and it was mostly derived from the somatic features of the species. Recently, Patil *et al.* (2018) reported two subadult males presumed to be *Phoroncidia septemaculeata* from the Maharashtra state in India. Until now, no mature specimen of the species has been reported and its genitalia remains unknown. This paper provides a detailed redescription of *P. septemaculeata*, including illustrations of male and female genitalia for the first time, based on fresh materials collected from different localities in the Coastal Plains and Western Ghats of Kerala state and Coastal plains of Tamil Nadu. Additionally, the current distributional range and new records of the species is mapped.

Fresh materials were collected directly by hand and by beating method. The digital micrographs were taken with Leica DMC4500 camera attached to a Leica M205C stereomicroscope with Leica Application Suite (LAS, Version 4. 3. 0). All measurements are in millimetres (mm). Length of palp and leg segments are as follows: Total (femur, patella, tibia, metatarsus (except palp), tarsus). Genital terminology follow Levi & Levi 1962 and Agnarsson 2004. The specimens are deposited in a reference collection housed at the Centre for Animal Taxonomy and Ecology (CATE), Department of Zoology, Christ College (Autonomous), Irinjalakuda, Kerala, India.

Abbreviations used in the text: ALE—anterior lateral eye, AME—anterior median eye, MA—median apophysis, MOQ—median ocular quad/quadrangle, OUMNH—Oxford University Museum of Natural History, London, PLE—posterior lateral eye, PME—posterior median eye, TTA—theridioid tegular apophysis, WWS—Wayanad Wildlife Sanctuary.

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Taxonomy

Theridiidae Sundevall, 1833

***Phoroncidia* Westwood, 1835**

***Phoroncidia septemaculeata* O. Pickard-Cambridge, 1873 (Figs 1–5)**

Phoroncidia septemaculeata O. Pickard-Cambridge, 1873: 124, pl. 14, f. 8
Phoroncidia aculeata Levi & Levi, 1962: 57, figs 235–237 (Misidentification, not examined)

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Type material: Syntypes female, male and immature female from Sri Lanka, G. H. K. Thwaites leg., 1871, deposited in OUMNH (not examined).

Remarks. Levi & Levi (1962) in their revision of the family Theridiidae, studied and illustrated the type species of the genus, *P. aculeata* Westwood 1835, using non-type specimens deposited at MNHN, Paris. However, it was depicted as lacking long spines on the abdomen in contrast to the original description of *P. aculeata*. These specimens which were collected from Malaya (now Malaysia) were mistakenly determined as *P. aculeata* by Berland at MNHN, Paris (Kariko 2014). Moreover, the illustrations of the body, male and female genitalia of the Malayan specimens looks strikingly similar to that of *P. septemaculeata* (Levi & Levi 1962: figs 235–237). So, this can be considered as evidence of its conspecificity with *P. septemaculeata,* thereby extending the known range of the species to South-East Asia.

Additional material examined: INDIA: Kerala: Ernakulam, Aluva, Manalpuram (10º07'21.3" N 76º21'07.1" E, 2 m alt), 17.X.2015, K. S. Nafin leg., night collection, 1 ♂ (CATE10301D), 1 ♀ (CATE10301A); Wayanad, WWS, Bathery range (11º42'09.8" N 76º20'39.6" E, 868 m alt), 9.VII.2015, P. P. Sudhin & K. S. Nafin leg., beating method, 4 ♂ (CATE10301F); Thrissur, Kodungallur, Sankukulangara Kavu (10º16'39.5" N 76º09'59.6" E, 9 m alt), 7.IV.2017, N. V. Sumesh leg., 1 ♂, 1 ♀ (CATE10301C); Thrissur, Irinjalakuda, Christ college campus (10º21'18.0" N 76º12'47.9" E, 15 m alt), 13.IX.2018, K. S. Nafin leg., 1 ♂, 1 ♀ (CATE10301E). **Tamil Nadu:** Kancheepuram, Vedanthangal Bird Sanctuary (12º32'40.0" N 79º51'14.3" E, 122 m alt), 28.II.2016, Pooja Anilkumar leg., 1 ♀ (CATE10301B).

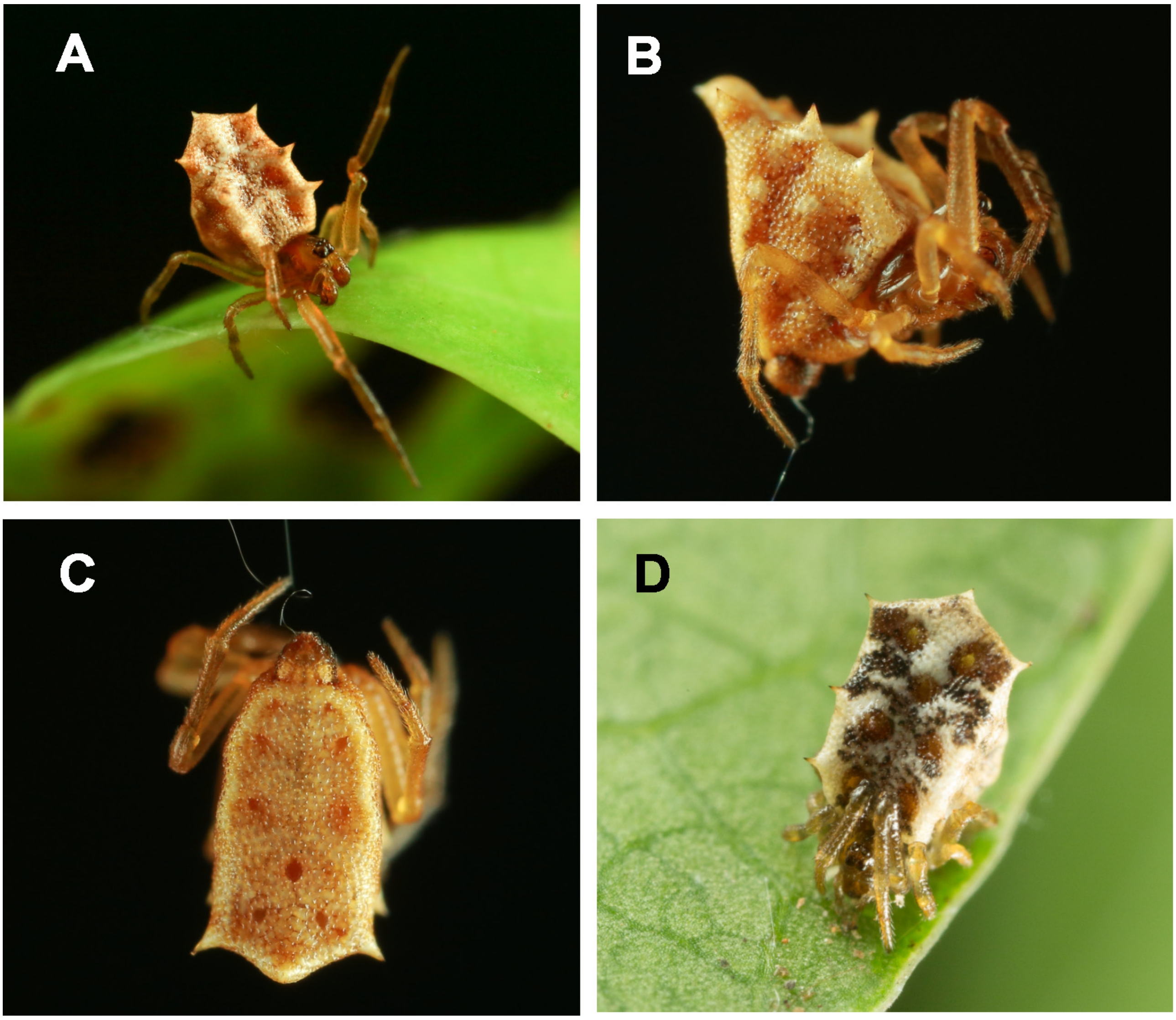

FIGURE 1. Photographs of *Phoroncidia septemaculeata.* A, Male, frontal view. B, Same, lateral view. C, Same, posterior view. D, Immature female from Christ college campus, Kerala, showing different colouration. Photos , Karunnappilli S. Nafin.

Diagnosis. *P. septemaculeata* can be readily distinguished from its congeners by the subtriangular shape of abdomen in lateral aspect, which is slightly humped anteriorly, anterior abdomen adorned with seven short and stout spines

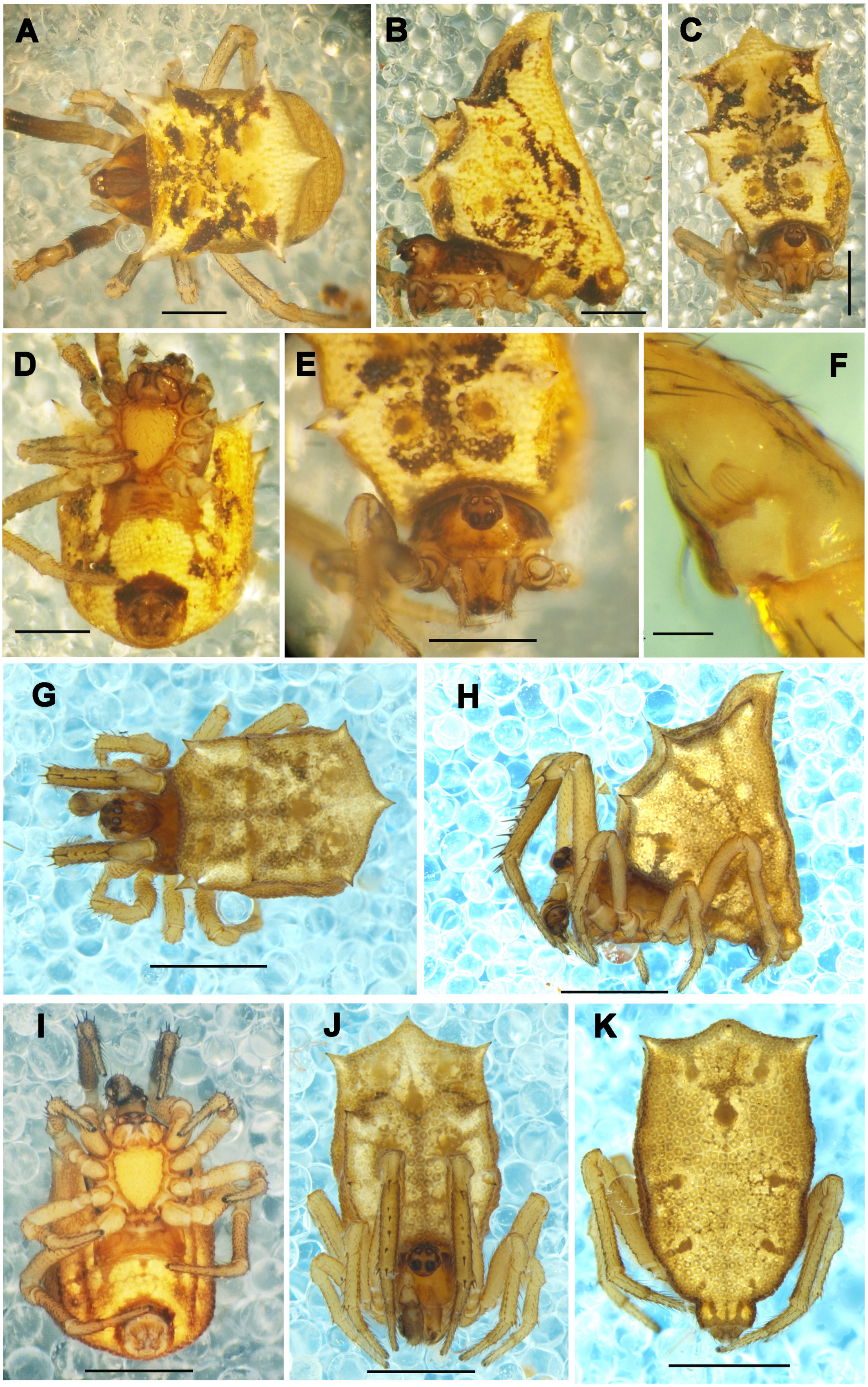

FIGURE 2. *Phoroncidia septemaculeata.* A, Female, dorsal view. B, Same, lateral view. C, Same, frontal view. D, Same, ventral view. E, Same, eye region. F, Male, Patella IV, showing lyriform organ. G, Same, dorsal view. H, Same, lateral view. I, Same, ventral view. J, Same, frontal view. K, Same, posterior view. Scale bars: A–E, 1 mm; F, 0.1 mm; G–K, 1 mm.

originating from protuberances, and shield-shaped posterior. (Figs 1A–C, 2B, H, K). The genitalia of *P. septemaculeata* is closest to *P. americana*, but can be distinguished from the latter by the following features: male palp with conductor on the prolateral side ventral to TTA (positioned retrolaterally, dorsal to embolic base in *P. americana*), embolic base lobed, almost heart-shaped, with a deep v-shaped excavation on prolateral side (irregularly shaped with a shallow excavation distally in *P. americana*); vulva of female genitalia with copulatory duct forming a loop over the posterior half of spermathecae (forms a loop almost over the entire spermathecae in *P. americana*), posterior spermathecae and fertilisation duct slightly bent laterally (bent 180 degrees medially in *P. americana*)(compare Figs 3A–C, E, 4A–C, F with Levi 1955: pl. 1, figs 1, 2, 4–6, 9, Levi & Levi 1962: fig. 245 and Agnarsson *et al.* 2007: fig 49)

Redescription. ***Male*** (CATE10301C) (Figs 1A–C, 2G–K, 3A–C, 4A–D): Measurements: Body length 2.27, carapace length 1.20, width 0.93, height at PME 0.76, sternum length 0.52, width 0.45, clypeus height 0.28, abdomen length 1.86, width 1.49, height 2.78. Eye diameters: AME 0.08, ALE 0.05, PLE 0.04, PME 0.07. Eye interdistances: AME-AME 0.06, AME-ALE 0.03, PLE-PME 0.06, AME-PME 0.08, PME-PME 0.03. Leg formula: I, IV, II, III. Measurement of palp and legs: Palp 1.13 [0.44, 0.12, 0.17, 0.40], leg I 3.51 [1.29, 0.38, 0.86, 0.47, 0.51], leg II 2.03 [0.70, 0.25, 0.44, 0.27, 0.37], leg III 1.77 [0.60, 0.22, 0.38, 0.22, 0.35], leg IV 2.96 [1.00, 0.38, 0.75, 0.36, 0.47].

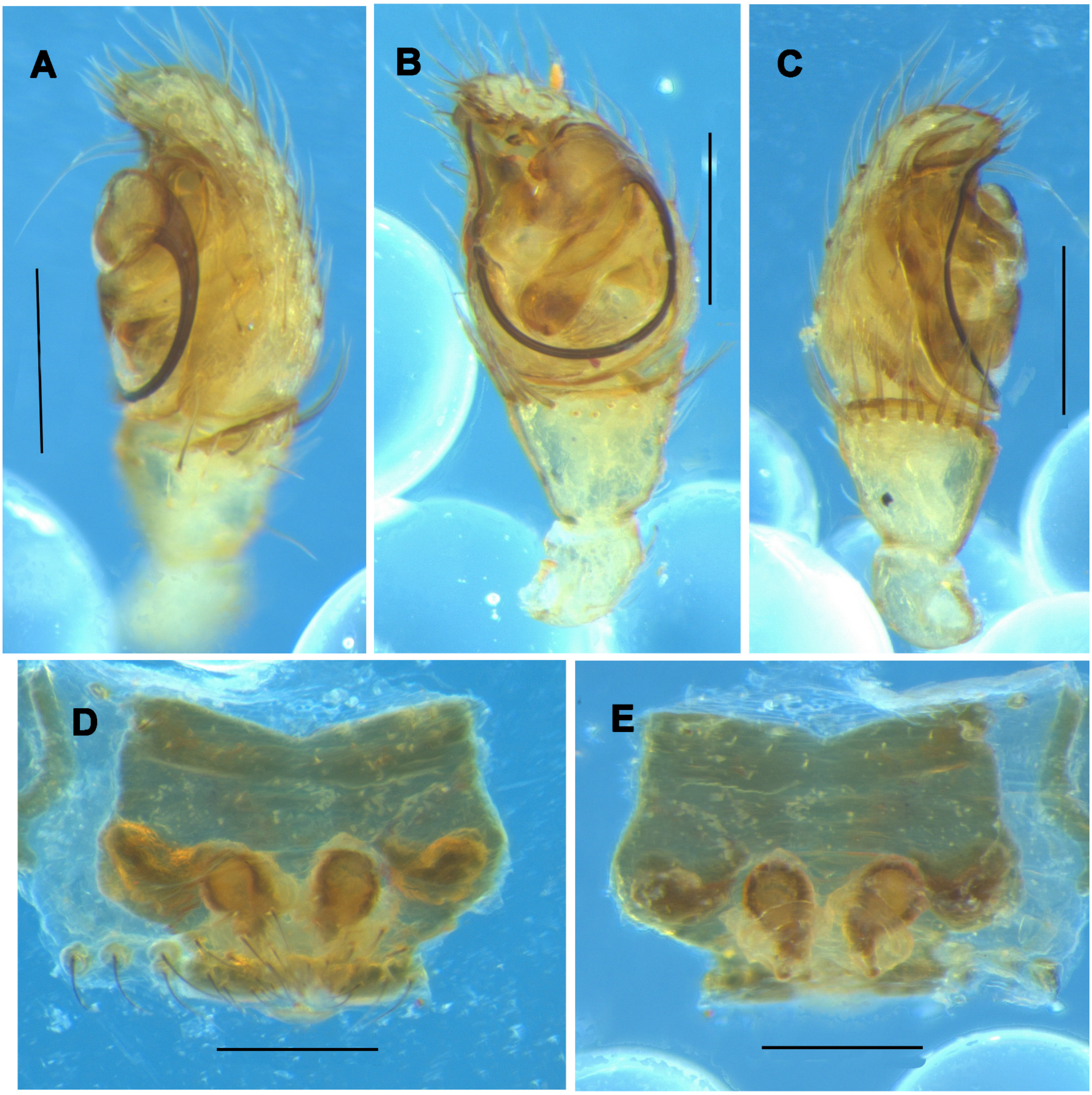

FIGURE 3. *Phoroncidia septemaculeata.* A, Male left palp, retrolateral. B, Same, ventral view. C, Same, prolateral view; D, Epigynum, ventral view. E, Same, dorsal view. Scale bars: A–E, 0.2 mm.

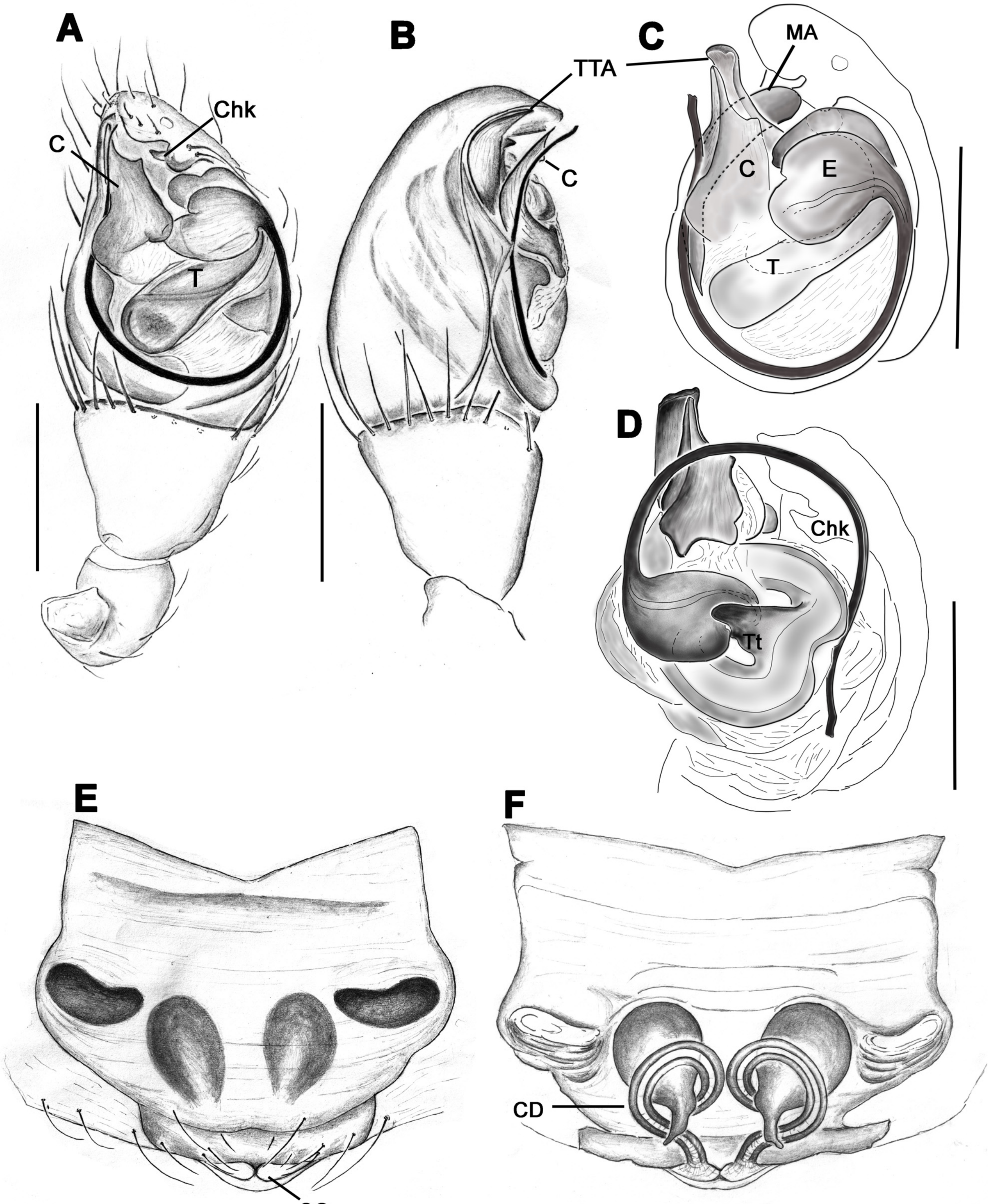

FIGURE 4. *Phoroncidia septemaculeata.* A, Male left palp, ventral view. B, Same, prolateral view. C, Same loosened, ventral view. D, Same, expanded, ventral view. E, Epigynum, ventral view. F, Same, dorsal view. Abbreviations: C—conductor, CD—copulatory duct, Chk—cymbial hook, CO—copulatory opening, E—embolus, MA—median apophysis, Tt—tegular tooth, TTA—theridioid tegular apophysis. Scale bars, 0.2 mm.

Carapace orange-brown, ocular area profoundly produced than female, covered with short spines, longitudinal rows of spines behind PME; AME largest, separated by half their diameter. MOQ almost square, ALE and PLE subequal and touching each other, PME slightly smaller than AME, with tapetum, located on top of the turret; thoracic area devoid of spines; chelicerae small, anterior inner margin with a row of long dark setae, with two closely situated promarginal teeth apically; labium and maxillae pale yellow-brown; sternum yellow-orange, shield-shaped with impressed dots, with sparsely situated long setae (Fig. 2I). Abdomen yellow to pale yellow, subtriangular laterally, projecting over the base of carapace, covered with circular impressed dots with a single setae (Fig. 2H); anteriorly adorned with seven short and stout spines originating from protuberances of abdomen, anteriorly with nine circular orange-brown spots and seven each on lateral and posterior, all symmetrically arranged, few dark patches also present on the anterior face (2G–H, J); ventral abdomen pale yellow, epigastric pale orange-brown, sclerotised. Legs yellow, Leg I longest, with a row of four long, prominent spines on dorsal tibia, tibia II with a row of small spines on prolateral and retrolateral, patella I–III with one dorsal spine, distal tibia I–III with short spines (Fig. 2H); basal half of tibia I–IV with two rows of trichobothria dorsally, lyriform organ present on retrolateral patella I–IV (Fig. F).

Palp. (Figs 3A–C, 4 A–D). Palp yellow, tibia bell-shaped, distal rim with a regular row of long setae; cymbium stout, covered in setae, tapering distally, cymbial hook tapering, hook tip blunt (Fig. 4D); embolus long, originating at 2–3 o'clock, tip of embolus at 12 o'clock; embolic base lobed, almost heart-shaped, with a deep v-shaped excavation on the prolateral (Figs 4A, C); conductor long and wide, positioned ventrally above TTA, with tip of embolus resting on the conductor (Figs 4A–D); TTA surface smooth, tip bent ventrally; MA without hood (Fig. 4C); when palp is expanded, large tegular tooth articulates with v-shaped excavation of embolic base, thereby locking the embolus in place (Fig. 4D).

Redescription. ***Female*** (CATE10301C) (Figs 2A–E, 3D–E, 4E–F): Measurements: Body length 3.36, carapace length 1.41, width 1.21, height at PME 0.93, sternum length 0.71, width 0.61, clypeus height 0.28, abdomen length 1.95, width 2.06, height 3.82. Eye diameters: AME 0.08, ALE 0.06, PLE 0.07, PME 0.07. Eye interdistances: AME-AME 0.07, AME-ALE 0.05, PLE-PME 0.05, AME-PME 0.12, PME-PME 0.04. Leg formula: IV, I, II, III. Measurement of palp and legs: Palp 0.81 [0.27, 0.11, 0.14, 0.29], leg I 3.83 [1.41, 0.44, 0.91, 0.49, 0.58], leg II 2.41 [0.83, 0.39, 0.52, 0.30, 0.37], leg III 2.27 [0.73, 0.28, 0.53, 0.28, 0.45], leg IV 4.12 [1.50, 0.47, 1.06, 0.48, 0.61].

In all details like male, except as follows: Body larger than males, carapace with ocular projection less prominent than males, turret with only a single row of short spines behind PMEs; leg IV longest, tibia I devoid of row of spines. Abdomen pale yellow, with irregular black patches on anterior and lateral faces.

FIGURE 5. Map showing distributional records of *Phoroncidia septemaculeata*. ●—new record, ?— question mark indicates that the type locality in Sri Lanka is unknown and locality in Malaysia is unknown.

Epigynum (Figs 3D–E, 4 E–F). Epigynum orange-brown, highly sclerotised, with a pair of bean-shaped sclerotised spots on the lateral sides, copulatory opening situated on arch-like protrusion beneath posterior margin of epigynal plate

(Fig. 4E); spermathecae separated from each other, pear-shaped, tapering posteriorly, with apical end slightly bent laterally; fertilisation duct bent laterally (Figs 3E, 4F); copulatory duct long, forms a loop around the posterior spermathecae before entering it posteriorly on the dorsal side (Fig. 4F).

Natural history. *P. septemaculeata* spins single almost horizontal thread, and hangs around the centre of the strand during night time.

Distribution. India (Kerala & Tamil Nadu [new record]), Malaysia (Levi & Levi 1962), Sri Lanka (O. Pickard-Cambridge 1873).

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Arthropoda Selecta 28(1): 125–130

A new spider species of the genus *Cocalus* C.L. Koch, 1846 (Araneae: Salticidae: Spartaeinae) from Western Ghats of India

Новый вид пауков из рода *Cocalus* C.L. Koch, 1846 (Araneae: Salticidae: Spartaeinae) из Западных Гат Индии

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KEY WORDS: Aranei, jumping spider, description, distribution map, Kerala, Wayanad Wildlife Sanctuary.

КЛЮЧЕВЫК СЛОВА: Aranei, паук-скакунчик, описание, карта распространения, Керала, Уэйнадский заповедник.

ABSTRACT. A new species of the jumping spider genus *Cocalus* C.L. Koch, 1846 — *C. lacinia* sp.n. (♂♀) — is diagnosed and described from the Wayanad Wildlife Sanctuary, Western Ghats, Kerala, India. A detailed morphological description, diagnostic features and illustrations of the copulatory organs of both sexes are given. The current distribution of the genus in India is mapped as well.

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РЕЗЮМЕ. Диагностирован и описан новый вид пауков-скакунчиков из рода *Cocalus* C.L. Koch, 1846 из Уэйнадского заповедника, Западные Гаты, Керала, Индия: *C. lacinia* sp.n. (♂♀). Приведены детальное морфологическое описание, диагностические признаки и иллюстрации копулятивных органов обоих полов. Также прокартировано современное распространение рода в Индии.

Introduction

The Spartaeine genus *Cocalus* C.L. Koch, 1846 is a poorly studied salticid group confined to the Oriental and Australian Regions. The genus is characterized by the presence of an elevation in the posterior ocular quadrangle in both sexes and the sinuous finger-like projection resting on the male palpal retrolateral tibial apophysis [Wanless, 1981]. Currently, the genus consists of five valid species, of which the only one, *Cocalus murinus* Simon, 1899, has been reported from the Indian subcontinent [Roy *et al*., 2016; WSC, 2018]. In the present paper, we aim to describe and illustrate a new species, *Cocalus lacinia* sp.n. (♂♀), collected from the Wayanad Wildlife Sanctuary lying in Western Ghats in Kerala, one of the biodiversity hotspots of the world [Myers *et al.*, 2000]. The current geographic distribution of the genus in India is mapped as well.

Materials and methods

Field photos were taken with a Canon EOS 5D Mark-III using Canon EF 100 mm f/2.8 Macro USM Lens, Canon MP-E 65 mm 1–5x Macro Lens and Canon MT-24EX Macro Twin Lite Flash. Spiders were hand-collected, and the specimens were stored in 70% ethanol. A morphological examination was undertaken under a Leica M205 C stereomicroscope. The microphotographic images were taken by means of Leica DMC4500 digital camera attached to Leica M205 C stereomicroscope, with the software package Leica Application Suite (LAS), version 4.3.0. LAS montage facility. All measurements are in mm. Measurement data for palps and legs are as follows: total length [femur, patella, tibia, metatarsus (except palp), tarsus]. The studied specimens are deposited in the reference collection at the Centre for Animal Taxonomy and Ecology (CATE), Department of Zoology, Christ College (Autonomous), Irinjalakuda, Kerala, India.

Abbreviations used in the text and figure plates: ALE — anterior lateral eyes, AME — anterior median eyes, co — copulatory opening, do — dorsal, e — embolus, ec — extension of cymbium, fd — fertilization duct, pl — prolateral, PLE — posterior lateral eyes, PME — posterior median eyes, plv — prolateral ventral, rl — retrolateral, RTA — retrolateral tibial apophysis, rlv — retrolateral ventral, t — tegulum, v — ventral, VTA — ventral tibial apophysis, vto — ventral tibial outgrowt. The terminology follows Reiskind [1969]; that for leg spination follows the format by Bosselaers & Jocque [2000].

Figs 1–2. General appearance of *Cocalus lacinia* sp.n. from the Wayanad Wildlife Sanctuary, Kerala, India: 1 — holotype male, dorsal view; 2 — paratype female, dorsal view.

Рис. 1–2. Общий вид *Cocalus lacinia* sp.n. из Уэйнадского заповедника, Керала, Индия: 1 — самец голотип, сверху; 2 — самка паратип, сверху.

Description

Genus *Cocalus* C.L. Koch, 1846

Type species: *C. concolor* C.L. Koch, 1846

Cocalus lacinia **sp.n.**
Figs 1–19, Map.

TYPE. Holotype ♂ (CATE, 8402A) from the Wayanad Wildlife Sanctuary (11°45"27.6''N, 76°14"50.5''E), Kurichiad Range, Wayanad District, Kerala, India, 916 m a.s.l., 10.06.2015, P.P. Sudhin & K.S. Nafin.

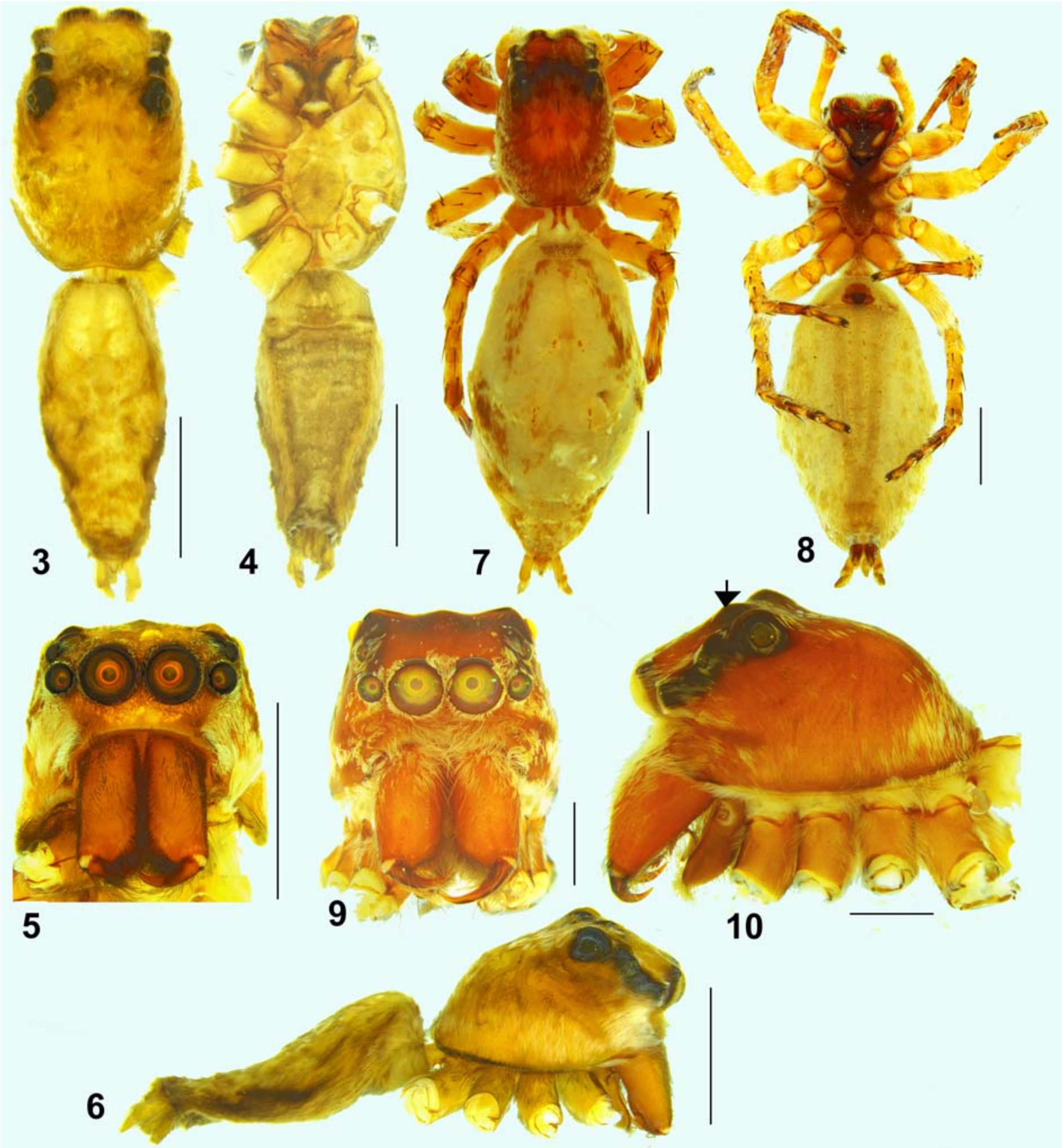
PARATYPE: India: 1 ♀ (CATE, 8402B), the same locality (11°45"56.3''N, 76°14"57.9''E), 842 m a.s.l., 9.06.2015, P.P. Sudhin & K.S. Nafin.

ETYMOLOGY. The specific epithet is a noun in apposition originated from the Latin word *lacinia*, meaning a flap and referring to the presence of a flap-like structure on the basal tibia of the male palp.

DIAGNOSIS. The male of *C. lacinia* sp.n. is similar to that of *C. gibbosus* Wanless, 1981 from Australia (Queensland), but differs from it in the following combination of characters: the embolus is positioned almost vertically at the distal end of the tegulum (slightly shifted retrolaterally in *C. gibbosus*); the VTA thumb-shaped, with a sub-acute tip (more stout and truncate in *C. gibbosus*); the palpal tibia basally with a flap-like ventral outgrowth (which is absent from *C. gibbosus*). The female of *C. lacinia* sp.n. is closest to that of *C. menglaensis* Cao, Li et Żabka, 2016 from China (Yunnan), but can be distinguished by the following characters: the abdomen elongated and robust (slightly shorter and linear in *C. menglaensis*); the epigynal plate without prominent posterior projections (prominent, heavily sclerotized and rectangular in *C. menglaensis*); the copulatory openings are located posteriorly (slightly below the middle area in *C. menglaensis*); the spermathecae globular, with a posterior triangular extension (phaseoliform, without posterior triangular extension in *C. menglaensis*) (cf. figs 7, 8, 12, 14–16, 18–19 with figs 4C–D in Wanless [1981], fig. 4 in Davies & Zabka [1989], and figs 18 A–B, D–E in Cao *et al*. [2016]).

DISTRIBUTION. The type locality only (Map).

DESCRIPTION. Male (holotype; Figs 1, 3–6, 11–13, 16–17). Measurements: body length 8.32. Carapace length 3.62, width (at the middle) 2.47, height at PLE 1.79. Abdomen length 4.41, width (at the middle) 1.81. Ocular area length 1.81, width 2.02. Eye diameters: AME 0.59, ALE 0.29, PME 0.16, PLE 0.31. Eye interdistances: AME–ALE 0.08, PME–PME 1.64, ALE–ALE 1.34, PME–PLE 0.47, PLE–PLE 1.64, ALE–PME 0.48. Clypeus height 0.32. Length of chelicera 1.01. Palp and leg measurements: palp 3.12 [0.84, 0.59, 0.52, 1.17], leg I 8.51 [2.14, 1.2, 2.28, 1.88, 1.01], II 9.49 [2.41, 1.09, 2.69, 2.29, 1.01], III 7 [1.96, 0.78, 1.76, 1.63, 0.87], IV 9.23 [2.48, 1.05, 2.24, 2.42, 1.04]. Leg formula: 2413. Spination. Palp: femur rl 1, do 2, pl 1; tarsus rl 1 pl 1; Legs: femur I–II rl 1 do 3 pl 2, III–IV rl 1 do 3 pl 2; patellae I–IV rl 1 pl 1; tibia I–II rl 3 rlv 3 do 3 pl 3 plv 3, III–IV rl 3 rlv 3 do 2 pl 3 plv 3; metatarsi I–II rl 3 rlv 2 do 1 pl 2 plv 1 v 1, III–IV rl 3 rlv 2 do 1 pl 3 plv 2 v 1; tarsi I–IV spineless. Carapace light yellowish brown, covered with white, brown and black setae, laterally with a white band extending from ALE to the rear end, narrowing towards it; carapace margins with a row of small black hairs (Figs 3, 6); eye field covered with chocolate white hairs; fovea light reddish brown, situated just behind PLEs (Fig. 3); clypeus low, vertical, covered with long white setae (Fig. 5); chelicerae light reddish brown, sub-vertical, frontal face with brown and white hairs (Fig. 5), pro- and retromargins with three teeth, fangs medium-sized, reddish brown; endites yellowish brown, with dull white inner tips and dark grey hairs on inner margin, margin of endites with narrow dark brown lines (Fig. 4). Labium light brown, scopulate, with a dull white tip. Sternum almost oval, yellowish brown, covered with brown and white hairs (Fig. 4). Pedicel light yellowish, with reddish-brown lateral stripes (Figs 3, 6). Abdomen pale yellow, ovoid, posteriorly narrowing, covered with black and white hairs, dorsally with irregular light brown transverse patches, laterally with continuous irregular black stripes (Figs 3, 6). Venter yellowish brown, covered with numerous brown hairs, its posterior tip with dense white hairs (Fig. 4). Spinnerets yellowish brown, covered with dark brown hairs. Legs yellow, covered with hairs, setae and spines, all trochanters with a row of prolateral and retrolateral black setae, tarsal claw with eleven teeth.

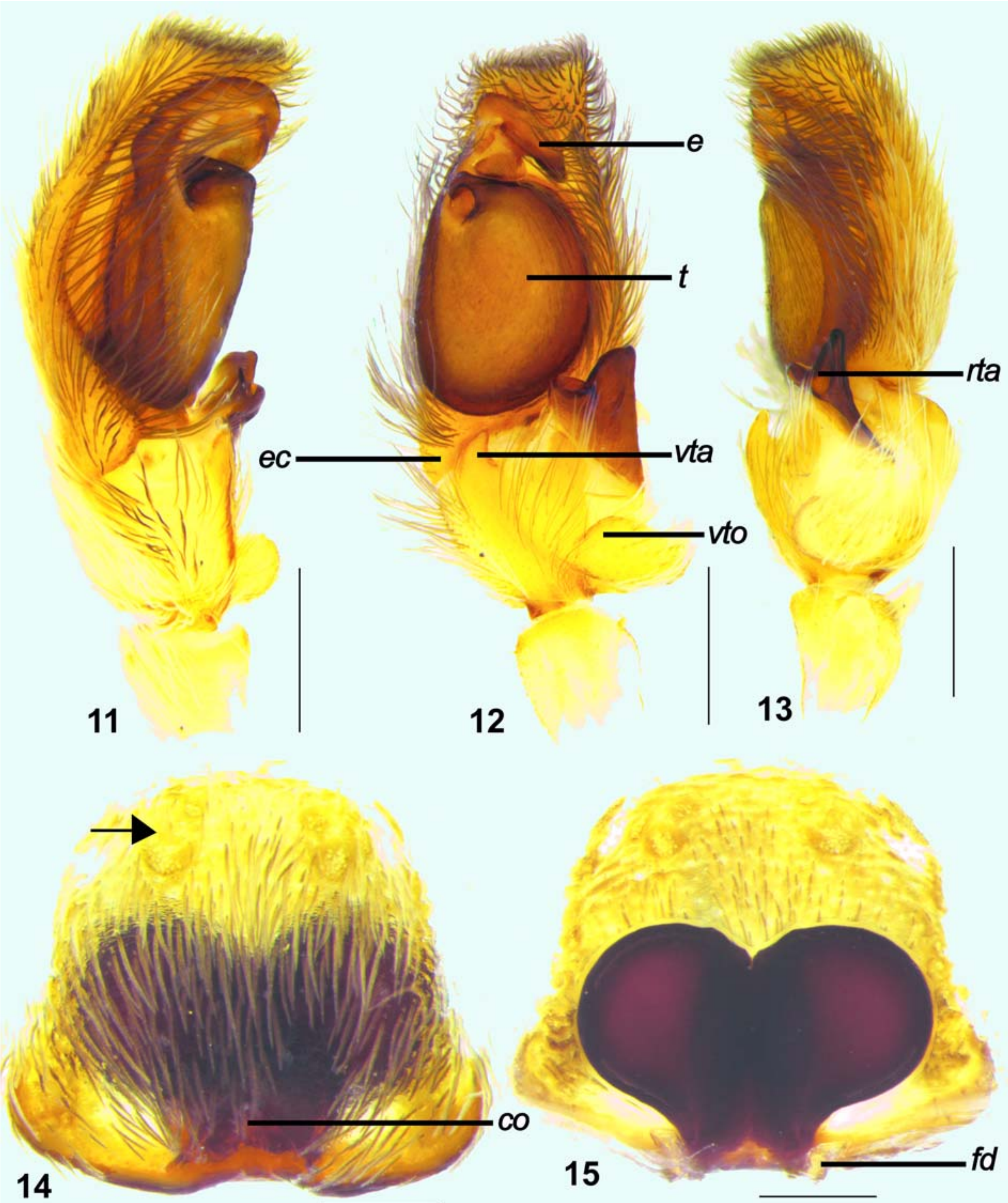


Figs 3–10. Somatic characters of *Cocalus lacinia* sp.n., holotype male (3–6) and paratype female (7–10): 3, 7 — body, dorsal view; 4, 8 — ditto, ventral view; 5, 9 — carapace, frontal view; 6 — body, lateral view; 10 — carapace, lateral view. Scale bar: (3–6, 7–8) 2 mm, (9–10) 1 mm.

Рис. 3–10. Соматические признаки *Cocalus lacinia* sp.n., самец-голотип (3–6) и самка-паратип (7–10): 3, 7 — тело, сверху; 4, 8 — то же, снизу; 5, 9 — головогрудь, спереди; 6 — тело, сбоку; 10 — головогрудь, сбоку. Масштаб: (3–6, 7–8) 2 мм (9–10) 1 мм.

Palp as shown in Figs 11–13, 16–17. Palp moderately long, pale yellowish, densely covered with hairs; tibia base with a flap-like ventral outgrowth, which is retrolaterally oriented (Figs 12, 16); VTA thumb like, wide at the base, with sub-acute tip (Figs 12, 16: vto); RTA dark reddish brown, with wide sinuous edge (Figs 12–13, 16–17: rta); cymbium broad, moderately long, distally truncate, with posterior triangular extension (Fig. 12: ec); tegulum ovoid, light brown with tegular furrow, retrolateral striae and dark reddish brown peripheral seminal duct (Figs 12, 16); embolus robust, hook-shaped, with the pointed tip curving inwards, towards the alveolar cavity (Figs 12–13, 16–17: e).

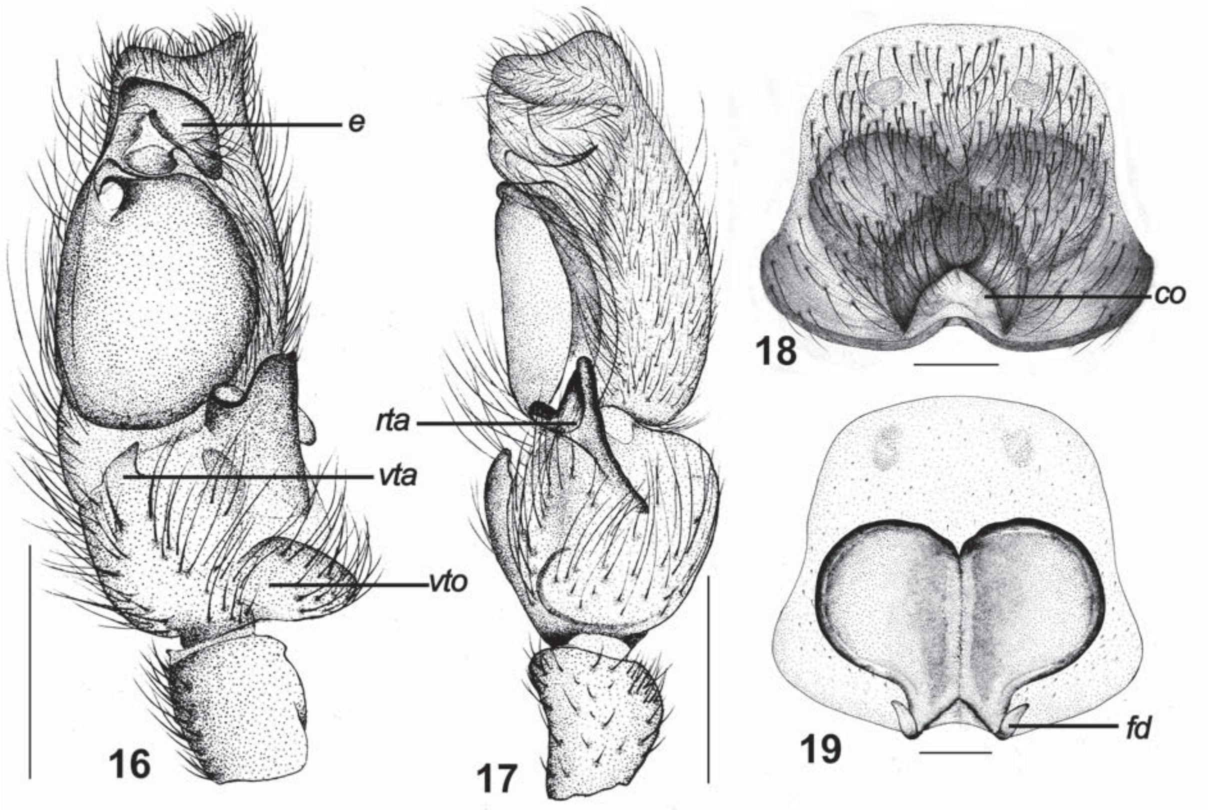
Female (paratype; Figs 2, 7–10, 14–15, 18–19): Measurements: body length 12.71. Carapace length 3.88, width (at the middle) 2.83, height at PLE 2.25. Abdomen length 8.34, width (at the middle) 4.01. Ocular area length 1.72, width 2.21. Eye diameters: AME 0.66, ALE 0.33, PME 0.22, PLE 0.32. Eye interdistances: AME–ALE 0.09, PME–



Figs 11–15. Copulatory organs of *Cocalus lacinia* sp.n. (holotype male and paratype female): 11 — male left palp, prolateral view: 12 — ditto, ventral view; 13 — ditto, retrolateral view; 14 — epigyne, ventral view; 15 — spermathecae, dorsal view. Scale bar: (11–13) 0.5 mm, (14–15) 0.2 mm.

Рис. 11–15. Копулятивные органы *Cocalus lacinia* sp.n. (самец-голотип и самка-паратип): 11 — левая пальпа самца, спереди-сбоку: 12 — то же, снизу; 13 — то же, сзади-сбоку; 14 — эпигина, снизу; 15 — сперматека, сверху. Масштаб: (11–13) 0,5 мм, (14–15) 0,2 мм.

PME 1.73, ALE–ALE 1.47, PME–PLE 0.32, PLE–PLE 1.88, ALE–PME 0.31. Clypeus height 0.35. Length of chelicera 1.51. Palp and leg measurements: palp 3.81 [1.08, 0.62, 0.77, 1.34], leg I 8.11 [2.28, 1.30, 2.18, 1.49, 0.86], II 7.73 [2.21, 1.21, 1.99, 1.44, 0.88], III 7 [2.21, 0.83, 1.88, 1.40, 0.68], IV 10.03 [2.72, 1.19, 2.43, 2.68, 1.01]. Leg formula: 4123. Spination. Palp: femur rl 1 do 2 pl 1 , tibia rl 1, tarsus rl 2 rlv 1 pl 1 plv 1 v 1; Legs: femur I–II rl 3 do 3 pl 2, III–IV



Figs 16–19. Copulatory organs of *Cocalus lacinia* sp.n. (holotype male and paratype female): 16 — male left palp, ventral view; 17 — ditto, retrolateral view; 18 — epigyne, ventral view; 19 — spermathecae, dorsal view. Scale bar: (16–17) 0.5 mm, (18–19) 0.2 mm.

Рис. 16–19. Копулятивные органы *Cocalus lacinia* sp.n. (самец-голотип и самка-паратип): 16 — левая пальпа самца, снизу; 17 — то же, сзади-сбоку; 18 — эпигина, снизу; 19 — сперматека, сверху. Масштаб: (16–17) 0,5 мм, (18–19) 0,2 мм.

rl 2 do 2 pl 3; patellae I–IV rl 1 pl 1; tibia I–II rl 3 rlv 3 do 3 pl 3 plv 3, III–IV rl 3, rlv 3 do 2 pl 3 plv 3; metatarsi I–II rl 3 rlv 1 do 1 pl 3 plv 1, III–IV rl 2 rlv 2 do 1 pl 2 plv 2 v 1; tarsi I–IV spineless. In all respects as the male, except as follows: carapace light reddish brown, covered with white setae, more elongate and appressed in the ocular quadrangle, margin of carapace with narrow dark reddish brown lines, region around the posterior quadrangle with a wide inverted V-shaped black mottling (Fig. 7); posterior ocular quadrangle elevation more prominent (arrowed in Fig. 10); fovea distinct, longitudinal, dark reddish-brown (Fig. 7); clypeus light reddish brown, densely covered with white hairs (Fig. 9); chelicerae reddish brown, promargin with three teeth and retromargin with four teeth; labium dark brown, maxillae and sternum light brown (Fig. 8). Abdomen more elongated, slightly robust, pale yellow, covered with white and brown setae, dorsally with a median light brown longitudinal stripe terminating at the middle, laterally with continuous irregular similar coloured stripes (Fig. 7). Venter pale yellow, medially with three longitudinal light greyish brown stripes and four longitudinal light brown dot lines (Fig. 8). Anterior and median spinnerets light yellowish brown, posterior spinnerets light brown. Epigyne as shown in Figs 14–15, 18–19. Epigyne bell-shaped, golden-light brown, covered with long creamy hairs, posterior borderline with a median invagination (Figs 14, 18), anteriorly with a pair of kidney-shaped thickenings (arrowed in Fig, 14); copulatory openings at the lateral margins of the posterior triangular groove (Figs 14, 18: co); spermathecae massive, globular, dark reddish brown, compact, with posterior triangular extension (Figs 15, 19); insemination duct short, entering the spermathecae mid-ventrally; fertilization duct short, anterolaterally oriented, located at the posterior tip of the spermathecae (Figs 15, 19: fd).

HABITAT. The studied specimens were collected from the bark of *Tectona grandis* (Lamiaceae) in the Teak plantation of the Wayanad Wildlife Sanctuary, Kerala, India.

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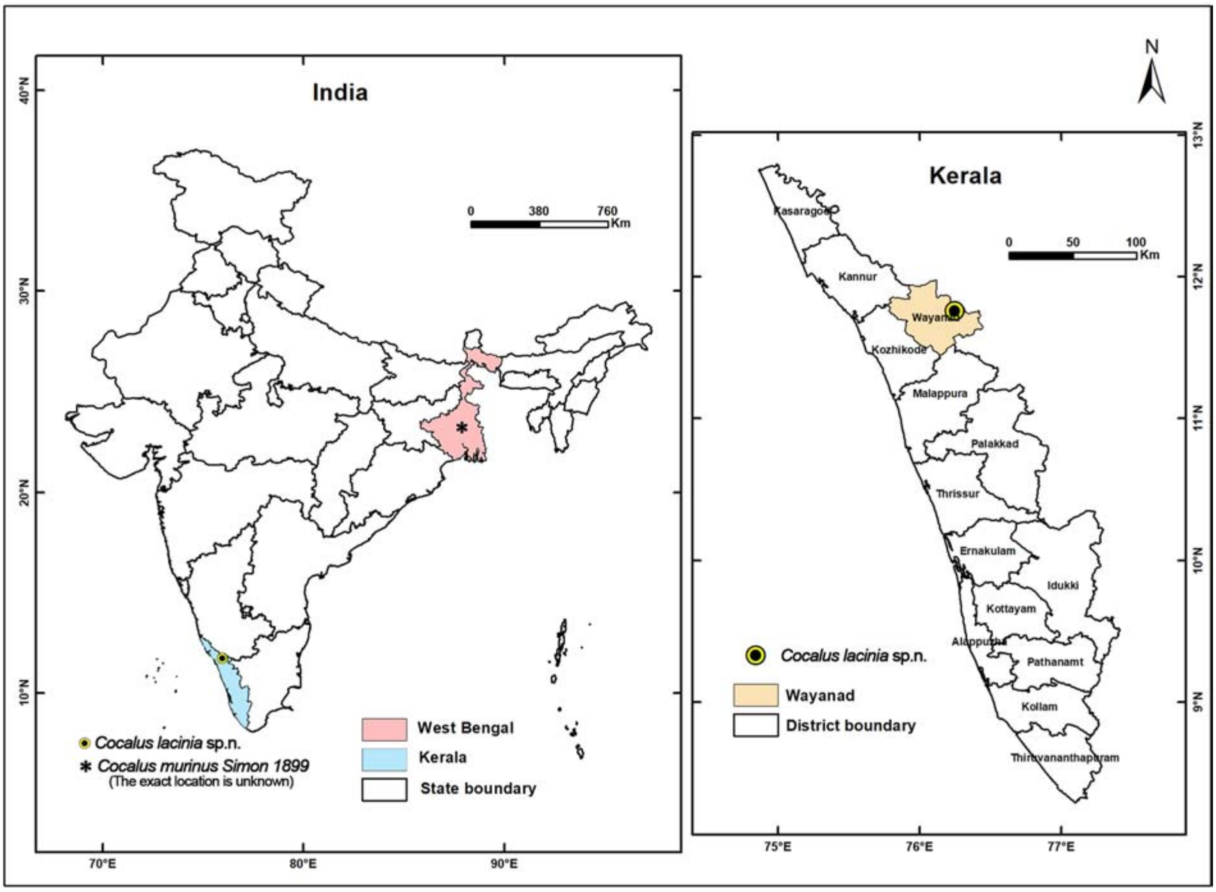

Map. Collecting localities of the genus *Cocalus* C.L. Koch, 1846 in India.
Карта. Точки находок рода *Cocalus* C.L. Koch, 1846 в Индии.

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Responsible editor D.V. Logunov

PLATES

Plate 7

Photographs of spiders collected from the study area

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Family: Araneidae (Clerck, 1757) - (1) *Anepsion maritatum* (O. Pickard-Cambridge, 1877), (2) *Arachnura* sp., (3) *Araneus ellipticus* (Tikader & Bal, 1981), (4) *Araneus mitificus* (Simon, 1886), (5) *Araneus* sp. I, (6) *Araneus* sp. II, (7) *Argiope aemula* (Walckenaer, 1841), (8) *Argiope catenulata* (Doleschall, 1859).

Plate 8

Photographs of spiders collected from the study area

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Family: Araneidae (Clerck, 1757) - (9) *Argiope pulchella* (Thorell, 1881), (10) *Chorizopes* sp., (11) *Cyclosa bifida* (Doleschall, 1859), (12) *Cyclosa confraga* (Thorell, 1892), (13) *Cyclosa hexatuberculata* (Tikader, 1982), (14) *Cyclosa moonduensis* (Tikader, 1963), (15) *Cyclosa neilensis* (Tikader, 1977), (16) *Cyrtarachne* sp.

Plate 9

Photographs of spiders collected from the study area

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Family: Araneidae (Clerck, 1757) - (17) *Cyrtophora citricola* (Forsskal, 1775), (18) *Cyrtophora unicolar* (Doleschall, 1857), (19) *Eriovixia excelsa* (Simon, 1889), (20) *Eriovixia laglaizei* (Simon, 1877), (21) *Eriovixia palawanesis* (Barrion & Litsinger, 1995), (22) *Eriovixia porcula* (Simon, 1877), (23) *Eriovixia sakiedaorum* (Tanikawa, 1999), (24) *Eriovixia* sp. I.

Plate 10

Photographs of spiders collected from the study area


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(27) **(28)**


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(31) **(32)**

Family: Araneidae (Clerck, 1757) - (25) *Eriovixia* sp. II, (26) *Gasteracantha dalyi* (Pocock, 1900), (27) *Gasteracantha geminata* (Fabricius, 1798), (28) *Gasteracantha hasselti* (C. L. Koch, 1837), (29) *Gasteracantha kuhli* (C. L. Koch, 1837), (30) *Gea spinipes* (C. L. Koch, 1843), (31) *Gea subarmata* (Thorell, 1890), (32) *Herennia multipuncta* (Doleschall, 1859).

Plate 11

Photographs of spiders collected from the study area

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Family: Araneidae (Clerck, 1757) - (33) *Nephila pilipes* (Fabricius, 1793), (34) *Neoscona bengalensis* (Tikader & Bal, 1981), (35) *Neoscona molemensis* (Tikader & Bal, 1980), (36) *Neoscona mukerjei* (Tikader, 1980), (37) *Neoscona theisi* (Walckenaer, 1841), (38) *Neoscona* sp. I, (39) *Neoscona* sp. II, (40) *Paraplectana* sp. (Brito Capello, 1867).

Plate 12

Photographs of spiders collected from the study area

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Family: Araneidae (Clerck, 1757) - (41) *Parawixia dehaani* (Doleschau, 1859), (42) *Poltys coloumnaris* (Thorell, 1890), (43) *Poltys* sp., (44) *Porcataraneus bengalensis* (Tikader, 1975), (45) *Plebs mitratus* (Simon, 1895). **Family: Cheiracanthiidae (Wagner, 1887)** - (46) *Cheiracanthium danieli* (Tikader, 1975), (47) *Cheiracanthium melanostomum* (Thorell, 1895), (48) *Cheiracanthium* sp. I.

Plate 13

Photographs of spiders collected from the study area

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Family: Cheiracanthiidae (Wagner, 1887) - (49) *Cheiracanthium* sp. II, **Family: Clubionidae (Wagner, 1887) -** (50) *Clubiona* sp. I, (51) *Matidia virens* (Thorell, 1878), **Family: Corinnidae (Karsch, 1880) -** (52) *Castianeira furva* (Sankaran et al., 2015), (53) *Castianeria zetes* (Simon, 1897), (54) *Corinnomma* sp. I, (55) *Corinnomma* sp. II, **Family: Ctenidae (Keyserling, 1877) -** (56) *Ctenus cochinensis* (Gravely, 1931).

Plate 14

Photographs of spiders collected from the study area

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Family: Gnaphosidae (Pocock, 1898) - (57) *Drassodes* sp., (58) *Zelotes ashae* (Tikader & Gajbe, 1976), **Family: Hersiliidae (Thorell, 1870)** - (59) *Hersilia savignyi* (Lucas, 1836), (60) *Hersilia* sp., **Family: Linyphiidae (Blackwall, 1859)** - (61) *Linyphia* sp., (62) *Neriene macella* (Thorell, 1898), **Family: Lycosidae (Sundevall, 1833)** - (63) *Hippasa agelenoides* (Simon, 1884), (64) *Hippasa holmerae* (Thorell, 1895).

Plate 15

Photographs of spiders collected from the study area

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Family: Lycosidae (Sundevall, 1833) - (65) *Hippasa madraspatana* (Gravely, 1924), (66) *Lycosa bistriata* (Gravely, 1924), (67) *Pardosa mysorensis* (Tikader & Mukerji, 1971), (68) *Pardosa pseudoannulata* (Bosenberg & Strand, 1906), (69) *Pardosa sumatrana* (Thorell, 1890), **Family: Mimetidae (Simon, 1881)** - (70) *Mimetus* sp., (71) *Mimetus* sp., **Family: Miturgidae (Simon, 1886)** - (72) *Systaria* sp.

Plate 16

Photographs of spiders collected from the study area

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Family: Oecobiidae (Blackwall, 1862) - (73) *Oecobius* sp., **Family: Oonopidae (Simon, 1890) -** (74) *Gamasomorpha.* sp., (75) *Opopaea* sp., **Family: Oxyopidae (Thorell, 1870) -** (76) *Hamadruas sikkimensis* (Tikader,1970), (77) *Oxyopes birmanicus* (Thorell, 1887), (78) *Oxyopes forcipiformis* (Xie & Kim, 1996), (79) *Oxyopes hindostanicus* (Pocock, 1901), (80) *Oxyopes javanus* (Thorell, 1887).

Plate 17

Photographs of spiders collected from the study area

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Family: Oxyopidae (Thorell, 1870) - (81) *Oxyopes lineatipes* (C. L. Koch, 1847), (82) *Oxyopes shweta* (Tikader, 1970), (83) *Oxyopes sunandae* (Tikader, 1970), (84) *Peucetia viridana* (Stoliczka, 1869), **Family: Palpimanidae (Thorell, 1870)** - (85) *Palpimanus* sp., (86) *Sarascelis raffrayi* (Simon, 1893), **Family: Philodromidae (Thorell, 1870)** - (87) *Tibellus elongatus* (Tikader, 1960), **Family: Pholcidae (C. L. Koch, 1850)** - (88) *Artema atlanta* (Walckenaer, 1837).

Plate 18

Photographs of spiders collected from the study area

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Family: Pholcidae (C. L. Koch, 1850) - (89) *Crossopriza lyoni* (Blackwall, 1867), (90) *Pholcus phalangioides* (Fuesslin, 1775), (91) *Pholcus* sp. I, (92) *Pholcus* sp. II, (93) *Smeringopus pallidus* (Blackwall, 1858), (94) *Pribumia atrigularis* (Simon, 1901), **Family: Pisauridae (Simon, 1890)** - (95) *Dendrolycosa gitae* (Tikader, 1970), (96) *Dendrolycosa robusta* (Thorell, 1895).

Plate 19

Photographs of spiders collected from the study area

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Family: Salticidae (Blackwall, 1841) - (97) *Ajaraneola* sp., (98) *Asemonea tenuipes* (O. P. Cambridge, 1869), (99) *Bianor albobimaculatus* (Lucas, 1846), (100) *Brancus calebi* (Kanesharatnam & Benjamin, 2018), (101) *Brettus albolimbatus* (Simon, 1900), (102) *Brettus cingulatus* (Thorell, 1895), (103) *Brettus* sp., (104) *Carrhotus viduus* (C. L. Koch, 1846).

Plate 20

Photographs of spiders collected from the study area

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Family: Salticidae (Blackwall, 1841) - (105) *Chalcotropis pennata* (Simon, 1902), (106) *Chrysilla volupe* (Karsch, 1879), (107) *Cocalus lacinia* (Sudhin, Nafin, Sumesh & Sudhikumar, 2019), (108) *Epeus tener* (Simon, 1877), (109) *Epeus triangulopalpis* (Malamel, Nafin, Sudhikumar & Sebastian, 2019), (110) *Epocilla aurantiaca* (Simon, 1885), (111) *Evarcha flavocincta* (C. L. Koch, 1846), (112) *Habrocestum* sp.

Plate 21

Photographs of spiders collected from the study area

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Family: Salticidae (Blackwall, 1841) - (113) *Hasarius adansoni* (Audouin, 1826), (114) *Hyllus semicupreus* (Simon, 1885), (115) *Indopadilla insularis* (Malamel et al., 2015), (116) *Langona* sp., (117) *Marengo sachintendulkar* (Malamel et al., 2019), (118) *Menemermus bivittatus* (Dufour, 1831), (119) *Myrmaplata plataleoides* (O. P. Cambridge, 1869), (120) *Phaeacius lancearius* (Thorell, 1895).

Plate 22

Photographs of spiders collected from the study area


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Family: Salticidae (Blackwall, 1841) - (121) *Phidippus yashodharae* (Tikader, 1977), (122) *Phintella vittata* (C. L. Koch, 1846), (123) *Plexippus paykulli* (Audouin, 1826), (124) *Portia fimbriata* (Doleschall, 1859), (125) *Portia labiata* (Thorell, 1887), (126) *Rhene flavigera* (C. L. Koch, 1846), (127) *Rhene rubrigera* (Thorell, 1887), (128) *Siler semiglaucus* (Simon, 1901).

Plate 23

Photographs of spiders collected from the study area

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Family: Salticidae (Blackwall, 1841) - (129) *Stenaelurillus albus* (Sebastian et al., 2015), (130) *Stenaelurillus lesserti* (Reimoser, 1934), (131) *Telamonia dimidiata* (Simon, 1899), (132) *Thiania bhamoensis* (Thorell, 1887), **Family: Scytodidae (Blackwall, 1864) -** (133) *Scytodes fusca* (Walckenaer, 1837), (134) *Scytodes thoracica* (Latreille, 1802), **Family: Sparassidae (Bertkau, 1872) -** (135) *Heteropoda venatoria* (Linnaeus, 1767), (136) *Olios milleti* (Pocock, 1901).

Plate 24

Photographs of spiders collected from the study area

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Family: Sparassidae (Bertkau, 1872) - (137) *Thelcticopis* sp., **Family: Tetragnathidae (Menge, 1866) -** (138) *Guizygiella nadleri* (Heimer, 1984), (139) *Leucauge decorata* (Blackwall, 1864), (140) *Leucauge pondae* (Tikader, 1970), (141) *Leucauge tessellata* (Thorell, 1887), (142) *Opadometa fastigata* (Simon, 1877), (143) *Tetragnatha cochinensis* (Gravely, 1921), (144) *Tetragnatha javana* (Thorell, 1890).

Plate 25

Photographs of spiders collected from the study area

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Family: Tetragnathidae (Menge, 1866) - (145) *Tetragnatha keyserlingi* (Simon, 1890), (146) *Tetragnatha mandibulata* (Walckenaer, 1842), (147) *Tetragnatha squamata* (Karsch, 1879), (148) *Tetragnatha viridorufa* (Gravely, 1921), (149) *Tylorida striata* (Thorell, 1877), (150) *Tylorida ventralis* (Thorell, 1877), **Family: Theridiidae (Sundevall, 1833)** - (151) *Achaearanea durgae* (Tikader,1970), (152) *Argyrodes argentatus* (O. Pickard-Cambridge, 1880).

Plate 26

Photographs of spiders collected from the study area

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Family: Theridiidae (Sundevall, 1833) - (153) *Argyrodes flavescens* (O. Pickard-Cambridge, 1880), (154) *Argyrodes gazedes* (Tiader, 1970), (155) *Argyrodes kumadai* (Chida et al., 1999), (156) *Argyrodes* sp., (157) *Ariamnes flagellum* (Doleschall, 1857), (158) *Chrysso angula* (Tikader, 1970), (159) *Chrysso urbasae* (Tikader, 1970), (160) *Episinus affinis* (Bösenberg & Strand, 1906).

Plate 27

Photographs of spiders collected from the study area


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Family: Theridiidae (Sundevall, 1833) - (161) *Meotipa multuma* (Murthappa et al.,2017), (162) *Meotipa picturata* (Simon, 1895), (163) *Molione triacantha* (Thorell, 1892), (164) *Nihonhimea mundula* (L. Koch, 1872), (165) *Parasteatoda celsabdomina* (Zhu, 1998), (166) *Phycosoma* sp. I, (167) *Phoroncidia septemaculeata* (O. Pickard-Cambridge, 1873), (168) *Rhomphaea projiciens* (O. Pickard-Cambridge, 1896).

Plate 28

Photographs of spiders collected from the study area

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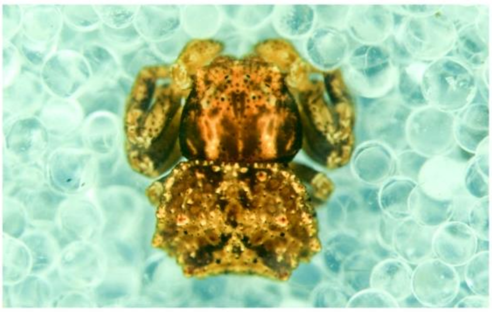

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Family: Theridiidae (Sundevall, 1833) - (169) *Thwaitesia margaritifera* (O. Pickard-Cambridge, 1881), **Family: Thomisidae (Sundevall, 1833)** - (170) *Amyciaea albomaculata* (O. Pickard-Cambridge, 1874), (171) *Amyciaea forticeps* (O. P. Cambridge, 1873), (172) *Boliscus tuberculatus* (Simon, 1886), (173) *Camaricus formosus* (Thorell, 1887), (174) *Camaricus khandalaensis* (Tikader, 1980), (175) *Indoxysticus minutus* (Tikader, 1960), (176) *Massuria sreepanchamii* (Tikader, 1962).

Plate 29

Photographs of spiders collected from the study area

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Family: Thomisidae (Sundevall, 1833) - (177) *Misumena* sp., (178) *Oxytate virens* (Thorell, 1891), (179) *Runcinia roonwali* (Tikader, 1965), (180) *Strigoplus netravati* (Tikader,1963), (181) *Thomisus lobosus* (Tikader, 1965), (182) *Thomisus projectus* (Tikader, 1960), (183) *Tmarus histrix* (Caporiacco, 1954), **Family: Trachelidae (Simon, 1897)** - (184) *Utivarachna rama* (Chami-Kranon & Likhitrakarn, 2007).

Plate 30

Photographs of spiders collected from the study area

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Family: Trachelidae (Simon, 1897) - (185) *Utivarachna* sp., **Family: Uloboridae (Thorell, 1869)** - (186) *Miagrammopes extensus* (Simon, 1889), (187) *Uloborus danolius* (Tikader, 1969), (188) *Uloborus khasiensis* (Tikader, 1969), (189) *Uloborus krishnae* (Tikader, 1970), (190) *Zosis geniculata* (Olivier, 1789), **Family: Zodariidae (Thorell, 1881)** - (191) *Suffasia* sp. (Jocqué, 1991).