STUDY OF SPIDER (ORDER: ARANEAE) DIVERSITY ON SELECTED SITES ADJOINING THE TRIBUTARIES OF BHARATAPUZHA IN 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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JULY 2024

DECLARATION

I, SHIHABUDEEN A.S., hereby declare that the work presented in the thesis entitled **"STUDY OF SPIDER (ORDER: ARANEAE) DIVERSITY ON SELECTED SITES ADJOINING THE TRIBUTARIES OF BHARATAPUZHA IN KERALA"** is based on the original work done by me under the guidance of Dr. Sudhikumar A.V., Associate Professor, Department of Zoology, Christ College (Autonomous), Irinjalakuda and has not been included in any other thesis submitted previously for the award of any degree. The contents of the thesis are undergone plagiarism check using Turnitin iThenticate software at C.H.M.K. Library, University of Calicut, and the similarity index found within the permissible limit. I also declare that the thesis is free from AI generated contents.

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CERTIFICATE

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ABSTRACT

Riparian habitats act as ecotones integrating the neighbouring terrestrial and aquatic ecosystems. These habitats are exhibit variation with respect to the nature of both the contributing ecosystems. Bharatapuzha, the second longest river in Kerala has a paramount importance in moulding biodiversity of central Kerala. A lot of anthropogenic interventions brought irrecoverable damage to the river, hence to the associated riparian habitats. Riparian spiders are highly versatile with respect to their trophic roles; being both predators and prey. Present study extended for a period of two years could document a total of 7151 individuals belonging to 27 families, 90 genera and 133 species. Around 44 % of the families reported from the country were represented in this sampling study. Standard sampling procedures like line transect method were followed. World Spider Catalogue version 25.0 was the reference for identification and scientific names. For convenience, the sampling was done from five selected sites adjoining distinct tributaries of the river, located in Palakkad and Malappuram districts. The samplings were carried out in three seasons, pre monsoon, monsoon and post monsoon. A considerably significant difference was found to exist among the sites and seasons. Both the abundance and richness were higher during post monsoon season. Habitat wise, site 1, Malampuzha recorded higher abundance and richness. Salticidae was the most dominant family followed by Araneidae and Tetragnathidae. Highest relative abundance value was recorded for *Hyllus semicupreus*. Species accumulation curve reached the asymptotic level indicating satisfactory coverage of the species distribution. Rarefaction curve corresponding to post monsoon season of Malampuzha reached the highest peak. Considering AIC values, Zipf – Mandelbrot was chosen as the best fit model. All the eight feeding guilds were represented in the study; other hunters were the most dominant one. No new species were reported in this study.

Key words: Riparian, Line transect, Species accumulation curve, Line transect, Rank abundance curve, Diversity profile curve.

സംഗ്രഹം (Abstract)

നദീതട ആവാസങ്ങൾ സ്ഥലീയവും ജലീയവുമായ ആവാസ വ്യവസ്ഥകളെ പരസ്പരം ബന്ധിപ്പിക്കുന്ന സുപ്രധാന കണ്ണികളായി വർത്തിക്കുന്നു. കേരളത്തിലെ നദികളിൽ നീളം കൊണ്ട് രണ്ടാം സ്ഥാനത്ത് നിൽക്കുന്ന ഭാരതപ്പുഴ മധ്യ കേരളത്തിലെ ജൈവ വൈവിധ്യവുമായി അഭേദ്യമായ ബന്ധം പുലർത്തുന്നു." **Study of spider (Order: Araneae) diversity on selected sites adjoining the tributaries of Bharatapuzha in Kerala** " എന്ന ശീർഷകത്തിലുള്ള ഈ ഗവേഷണ പ്രബന്ധത്തിൽ ഭാരതപ്പുഴയുടെ കേരളത്തിലൂടെ ഒഴുകുന്ന പ്രധാന കൈവഴികളുമായി ബന്ധപ്പെട്ട നദീതട ആവാസങ്ങളിലുള്ള ചിലന്തികളുടെ വൈവിധ്യമാണ് പഠന വിധേയമാക്കിയത്. മലമ്പുഴ, ചിറ്റൂർ, ഒറ്റപ്പാലം, കണ്ണാടി, പൊന്നാനി എന്നിങ്ങനെ അഞ്ച് വ്യത്യസ്ത സ്ഥലങ്ങളിൽ നിന്നും Line transect method ഉപയോഗിച്ച് സാമ്പിളുകൾ ശേഖരിക്കുകയുണ്ടായി. കേരളത്തിൽ ലഭ്യമാകുന്ന തെക്കു കിഴക്കൻ മൺസൂണിനെ അടിസ്ഥാനമാക്കി പഠന കാലത്തെ മൺസൂൺ പൂർവ കാലം, മൺസൂൺ കാലം, മൺസൂണിന് ശേഷമുള്ള കാലം എന്നിങ്ങനെ മൂന്ന് സീസണുകളായി തിരിച്ചാണ് സാമ്പിൾ ശേഖരണം നടത്തിയത്. ഈ പഠനത്തിൽ 27 ഫാമിലികളിൽ ഉൾപ്പെട്ട 133 സ്പീഷീസ് ചിലന്തികൾ റിപ്പോർട്ട് ചെയ്യപ്പെട്ടു. ഏറ്റവും അധികം ജീവികളും വർഗ്ഗങ്ങളും ലഭിച്ചത് കല്പാത്തിപ്പുഴയുമായി ബന്ധപെട്ടു കിടക്കുന്ന മലമ്പുഴയിൽ നിന്നാണ്. ' Salticidae ' ഏറ്റവും വൈവിധ്യമുള്ള ഫാമിലി ആയും 'Araneidae ' അടുത്ത

സ്ഥാനത്തു നിൽക്കുന്നതായും കണ്ടെത്തി. മൺസൂൺ ശേഷ കാലത്താണ് പരമാവധി ജീവികളും സ്പീഷീസുകളും ലഭ്യമായത്. 'Salticidae ' ഫാമിലിയിലെ *'Hyllus semicupreus '* എന്നയിനം ചിലന്തിയാണ് ഏറ്റവും അധികം ലഭ്യമായത് .താരതമ്യ പഠനത്തിനായി Species accumulation curve, Rank abundance curve, Diversity profile curve, Rarefaction curve മുതലായവ ഉപയോഗപ്പെടുത്തുകയുണ്ടായി. ഇരപിടിക്കാനു പയോഗിക്കുന്ന പ്രധാന ഉപാധികളുടെ അടിസ്ഥാനത്തിൽ ഈ പഠനത്തിൽ ലഭിച്ച ചിലന്തി കുടുംബങ്ങളെ 8 'guild' കൾ ആയി വേർ തിരിച്ചു. 'Other hunters' എന്ന guild ൽ ആണ് ഏറ്റവും വൈവിധ്യം കാണാനായത് .

പ്രധാന പദങ്ങൾ : നദീതട ആവാസങ്ങൾ, Species accumulation curve, Line transect, Rank abundance curve, Diversity profile curve.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ACRONYMS AND ABBREVIATIONS

AIC	Akaike Information Criterion
ALE	Anterior Lateral Eye
AME	Anterior Median Eye
ANOSIM	Analysis of Similarity
ANOVA	Analysis of Variance
BIC	Bayesian Information Criterion
BNR	Blouberg Nature Reserve
CWC	Central Water Commission
EIA	Environmental Impact Assessment
GIS	Geographic Information System
IISc	Indian Institute of Sciences
IMD	Indian Meteorological Department
IPM	Integrated Pest Management
MLE	Maximum Likelihood Estimation
MOQ	Median Ocular Quadrangle
NMBE	Natural History Museum Bern
nMDS	Non-metric Multidimensional scaling
PCB	Poly Chlorinated Biphenyls
PERMANOVA	Permutational Analysis of Variance
PLE	Posterior Lateral Eye
PME	Posterior Median Eye
Q - Q plot	Quantile – Quantile plot
RAC	Rank Abundance Curve
SD	Standard Deviation

se	Standard Error
SRTM-DEM	Shuttle Radar Topography Mission – Digital Elevation Model
UNEP	United Nations Environment Programme
WCMC	World Conservation Monitoring Centre
WSC	World Spider Catalogue
WSC	Western Soutpansberg Conservancy
WWF	World Wildlife Fund

Study Sites & Seasons

CTR	Chittur
KND	Kannadi
MPZ	Malampuzha
OTP	Ottappalam
PNI	Ponnani
MON	Monsoon
POM	Post monsoon
PRM	Pre monsoon

Chapter 1.
Introduction

INTRODUCTION

"Words are like the spiders' web, a shelter for the clever ones and a trap for the not so clever".

------------- Madagascan Proverb.

1.1. General Introduction

Spiders have always been enigmatic organisms for human beings. Their unparalleled hunting strategies, along with the perplexing craftsmanship in web making continues to bewilder us! From a biologists' perspective, they are a group of highly diverse, laborious invertebrates belonging to order Araneae of phylum Arthropoda. Their origin dates back to Devonian period (Coddington & Levi, 1991; Craig, 2003), 350 million years ago. The highly deviant behaviour patterns in terms of locomotion, food gathering, and ingestion, can be attributed to their survival and sustenance, even in highly hostile habitats. They are the largest group of Arachnids, ranking seventh in total species diversity. Their evolutionary success as highly divergent arthropods on par with insects can be attributed to their sensory system that are reliable enough to keep the organism always aware of the potential predators and availability of prey in their habitat (Nyffeler & Birkhofer, 2017).

On a global scale, there exist 52078 species of spiders belonging to 4381 genera and 135 families (World spider catalogue, 2024). Out of these Salticidae, Linyphiidae and Araneidae constitute the most diverse families, with 6670 species in 681 genera, 4847 species in 634 genera and 3132 species in 191 genera respectively. These three families together constitute 28% of the total species described. Families like Fonteferridae, Huttonidae, Megahexuridae and Trogloraptoridae have single species representatives only. In India, one of the 17 mega diversity countries as per the report of World Conservation Monitoring centre (WCMC) of UNEP, there exist 1990 species of spiders classified under 502 genera and 62 families (Caleb & Sankaran, 2024). Salticidae (108 genera and 326 species), Araneidae (34 genera and 192 species) and Gnaphosidae (28 genera and 141 species) are the most numerically abundant families, together constituting 33% of the total species reported from India.

As is true with the insects, species richness of spiders (Alpha diversity) also follows a horizontal gradient; being highest in wet tropics and gradually diminishing towards the poles. 70% of the total diversity is contributed by just 15 families of spiders. According to experts, the ratio of number of species of spiders expected to those already described is 3.18; implying that around 2/3rd of the spiders still remains to be discovered. The following formula is often adopted to explain the extent of species that remains to be discovered, relative to those already discovered or described (Mendenhall et al., 2014).

[ES= (KS-S)*US]

where,

ES- estimated total species richness, KS- known species, S- estimated rate of synonymy plus invalid names at 10%, US- the expected ratio of unknown to known.

Spiders differ remarkably from other arachnids, by the presence of a pedicel connecting the prosoma and opisthosoma (Preston-Mafham & Preston-Mafham, 1984), presence of spinnerets and web making ability. In size, shape and appearance also, they exhibit extreme variations, from barely visible forms to large Theraphosids, measuring up few inches. Some of them are endowed with remarkable powers of camouflage; mimicking inanimate objects like bird droppings, dry twigs etc., to other arthropods like ants. Sexual dimorphism also reaches its extreme in some groups, where the two sexes of the same species appear totally unrelated both in size and colouration. The colour patterns also constitute a wide spectrum ranging from dull sandy colour as in Lycosids to bright cocktail of colours as in *Chrysilla* or *Maratus*. Among the arthropods, spiders are endowed with the most centralized nervous system with all the ganglia in cephalothorax fusing together to a single mass.

Perhaps one of the most noteworthy aspects of the spiders is the intricate webs they make. Spinnerets located at the base of the abdomen guide the process of making webs. The number of spinnerets is variable; four or six in Mygalomorphs and six in Araneomorphs. The pattern of weaving webs is characteristic of families and are of extreme help in taxonomic studies, especially in assigning guilds. At present, spider webs of more than 130 varying shapes are known to exist (Romer & Scheibel, 2008).

A unique protein, Spidroin forms the raw material in web making. Spider silk is of high tensile strength and hence could be utilised as substitute for many artificial fibres. In addition to insects, spiders are the only group of animals that produce the biomaterial called silk subserving diverse biological activities (Sehnal & Sutherland, 2008). Spider silk, being bio degradable, bio compatible and free from eliciting immunogenic responses in the recipient, could find wide range of applications (Jastrzebska et al., 2016). Plastic, reconstructive and many cosmetic surgical procedures utilise silk (Wendt et al., 2011). Cosmetic surgeons could successfully develop and test breast implant coatings made of spider silk, an approach thought to be helpful in combating the after effects of the process. Potential of spider venom, in developing updated pharmacological formulations that could be utilised to cure anxiety disorders, was being investigated (Beleboni et al., 2006; Liberato et al., 2006)

Making retreats, egg sacs, drag lines, wrapping the prey and ballooning are some additional functions that spider silk is being brought into use (Savory, 1964; Greenstone, 1982; Kovoor, 1987; Nentwig & Heimer, 1987; Foelix, 1996). Apart from the immediate function of gathering prey, these webs also serve diversified functions like extended sensory structures and scaring away enemies; as in *Argiope*.

Food gathering mechanism are of diverse types; ranging from actively hunting the prey, as in stalkers, stealthily waiting for the prey, as in ambushers, to co-ordinated capturing and sharing of prey. Co-operative or 'quasi social' spiders occupy a single web; help each other in nest construction, capturing of prey and parental care (Bilde & Lubin, 2011). Colonial or 'communal' spiders are seen constructing webs in tandem, use the support threads in a sharing manner, but are averse from direct co-operation (Whitehouse & Lubin, 2005). 'Sub-social' spider groups consist of single mothers along with their offspring, later dispersing for reproduction.

It is highly essential that the spiders consume wide variety of insect preys to ensure nutrition for optimal survival and reproduction (Uetz et al., 1999). The prey is immobilised by injecting the venom and the body fluid is sucked off. Spiders compensate for the inability to deal with solid food by liquefying the food, and in many cases grinding the food with sclerotized bases of pedipalps. A male spider commonly invest more energy for mate selection or in competition with conspecific males, in contrary to the females, in which lion's share of energy is invested in egg production and care of offsprings (Trivers, 1972; Andersson, 1994; Eberhard, 2004). An interesting case of food procuring, kleptoparasitism is also met with among spiders, where an individual of entirely different species gets occupied in the extensive webs made by larger spiders and consumes the smaller or less conspicuous prey entangled in the web. Kleptoparasitism is exhibited by members of a few families, namely: Anapidae, Dictynidae, Eresidae, Mysmenidae, Oonopidae, Salticidae, Sparassidae, Symphytognathidae, Theridiidae and Uloboridae (Kaston, 1965; Ramirez & Platnick, 1999; Agnarsson, 2002; Dupérré & Tapia, 2015). Some spiders even maintain commensalism with others. Nectar is being utilised as occasional supplement to animal prey by several cursorial spiders, Juvenile orb weavers sometimes consume pollen during the web recycling.

Next to web building, spiders have always been in discussion for their mating rituals; ranging from 'dances' to providing 'gifts' by the males. Studies by Rypstra et al. (2003) revealed the differences in the cues made by male and female spiders prior to mating. The characteristic behaviours from the part of males; leg raises and shaking of body are sensed by the female, so as to evoke the readiness for courtship. Also, it was found that sensing the substrate borne cues from the females are enough to distinguish a virgin female and a mated one. Even though multiple mating occur, males are found to have a preference for virgin females.

In some cases, the elaborate courtship rituals culminate in the consumption of males by the females; the notorious cannibalistic behaviour. Curiously enough, some of the nocturnal spiders unwind their webs during dawn and consume the threads; a mechanism to compensate for the loss of proteins. A male undergoes about 5 moults before becoming sexually mature while female has to moult 7 or 8 times. The number of moults and intervals at which they occur vary from species to species. One or two days before moulting take place the spider stops feeding. They exhibit varying degrees of parental care; wolf spiders (Lycosidae) carry their young ones on their back, while females of the nursery web spiders (Pisauridae) carry the cocoon in her chelicerae. Female members of families Amaurobiidae, Agelenidae and Thomisidae produce ‘trophic eggs’, specifically meant for nourishing the juveniles. ’Matriphagy’, an extreme case of parental care could be met with in Eresidae. Here, the mother offers herself as a food to the spiderlings (Schneider, 2002). Young spiders exhibit a special pattern of ballooning mechanism to get dispersed.

The bizarre behaviour patterns and the degree of precision and skill employed in making webs were noticed by humans from time immemorial and hence spiders were portrayed in many myths and religious stories. Several myths connected with spiders do exist among different countries. Some people consider them as wholly venomous group and hence are killed at sight. ‘Arachnophobia’ is quite wide spread among people of all continents. As per Hopi’s creation story, spider woman, goddess of the earth, together with Tawa, sun God created the first living being. According to Greek legend, spiders represent the highly skilful weaver Arachne, cursed by Goddess Athena. Spiders also find place in ancient religious contexts; one of them related to Prophet Mohamed and another one involving King David also.

1.2. Features of taxonomic importance

1. Eyes - Number, position and arrangement of eyes are of great taxonomic significance. Eyes are generally eight in number, but may be secondarily reduced to six, four, two, or none. The arrangement of eyes is highly variable among families; e.g., three rows; 2:4:2 as in Ctenidae, two rows; 4:4 in Miturgidae, 3:3 in Scytodidae. The rows of eyes may be straight, pro curved or re curved; e.g., posterior row recurved in Pisauridae, straight in Zodariidae. Anterior eyes include a

pair of anterior medians (AME) and anterior laterals (ALE). Similarly, posterior medians (PME)and posterior laterals (PLE) also do exist. The area between AME and PME, Median Ocular Quadrangle (MOQ) is of great value in taxonomy.

2. Palpal organs - Highly developed and modified appendage among males. It serves to transfer the seminal fluid to females during mating. Based on the complexity, the male spiders may be Entelegyne (palp with complicated structure, adorned with hairs) or Haplogyne (palp is very simple in structure).

3. Epigynum - External genitalia of female spiders. It is located in epigastric furrow and is highly sclerotised. As the finer details of epigynum shows high degree of variability among species, it is considered as one of the most distinctive characters in spider taxonomy.

4. Cribellum - Special silk producing organ situated in front of the spinnerets. Spiders may be referred to as cribellate or ecribellate based on the presence or absence of cribellum. In Cribellate spiders, a specialised comb like structure, calamistrum is seen on the fourth metatarsus and is helpful in pulling out the silk produced in cribellum.

5. Trichobothria - Fine hairs that extend at right angles from the surface of the leg can be found on all leg segments. The presence and arrangement of trichobothria helps in allocating spiders into families.

6. Length and width of cephalothorax and abdomen are also features of taxonomic interest.

1.3. Why spider diversity?

Under a false notion of lacking a universal appeal, researchers across the globe often ignored the spiders in their studies, in comparison to organisms of equal importance, or even organisms of lesser importance were given pre-ponderance (Barth et al., 1995). Considering the pivotal and beneficial roles played by spiders in many ecosystems, Skerl (1999) opined that implementation of any major developmental projects has to be preceded by a checklist preparation of spiders endemic in that area.

Studying spider diversity is of paramount importance considering the following;

(i) High degree of diversity: As already indicated, there exists a bewildering diversity in these creepy organisms. Even though highly specific with respect to tolerance of environmental conditions, they invaded and got acclimatised to regions that seem to be uninhabitable to them. Considering the prevailing trend, in our country, the Western Ghats, North- eastern hill states and arid, sandy areas of Rajasthan, all are expected to harbour a treasure house of spiders. Systematic and goal-oriented explorations will definitely bring a sudden spurt in the number of species of spiders reported from our country.

(ii) Ubiquitous nature: It won't be an exaggeration to state that there doesn't exist any terrestrial ecosystem on the globe sans spiders (Nyffeler & Birkhofer, 2017). Their presence can be attributed at any improbable or hostile habitats on earth; from cold tundra alpine ecosystem, tropical rain forests, salt pans, high mountains, barren lands, marshy bogs and deserts with extreme diel temperature fluctuations. Many species of spiders were reported from localities of Russia, where the annual temperature drops to even negative range. In contrary, presence of spiders was reported from Death Valley, California, the hottest place on earth, experiencing a scorching temperature of 93.9 °C (Kubecka, 2001; Crews & Gillespie, 2014).

(iii) Obligatory predaceous nature: With reference to food selection, they are agile polyphagous predators. Their prey generally includes insects of various orders, and serves to check the excessive growth in population. Spiders constitute one of the most important 'safety valves' that prevent the potential of many insects from emerging to the level of causing economic loss.

(iv) Bio control potential: Spiders prove to be of immense application as biological control agents, especially in agroecosystems. The polyphagous, predatory nature of spiders could be exploited to varying degrees, to be used in integrated pest management practices. A lot of research has been carried out in connection with channelising the biocontrol potential; especially by workers in applied ecology. Venturino et al. (2008) studied the use of wanderer spiders as biocontrol agents in agroecosystems. As per their findings, during periods of severe shortage of prey, wanderer spiders resort to modified behavioural strategies including migrating to more productive habitat.

(v) Ecological indicators: Being sensitive to fluctuations operating in their habitats, spiders are good indicators of ecological conditions. Their large-scale retreat or sudden flourishing in any habitats hint towards a cascade of natural phenomena operating there. Cardoso et al. (2010) opined that spider forms an ideal group for predicting the probability of species extinction due to habitat destruction. Apart from indicating their diversity, the multitude of prey capturing strategies adopted by them can also reflect diversity at other trophic levels (Żmudzki & Laskowski, 2012). They prove to be useful as bioindicators to assess the degree of impact of human disturbances on natural ecosystems (Maelfait & Hendrickx, 1998; Hore & Uniyal, 2008). As spiders respond quickly and persistently to any sort of habitat alterations, they constitute a highly reliable category of ecological indicators (Tandon & Lal, 1983). In forest ecosystems, spiders prey on the decomposers and thus regulate their populations (Clarke & Grant, 1968). Hence, they could be employed as indicators to assess any alterations in terms of structure, complexity, depth and nutrient contents of litter (Uetz, 1991). Spider webs collected from localities subjected to severe air pollution were seen to contain traces of the active pollutants, including heavy metals. The extent of air pollution in an area can be indirectly assessed by the analysis of webs (Xiao-li et al., 2006; Ayedun et al., 2013).

(vi) Model organisms: Owing to the ease of collection, handling and observation, spiders have the potential to be used as model organisms in many studies relating to ethology, ecology, conservation biology, entomology and toxicology. Riparian orb-weaving spiders, for example, could be employed in studies dealing with population interactions, predator - prey fluctuations, preferential selection of preys, complexity of food webs, etc. To be more specific, the unparalleled diversity, strictly predaceous nature with a vast array of hunting strategies, make them a good model organism for community ecology (Wise, 1993; Toti et al., 2000; Hesselberg & Galvez, 2023).

Studies conducted on Tetragnathid cave-dwelling spider, *Meta menardi*, revealed significant difference in web making and abnormally long limb segments (Simonsen & Hesselberg, 2021). These are considered to be the representative adaptations for coping up with energy - deficient environments. Hence these categories of spiders could be used as model organisms to study species living in hostile environments. Similarly, sub social spiders could be utilised as model organisms in studies of various topics in ecology, like kin recognition and parental care (Yip & Rayor, 2014).

(vii) Commercial uses: Considerable quantum of research has been carried out on exploiting the high tensile strength of spider silk. Bullet proof clothing, parachutes, surgical threads, artificial tendons, biodegradable vials etc. are already in vogue

(Vollrath & Knight, 2001; Hinman et al., 2014). Studies on spider venom revealed the existence of many neurotoxins. One of these has yielded promising results in controlling the troublesome cotton pest, *Helicoverpa armigera* (King et al., 2002). Some of the spiders are utilised in the preparation of Homeopathic medicines (viz. *Aranea diadema, Latrodectus mactans, Latrodectus hasselti, Tarentula hispania, Lycosa*, etc.) where tinctures are prepared by putting the living spiders into absolute alcohol (Richardson-Boedler, 2002; Avedissian, 2005). In some tribal areas of Maharashtra, spider silk is mixed with jaggery and consumed in order to control certain recurring fevers (Vijayalakshmi & Ahimaz, 1993). In Cambodia cooked Tarantula spiders are considered as a delicious food (Baerg, 1938).

(viii) Ecosystem services: Birds, frogs, lizards and many other insectivorous animals consume spiders, as the plentiful and easily available prey (Peterson et al., 1989; Polis, 1989; Wise, 1993; Gaiarsa et al., 2012). They offer great help in balancing the energy transfer pathways in ecosystems. By occupying themselves at various trophic levels, spiders alleviate the disruptions in ecosystems, in terms of energy transactions and ultimately ensuring the self-reliant nature. The burrows made by *Geolycosa* and Tarantulas help in percolation of water. Being rich in simple proteins, spiders form an integral part of the diet of lizards, birds, many hymenopterans, etc. Also, the ground dwelling spiders play a key role in transferring energy trapped in the below-ground detritus food webs to the above-ground terrestrial food web comprising familiar vertebrates; birds, reptiles, amphibians and mammals (Johnston, 2000). Prevalence of highly diverse spider populations have been denoted as a sort of 'insurance' with respect to many vector borne diseases (Nelson & Jackson, 2006). A considerable degree of reduction in spreading of mosquito borne disease, Malaria has been reported (Jackson & Cross, 2015). During prey capturing, spiders inadvertently feed on the insect pests, which in turn has been shown to result in increased productivity of primary producers. The overall effect is ecosystem with highly stabilized trophic interactions (Rypstra & Carter, 1995).

20^{th} century recorded a sudden spurt of development in Araneology. Incorporation of modern and state of the art techniques heralded various arenas in spider research; especially systematics. Species level identification based on molecular data, use of improved and sophisticated imaging techniques, development of special databases for large scale data handling, adopting geo sensing strategy of specimens, digitization of the major break throughs in spider research and ensuring data availability through public databases, etc., could be considered as milestones in the growth of Araneology.

On a global perspective, biological wealth of any country is put under maximum threat, in comparison to the material and cultural wealth. In spite of worldwide campaigns destined for prevention of biodiversity loss and the subsequent conservation of each and every living being, these programs mainly focus on larger animals and hence smaller organisms like spiders are not among the beneficiaries. Documentation and periodic updation of the biological wealth are of immense importance in the present scenario. Thirteen families of extant spiders have been recorded after 1950;.Entypesidae (2020), Microhexuridae (2020) Statimopidae (2020) and Fonteferridae (2023) are some of the recent additions to the families of spiders.

1.4. Riparian habitats

Latin word '*ripa'*, meaning river bank is the source of the word riparian. Periodically the term has been redefined to include areas along more types of water bodies, like lakes, ponds and other wetlands. Nowadays, those zones that influence and that are strongly influenced by adjacent aquatic environments are considered to be riparian. Riparian areas are unique ecosystems in the manner in which some of the energy as organic matter or organic carbon is transferred from producer to consumer organisms. This uniqueness derives from the fact that litter-fall produced within the riparian ecosystem may be transported laterally and made available to instream animal communities as well as those downstream from the source of organic matter production. As compared with purely aquatic or terrestrial ecosystems, organic matter produced in riparian ecosystems has the potential of supporting a diversity of food webs within both habitat types. Riparian habitats are highly complex in terms of structure, with characteristic vegetation and topographic features (Malanson, 1993).

They can be better represented as transition zones between truly terrestrial and aquatic ecosystems. The extent of biological processes and biodiversity tend to be maximum at these zones (Bell et al., 1999). A highly complex and unparalleled energy flow patterns do exist via the food webs. The flanking ecosystems share ecosystem subsidies in the form of litter, periphyton, emerging insects, etc. Owing to the peculiar position occupied in the landscape, and being the sites of maximum human interference, riparian ecosystems are subjected to maximum alterations, unparalleled degradation and ends up as highly vulnerable ones.

Rivers during their course of flow, carry elements in suspended or dissolved form and later on deposit the same at different locations. This suspended matter can simultaneously act as a sink or source for nutrients as the case may be. Arkle et al. (2010) opined that habitat mosaics are created as a result of disturbances in riparian habitats; sediment accumulation, accumulation of wood and debris, bank erosion, etc. Efficient and goal-oriented approaches for the management and restoration of the riparian ecosystems turn out to be the need of the hour, not only to conserve the diversity on the flanking ecosystems, but also to ensure the well-being throughout the world.

Riparian areas help to palliate pollution, especially from non-point sources. The vegetation found in these habitats are of key importance, in stabilizing the banks, preventing soil erosion (John et al., 2022), slowing the flood flow and maintaining the temperature of water body. Pressey et al. (2007) opined that biological invasion, supplemented by climate change triggers and catalyses ecological changes happening in all sorts of environments. The magnitude of these changes is so pervasive and unpredictable that in future, not so distant, majority of the world's ecosystems will transform to radically different states, including riparian zones. Human activities left long lasting adverse effects on the riparian habitats and their components; agriculture, grazing by livestock, logging, mining, etc. (Manci, 1989; Alonso et al., 2014).

Exhaustive studies on faunal diversity, hydrological data and flow characteristics were carried out mainly on Indian rivers flowing through Indo Gangetic plains. Large floods, drought, wild fire, landslide etc., act as natural stressors, disrupting the integrity of riparian ecosystems (Bendix & Hupp, 2000).One of the potential threats faced by many riparian habitats is those pertaining to alterations in river discharge; if the present scenario and climate prevails, we could expect many of the river basins experiencing water stress; from extended waterlogging or from drought (Palmer et al., 2008; Vorosmarty et al., 2010). Expeditious climatic changes will have their tolls on the habitable space available for many species (Pressey et al., 2007). The ensuing results may be aberrant biogeochemical cycles, altered patterns of species distribution, and unprecedented biotic interactions (Morin & Thuiller, 2009).

A vast majority of authors describe riparian ecosystems as highly degraded, threatened and vulnerable ones, with characteristically different and numerically high diversity of flora and fauna. Some of them even suggest the imminent probability of extinction as a general attribute of riparian species. However, later on a highly contradictory opinion also emerged which portrays riparian ecosystems as those which can resist climate change, mainly because of their origin in highly fluctuating environmental conditions and often subjected to hydrologic extremes (Seavy et al., 2009; Catford et al., 2013).

According to Hatley & MacMahon (1980), there do exist a positive correlation between the complexity of habitats and species diversity of spiders. A similar relationship is also believed to exist between the complexity of habitats and guilds of spiders (Cardoso et al., 2011). An ecosystem with spiders belonging to highly diverse guilds, is potentially a stable one, with reduced probability of competition for resources. As is true with others, riparian ecosystems also experience carbon dioxide enrichment and increasing temperatures of air and water, all occurring as a result of human influenced climate change. Negligence or delay in checking the above disrupting factors will eventually terminate in episodes of anthropogenic extinctions of species.

The degree and extent of climate change incident on riparian ecosystems show high variability both in a global and river basin scales, and in varying reaches of the aquatic body which forms the core of that ecosystem (Palmer et al., 2009). Their topographic position, generally within river corridors, renders the riparian ecosystems highly prone to the action of extremes of those natural catastrophes like cloud bursts, floods, droughts and storms, all leaving some detrimental effects on regional biodiversity and highly disrupting the environmental balance (Pickett et al., 1987; Bates et al., 2008). These disrupting factors may be derived from fluvial processes (e.g., floods, drought) or of general terrestrial origin (e.g., wildfire, avalanches) (Bendix & Hupp, 2000). Furthermore, considering the pace and quantum in increase of factors contributing to climate change, these catastrophes are believed to become more intense and frequent in many regions of the world.

Riparian habitats are often associated with characteristic vegetation, depending on the soil, seasonal variations in water level and salinity, presence of other disturbances (natural or anthropogenic) including fire, soil erosion, grazing of cattle herds, alternative uses of the parts of river with soil beds, when the water level recedes, etc. Riparian plants may range from short lived peripherally rooted grass family members to deep rooted, shrubby plants with reduced leaves, or larger perennial trees in some cases. Gramineae family members with typical elongated and sharp-edged foliage are generally a preferred cryptic hiding place for riparian spiders like Tetragnathids. Considering their significance in perpetuation of resources, riparian vegetation, has often been referred to as the 'aorta' of the ecosystem.

1.4.1. Riparian habitat - functional aspects

i) Act as transition zone between two structurally and functionally distinct ecosystems.

ii) Serve as natural areas of detention during flooding; thereby contributes significantly to ground water recharge.

iii) A reciprocal flow of energy is ensured between fishes in the streams consuming terrestrial invertebrates and aquatic insects emerging to riparian habitat (Knight et al., 2005).

iv) There exist unique species interactions and characteristics food chains in operation; rendering these habitats as novel.

v) Riparian zones are prone to both point and non-point sources of pollution and hence can be useful in assessing the degree of alteration in environment as a function of human interference.

1.5. Riparian spiders

Riparian spiders serve as bi directional links between neighbouring ecosystems. Besides falling prey to predatory birds or other arthropods, they also act as top predators in some food chains; there by increasing the complexity of food webs. They actively prey upon aquatic insects or some insect groups which have aquatic larval phases during development.

Presence of a tough and impervious cuticle and simple ramified respiratory organs makes the arthropod body befitting for both aquatic and terrestrial modes of life (Dunlop et al., 2013). Purely aquatic existence is restricted to a single genus of spiders; *Argyroneta*. It has developed characteristic adaptations for such a challenging life. Members of at least 21 families of spiders have evolved the essential contrivances for associating with aquatic habitats. Dictynidae, comprises several members adapted for remaining associated with aquatic habitats. This family enjoys a world-wide distribution with 461 species in 52 genera. Orb-weavers constitute the most dominant guild in riparian habitats (Reyes-Maldonado et al., 2017).

Dolomedes, the common fishing spiders are equipped with adaptations for semi aquatic mode of existence. Their legs are adapted for effortlessly running over fresh water bodies and can dive and survive under water for brief periods of time. The coastal spider, *Nephila plumipes* has developed strategies for surviving in coastal waters with high range of salinity (Preston - Mafham & Preston - Mafham, 1984).

Spiders inhabiting riparian zones, acting as a viable bilateral transfer pathway, stabilize the food webs and play a pivotal role in ecosystem dynamics (Baxter et al., 2005). Studies conducted by Akamatsu et al. (2004), regarding the food source of riparian spiders, in Chikuma river, Japan using stable isotopes of Carbon and Nitrogen revealed that the isotope ratios of riparian spiders were intermediate between that of terrestrial and aquatic insects. Results of this experiment indicated that the organic materials produced in the water-logged area and terrestrial area blended together at the trophic level of riparian spiders. Based on the observations of semi aquatic spiders predaceous on fishes, Nyffeler & Pusey (2014) opined that predation of fishes by semi-aquatic fauna was a rather widespread phenomenon on all continents, except, probably on Antarctica.

Despite the most fundamental and decisive roles played in ecosystems, study of spiders has often been side-lined or ignored in contexts of conservational studies (Pearce & Venier, 2006). Spiders associated with riparian habitats seem to be highly flexible enough in terms of the functional roles they have to serve. In the food chains operating in such a complex habitat, spiders could be met with in a variety of trophic levels; from secondary consumers to top predators. This itself is sufficient to prove that how significant the spiders are in sustaining and balancing the ecosystem as a whole. Moreover, it points towards the need of conserving riparian ecosystems.

Proximity to rivers or any other water bodies proves to be highly beneficial to organisms in riparian zone, as they are ensured of food resources in the form of algae, arthropods emerging from water and anadromous fishes. Even though, the presence and distribution of web building riparian spiders depend, to a large extent, on the availability of emerging aquatic insects, presence of substrates for web building has got an equally important and decisive role in spider dynamics. By the linkage of aquatic and terrestrial food chains established by them, riparian spiders occasionally resort to a trophic by pass, where, they feed upon adult aquatic organisms emerging from aquatic bodies subjected to contamination by highly toxic substances like heavy metals, methyl mercury, PCBs etc.

Invasive species emerged as a new decisive factor of species diversity and abundance of riparian spiders. In USA, following the introduction of invasive brook trout to rivers resulted in 24% reduction in aquatic insects, subsequently leading to 6 to 20% reduction in spiders of riparian zone. The complex intertwining of food chains operating in riparian zones, brings unprecedented population interactions; competition among populations which have no chances of direct interaction. Riparian animals including spiders exploit the allochthonous resources available from nearby aquatic body and in turn affect the primary producers (Murakami & Nakano, 2002; Sabo & Power, 2002; Woodward & Hildrew, 2002). In ecological taxa subjected to less interferences and manipulations, the abundance and species richness of spiders were found to be comparatively higher (Culin & Yeargan, 1983). As it could be expected, sustenance in a riparian habitat demands some flexibility from the organisms, in terms of foraging, searching for themselves.

1.6. Bharatapuzha

Bharatapuzha is one among the 41 rivers originating in Western Ghats and flowing west ward to join the Arabian sea. It is the second longest perennial rivers of the state. Flowing between 10°25'-11°15'N and 75°50'-76°55'E, it traverses 209 km. From different locations of Western Ghats, small rivulets originate, that later on join forming the major tributaries of the river; Kalpathipuzha, Kannadipuzha, Gayatripuzha, Thootha and Chitturpuzha that finally discharges to the Arabian sea at Ponnani, Malappuram distrct, Kerala.

Kannadipuzha, one of the major tributaries of Bharatapuzha, flows through the southern border of Palakkad district, later joins with Kalpathipuzha. Major portion of Palakkad district gets irrigated by the Kannadipuzha, Kalpathipuzha and Gayathripuzha. Chitturpuzha, locally knows as 'Shokanashini', the most upstream tributary, joins the Kalpathipuzha at Parali, and forms the river Bharatapuzha.

The Central Water Commission, (CWC; Government of India), has established five river gauge stations along the tributaries of this river; Amparampalayam, in Coimbatore district, Pudur, Mankara and Kumbidi (all in Palakkad district) and Pulamanthole (Malappuram district). These stations help to maintain the annual record of rainfall as a factor of the fluctuations in water level along the river.

Located in south – western coast of India, Kerala receives heavy and seasonal monsoon rains, which is highly instrumental in deciding the climatic regime of the state. This monsoon in turn dictates the hydrological features of the rivers in the state (Nair & Sreedharan, 1986; Padmalal & Maya, 2014). Western Ghats, covering up to 72.08% of the geographical area of the state, not only decides the precipitation, but also act as home for multitude of fauna and flora, there by acting as a repository of biological diversity (Sudha, 2011).

Out of the total 6186 km^2 area of the river basin, 4400 km^2 lies within Kerala and the remaining part in Tamil Nadu. Importance of the river could be deduced from the fact that approximately one – ninth of the total geographical area of Kerala is supplied by the network originating from this river. The hydrological regime of Bharatapuzha river and its tributaries is characterised by seasonal variations, with alternating wet and dry periods (Heckman, 1998). During the aquatic phase, due to the low drainage capacity, the plains are flooded by overflowing river. Uncontrolled sand mining and clearing of vegetation along the banks force the river to literally turn to narrow channel during the terrestrial phase.

Uncontrolled development plans implemented in riparian zones, mainly keeping in mind the scope of tourism and water transportation facilities, had tragic after effects (Sasidevan et al., 2018). Highly dynamic and biodiversity rich riparian habitats got converted to garbage dumping sites and the pollutants including metal cans and plastics were carried to the benthic regions, there by posing a perennial threat to inherent fauna and flora. Excessive human intervention in these habitats led to the accidental introduction of propagules of non-native plants, which later on rose to the status of invasive alien species.

Large scale invasion by creepers like carrot grass (*Parthenium* sp.) has triggered a total replacement of vegetation, in turn paving the way to change in associated fauna of insects and predatory spiders. Another factor contributing to this scenario is the disturbances in climate; both local and global, and the subsequent CO_2 enrichment. Dukes et al. (2011) observed a many fold increase in growth rates of invasive plant species compared to the indigenous ones, as the aftermath of CO_2

enrichment. In such complex situations, the invasive species of plants and animals (to certain extent) may emerge as the dominant and decisive species (Canning - Clode et al., 2011; Davey et al., 2012).

Conservation biologists assign biological values or weightage to habitats, based on the richness of species and relative fraction of endemic organisms inhabiting there. Various disrupting factors, both natural and anthropogenic, are also taken into serious consideration. The intrinsic biological values of spiders are far ahead than that of vertebrates (Mittermeier et al., 1999). This in turn proves to be helpful in demarcating zones for conservation.

1.7. Importance of the study

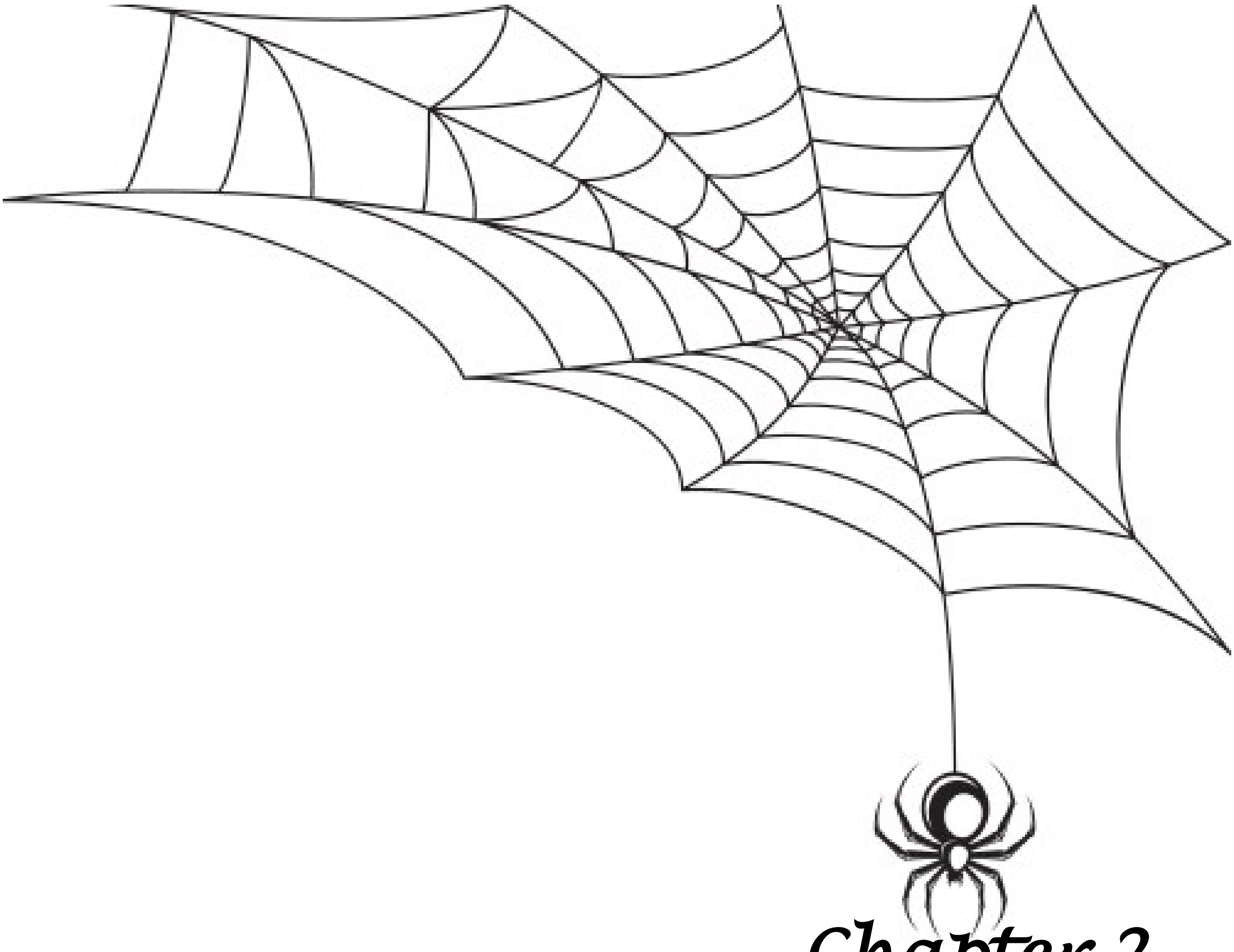
Riparian habitats are highly dynamic and extremely significant from an ecological perspective. Proximity to water dictates the unique features of the ecological interactions operating there. Study of riparian habitats of Bharatapuzha gains significance in that the river is facing severe degree of anthropogenic threats. It has undergone subtle and unprecedented variations in its appearance and quality of water. Unscientific and non- judicious use of riparian resources including fish and nutrient rich alluvial soil has converted the river to the status of a barren land. Noticeable reduction in availability of fresh water fish has often been reported.

Study of spider diversity has many advantages; spiders being exclusively predatory, the food preferences and the ultimate fate of each food stuff can be conveniently traced. Riparian spiders derive food from two different kinds of ecosystems; terrestrial and aquatic. They are of unparalleled ecological importance as indicator species of both. As is true in the case of animals, riparian habitats of Bharatapuzha is home to many rare, endemic and seasonal plants having complicated nutrient requirements (Cherullipadi & Paul, 2016). Increased awareness regarding the biodiversity inherent in riparian ecosystems can hopefully pave the way for many conservation movements and outreach programmes regarding these special ecosystems. Discovery and description of any new species of spiders specifically adapted to these areas can enrich the field of arachnology.

The study revealed the necessity of protecting the riparian habitats of Bharatapuzha; being rich in araneofauna. Along with the spiders, protection of characteristic riparian vegetation is also of paramount importance.

1.8. Objectives

- Study the diversity of spiders along the banks of major tributaries of Bharatapuzha in Kerala.
- Compare the diversity associated with major tributaries.
- Record trends in distribution and abundance of spiders in conjunction with the seasons.
- Find out any new species or very rarely reported species from Kerala.



Chapter 2.
Review Of Literature

REVIEW OF LITERATURE

"The focus of a literature review is to summarize and synthesize the arguments and ideas of others without adding new contributions or new arguments"

2.1. Studies from abroad

Perhaps, one of the pioneer attempts in spider taxonomy could be found in '*Systema Naturae*' (Linnaeus, 1758), containing descriptions of 30 species. In 19th century, more and more scientists got attracted to spider taxonomy and as a result, there was a sudden spurt of published works including those of Leach (1815), Walckenaer (1826), Blackwall (1841), Simon (1884), Pickard-Cambridge (1885), and Keyserling (1886). Studies conducted by Doleschall (1859) on spiders of Indonesian Archipelago, were instrumental in describing a few species of spiders that are found in Indian region as well.

Comprehensive works describing spiders of different regions came out with plenty of new descriptions; catalogue of Burmese spiders (Thorell, 1895), Malaysian Spiders (Workman, 1896), Spider fauna of North America (Kaston, 1948), Spiders of Great Britain (Locket & Millidge, 1951), Spiders of Tokyo (Shinkai, 1969), Spiders of Australia (Mascord, 1970), Spiders of China (Feng & Yin, 1990), Spiders of Madagascar (Ono, 1993), Spiders of Korea (Kim, 1991; Namkung, 2002). Hatley & Macmahon (1980), tried to bring out the relationship among spider communities, seasonal variation and vegetation architecture. The shrub architecture was experimentally manipulated either by clipping off the foliage by 50% or tying additional branches to the shrubs. Results indicated a higher incidence of occurrence of spiders in shrubs with dense foliage.

Spiders, being highly agile and swift moving groups, to study the diversity of a particular habitat, we have to consider the parts of adjacent habitats intimately associated with the previous one (Duelli et al., 1990). Biswas & Raychaudhuri (1998, 2000, 2003, 2004, 2005, 2012, 2013, 2014, 2019) carried out exhaustive surveys of spiders of Bangladesh and described them in various publications. Similarly, Tu & Li (2003, 2004, 2006) described spiders of Vietnam in various volumes. Spiders of the world (Preston - Mafham & Preston - Mafham, 1984), carried generalised descriptions of spiders on a global scale.

Many noteworthy works on spider taxonomy continued to emerge from various regions; descriptions of spiders of central Europe (Heimer & Nentwig, 1991; Kuntner & Sereg, 2002), spiders of northern Europe (Roberts, 1995), spiders from Missouri, USA (Stirnaman et al., 1998). Merrett & Murphy (2000) prepared a checklist of spiders of Britain, carrying 645 species. Descriptions of Korean spiders were published by Kim & Kim (2002) and later by Namkung (2003). An online key for the identification of families of Central European spiders was published (Nentwig et al., 2013) (https://araneae.nmbe.ch/).

Commendable work on rice land spiders of South and Southeast Asia were being carried out by Barrion & Litsinger (1995). 21 new species of Australian funnel web spiders (sub family Atracinae) were described by Gray (2010), 25 new records were reported from Golestan Province, Iran by Kashefi et al. (2013). New species from China were being described in the Lycosid genus, *Hippasa* by Yin & Wang (1980). An account on the spiders of Africa in Savannah biomes was given by Foord et al. (2011). A worldwide revision of the families Pacullidae and Tetrablemmidae was carried out by Lehtinen (1981). He could also describe several species and genera in these families.

A new genus under family Gnaphosidae; *Gertschosa* was described from America (Platnick & Shadab, 1981). The Gnaphosid genus *Drassyllus* was revised (1982), described species in the Gnaphosid genus *Apodrassodes* (1983a) and synonymized the species *Apodrassodes conjuncta*, *A. rouxi*, and *A. singularis* with *A. guatemalensis* (1983b). They removed the genus *Teminius* from the synonymy with *Syriska.* Preston-mafham & Preston-mafham (1984), provided a general description of spiders from all over the world. Kremen et al. (1993), studied pattern of distribution of spiders in natural habitats and suggested the potential of spiders as ecological indicator species. A new genus, *Camptoscaphiella* in Oonopidae was described by Deeleman-Reinhold (1995) from a cave in China. Costello & Daane (1995), assessed the effect of native spider populations on leaf hopper *Erythroneura variabilis*, species composition, relative abundance, and seasonality in occurrence were determined. 27 species of spiders were recorded, representing 14 families. They also compared the sampling methods used to estimate spider species abundance and composition in grape vineyards (1997). Their methods included drop-cloth method, a funnel method and a D-vac method. They suggested funnel method as the best one considering the efficiency in estimating spider densities and reduced cost.

Greenstone (1984), observed a positive correlation between diversity of web makers and the height of dominant vegetation. A similar relationship among ground dwellers and the amount of litter was also noticed (Uetz, 1975; Green, 1999). Uetz et al. (1999) studied guild structure of spiders in major crops. An alternative approach to guild classification was proposed using quantitative analysis of ecological characteristics of spider families.

Biswas worked on the spiders of Bangladesh. He described many new species of family Salticidae (Biswas & Begum, 1999; Biswas , 2016, 2017, 2019) and also described new species as well as new records of spiders belonging to other families (Biswas & Raychaudhuri, 1998, 2000, 2003, 2004, 2005, 2012, 2013, 2014, 2019). They worked extensively on sac spiders, orb weavers, huntsman spiders, and wolf spiders and described various new species along with new records from the region in many consecutive papers. *Castianeira* (Corinnidae), and *Sphingius* (Liocranidae) were redescribed from Bangladesh (Biswas & Raychaudhuri, 2000). Exhaustive studies conducted in different zones of Bangladesh (Biswas, 2020) could report two new species of *Cyrtarachne* (Araneidae), *C. biswajiti* and *C. sundari*.

A specially dedicated web catalogue for compiling Jumping spiders; Salticidae of the world, was contributed by Prozynski (2005). Venturino et al. (2008) studied the efficacy of wanderer spiders as biocontrol agents in intensive agroecosystems of Langa Astigiana. A working mathematical model was being developed to assess the predation efficiency of spiders under consideration. The authors worked out the population dynamics of wanderer spiders.

Topping & Lovei (1997) surveyed spider density and diversity in relation to disturbance in agroecosystems in New Zealand. They observed that population density and species diversity decreased with increase in disturbances. This study recorded highest diversity in an abandoned, un grazed pasture. Three volumes published by Platnick (1989, 1993, 1999), compiling the literature from 1981 to 1995. The online version of these three volumes (Platnick, 2005) was highly accepted one and was being utilised as a ready reference material by researchers all over the world.

Martisova et al. (2009) studied the sex-specific kleptoparasitic foraging in ant-eating spiders. They analysed the effect of sex and life history stage on the frequency of kleptoparasitism in ant-eating spiders of the genus *Zodarion*. A difference in strategies of capturing ants were noticed; adult females consistently hunted actively, while adult males shifted almost entirely to kleptoparasitism. Juvenile spiders, irrespective of sex, were found to be active hunters. Males preferred to feed on freshly killed prey while live prey were being preferred by females.

Buckland & Turnock (1992) came forward with a more practical alternative to the traditional line transect method. They proposed a robust field methodology which requires only single trials. The newly proposed approach works well only in surveys with two observation platforms are available.

Punzo (2002) studied the effect of food imprinting and it's after effects in the lynx spider, *Oxyopes salticus* (Oxyopidae). He concluded that the type of food being offered to newly hatched spiderlings leave a far-reaching influence on its future prey preferences. Rypstra et al. (2003) observed the courtship behaviour patterns of wolf spiders and compiled the differences in the cues used by males and females. They specifically determined whether males were capable of detecting the mating status of a female and the nature of cue in such a case. Also, quantification of conspicuous aspects of the male courtship including leg raises and body shakes, was done to find out the relationship among courtship intensity and female choice. Muelelwa et al. (2010), worked with a pioneer attempt to list out spider diversity in Savannah biomes. The project was implemented in Blouberg Nature Reserve (BNR) and Western Southpansberg Conservancy (WSC) situated in the Savannah Biome, Limpopo Province, South Africa. Hogg & Daane (2011a), studied the interactions between the exotic species of spider *Cheiracanthium mildei*, its native ecological homologue *Anyphaena pacifica* and a native spider utilising different hunting mode, *Theridion melanurum* in a field experiment. Grape leafhopper *Erythroneura elegantula* was introduced in the experimental set up as a herbivore prey shared by them. The results indicated that exotic spider exerted a negative impact on a range of spiders. Intraguild predation was found to be the major factor for this. They also sampled native and non-native spiders along line transects to assess the role of natural habitats in controlling spider diversity (2011b). Results of the survey suggested that a considerable difference do exist in the ecosystem services provided by natural habitat and in agricultural landscapes dominated by exotic species.

Biswas (2020) gave the first report of the genus *Misumenoides* from Khulna, Bangladesh. *M. deccanes* was recorded for the first time. Hogg et al. (2010) analysed regional patterns in the invasion success of *Cheiracanthium* spiders in vineyard ecosystems of California. The results indicated a significant shift towards the invasive species occurs only in highly disturbed habitats. Hanna et al. (2003) discussed relative impact of spider predation and cover crop on population dynamics of *Erythroneura variabilis* in a raisin grape vineyard. They could demonstrate many fold increase in spider abundance in vineyards supported with cover crops.

Bukhari et al. (2012a) made an elaborate study of species abundance of spiders along with the seasonal fluctuations in their occurrence from citrus orchards of Sargodha district, Pakistan. They also worked out the diversity indices of spider fauna collected specifically by pit fall trap method from Guava orchards, Gujranwala, Pakistan (2012b). The spiders collected belonged to 7 families, 10 genera and 22 species. Shannon diversity index, Pielou's evenness index and Simpson diversity index was calculated.

Ferretti et al. (2013) made a comprehensive analysis of sexual behaviour patterns exhibited by Mygalomorph spiders. They provided a systematic treatment of the available literature published in the last 21 years about the same. Dippenaar-Schoeman et al. (2013) reviewed the diversity and distribution of spiders in different agroecosystems of South Africa.

Anderson et al. (2015) updated the guidelines for line transects sampling of biological populations. They emphasized the importance of conducting observations along straight transects and obtain accurate measurements of distances and sighting angles. Yip & Rayor (2014) studied social interactions and a detailed account of maternal care and sub social behaviour in spiders were provided. A thorough review of literature related with sub social and maternal behaviour in spiders was done. They found out that sub social behaviour has evolved at least 18 times in spiders, on an independent basis. El-Hennawy (2020) published notes on family Segestriidae from Egypt. The specimen being studied was *Segestria florentina.*

Simonsen & Hesselberg (2021) focussed on the unique behavioural modifications in the web structure of the cave orb spider *Meta menardi* (Tetragnathidae). A comparison was being made both in morphological traits, (in terms of relative leg lengths), and behavioural traits, (in the geometry of the spider web), between the cave-dwelling spider, *Meta menardi*, and two plane- dwelling species from the same family (Tetragnathidae); *Metellina mengei* and *Tetragnatha montana*. Remarkable differences in webs; in terms of size, web asymmetry, etc., were found among the two groups. Deng et al. (2022), reviewed *Meotipa* species

(Theridiidae) from China. They described two new species; *Meotipa pseudopicturata* and *Meotipa striata*. Redescription of five known species was also done*: Meotipa argyrodiformis, M. pulcherrima, M. picturata, M. spiniventris and M. vesiculosa*.

2.2. Studies from India

2.2.1. From Kerala

Ferguson (1906), recorded 12 common species of spiders from erstwhile Travancore state. Studies by Sathiamma et al. *(*1987) on coconut plantations of Kayamkulam reported several species of spiders. The first report of *Argyrodes flagellum* was published by Sudhikumar et al. (2003). Description of *Trignobothrys* (2004), a hitherto unknown genus from India, elaborate description on diversity of web-making spiders in rice agroecosystems in Kuttanad (2005a), were other valuable contributions by these authors. A pioneer survey of spider diversity existing in Mannavan shola, the largest patch of shola forests in Asia (2005b), was being carried out. 72 species of spiders included in 57 genera of 20 families were reported. Guild structure analysis revealed 6 feeding guilds. 15 species reported from Mannavan shola are endemic to Western Ghats of Kerala. Sebastian et al. (2005) documented the araneofauna in Mangalavanam, a threatened mangrove forest in Cochin, Kerala, India. 51 species of spiders under 40 genera and 16 families were reported in this study. Araneidae and *Pisaura gitae*, respectively were the maximum represented family and species. They described the genus *Tapponia* for the first time from India.

Ramesh et al. (2016) analysed the variety of responses of a praying mantis to ant-mimicking spiders. The study demonstrated that the mantids exhibited different types of responses when provided with ants and ant mimicking spiders. It was concluded that an invertebrate predator, the praying mantis, is capable of discriminating between two closely related mimetic preys. Rajeevan et al. (2019) investigated the spider faunal diversity in selected habitats in the Western Ghats of North Wayanad region, Kerala. 150 species of spiders belonging to 73 genera under 20 families were recorded. Kattikulam forest reserve showed the highest species richness. Seven functional guilds were recorded.

Malamel et al. (2019) carried out taxonomic revision of the genus *Psellonus* (Philodromidae). This work contained first description of the male of *Psellonus planus*. They proposed the synonymization of *Philodromus kendrabatai* with *Psellonus planus.* First reports of *Neoscona usbonga* (Araneidae) and *Hamataliwa pentagona* (Oxyopidae) from India was done by Asalatha & Prasadan (2020), specimens being collected from Kareem forest, Kasaragode.

Karthika & Jose (2020) published new distributional record of *Ctenus indicus* from Western Ghats, Kerala. Previously reported from Parambikulam, Kerala, this report resulted in extension of the range extension of this genus over Kerala. Sankaran et al. (2020a) described a new species of orb weaver, *Glenognatha; G. paullula*, from Akampadam, Malappuram . They shifted *P. silentvalliensis* to a junior synonym status of *T. marmorea.*

Malamel & Sudhikumar (2020) carried out study of diversity and bioecology of spider fauna of Pathiramanal Island in Vembanad Lake, a Ramsar site, Kerala, India. They prepared a checklist of the study site comprising 147 species belonging to 26 families under 92 genera. Seven new species were described; *Indopadilla insularis, Epeus triangulopalpis, Marengo sachintendulkar, Indomarengo chavarapater, Icius vikrambatrai, Piranthus planolancis* (Salticidae) and *Wolongia papafrancisi* (Tetragnathidae). First time reports of the males of

Meotipa picturata, Curubis tetrica and *Pscellonus planus* were also incorporated. First time report of mating plug formation in *Argyrodes flavescens* was also given. Spider species from Pathiramanal Island bear affinities with Oriental and Palearctic regions. The first record of distribution of the jumping spider *Bianor angulosus* from Kerala was provided by Babu et al. (2021) from Kainakary in Kuttanad.

Prajapati et al. (2020) described a new genus of jumping spiders, *Uroballus* from Kerala, India. *Uroballus nazirwanii*, a new species was also described by them from Pathiramanal Island in Alappuzha, Kerala. Abhijith et al. (2021) synonymized *Pardosa mysorensis* with *Pardosa sumatrana* based on studies conducted on specimen from Kerala.

Vishnudas et al. (2021) studied the diversity of spiders in Poovar, a fragile mangrove centred tourist place, Thiruvananthapuram, Kerala, India. The study recorded 70 species of spiders from 45 genera and 16 families, representing 26% of the total families reported from India. Sumesh & Sudhikumar (2020) studied the regional diversity of spiders from fifteen selected sacred groves of Kasaragod and Kannur districts. Line transect survey was the predominant method of collection. 11308 individuals belonging to 257 species and136 genera were recorded. Anju et al. (2021a), provided the first report of male of *Leucauge fastigata* from India. They also re described *Tetragnatha cochinensis* after a century in India (2021b).

2.2.2. From other states

In comparison to other regions of the world, very scanty isolated works on spider diversity were being carried out in our country. Considering the fact that India is one among the 17 mega diversity countries, with rich diversity of spiders as well, makes us bewildered. Pioneering works on Indian spiders were done by Europeans; as per the available literature, began with Blackwall (1864). Stolickza (1869); Simon

(1886); Thorell (1895) and Pocock (1900a), followed this legacy and made notable contributions on Indian spiders. Pocock (1900b), in his publication, 'Fauna of British India: Arachnida', considered as the Bible of Indian spiders, listed 216 species of spiders under 17 families.

Among the Arachnologists of Indian origin, Binoy Krishna Tikader holds the most prominent position. A checklist of modern Indian spiders was published by Tikader (1987). Starting from 1960, he enriched Indian Arachnology realm by his published works, attributed to Indian spiders as a whole, single families and single genus or species. To cite some of them; works on Thomisidae (1960), *Cyrtarachne* (1961), Indian spiders (1962a), *Philodromus* (1962b), *Tibellus* (1962c), *Argyrodes* (1963a), *Loxosceles* (1963b), Indian Cho-Oyu Expedition (1964), Thomisidae (1965a), Oxyopidae (1965b), *Marpissa* (1965c), *Triaeris* (1966a), *Dictyna* (1966b), *Xysticus* (1966c). Salticidae of Sikkim (1967)), *Uloborus* (1969), revision of Indian crab spiders (1971), ant-like spiders from India (1973a), jumping spiders from India (1973b), *Phidippus* (1974), *Cheiracanthium* (1975), wolf-spiders from Ladakh (1977), *Neoscona* (1980) etc.

Several species of spiders were reported from Madhyapradesh as a result of extensive surveys made by Gajbe. Some of his notable contributions include; *Uloborus danolius* (1991), *Haplodrassu*s (1992a), *Oxyopes* and *Peucetia* (1992b), and Oxyopidae (1999). In association with Pawan Gajbe, he could publish some additional species like *Xysticus* (1999a), *Tibellus* (1999b), *Thanatus* (1999c), *Cyrtophora* (1999d), *Pardosa* (1999e), *Sergiolus* (1999f), *Philodromus* (2000a), *Thomisus* (2000b), *Neoscona* (2000c), and *Runcinia* (2000d).

Detailed account of maternal care in highly venomous redback spider *Latrodectus hasselti* was given by Patel et al. (1987). They also made valuable study on araneofauna of riceland ecosystems of south Gujarat (2003). Patel & Pillai (1988), Sudhikumar et al. (2005a) described Lycosidae as a highly numerically abundant family in agroecosystems of India. Bayram et al. (2007), Mukhtar et al. (2012) was of similar opinion with respect to agroecosystems of Asia as a whole. Four new species of spiders in Gnaphosidae, Lycosidae, Philodromidae and Uloboridae were described from Madhyapradesh (Bhandari & Gajbe , 2001a). Many new species were added to the fauna of spiders prevalent in Madhya Pradesh (Bhandari & Gajbe, 2001b)

Patel (2003) published a comprehensive list of spiders of Vansda National Park Gujarat, the smallest national park of the country. 22 families were reported from the site, of which Lyssomanidae and Theraphosidae were first reports from the state. The genus *Scoloderus* (Araneidae) was first reported from the country. Siliwal et al. (2003), studied spiders of Purna wildlife sanctuary, Dangs, Gujarat. The study yielded 116 species of spiders in 66 genera and 25 families. *Rhene khandalaensis* and *Stegodyphus mirandus* were the first records from Gujarat. A new species in the genus *Castianeira* (Corinnidae) was described from Madhyapradesh (Gajbe, 2003).

Studies conducted by Jager (2005) in Meghalaya reported a new species in the genus *Heteropoda* (Sparassidae). A detailed re description of the female of *H. robusta* was provided. First report of *H. afghana* in India was also a significant contribution by him. A new species under the genus *Otiothrips* (Palpimanidae) was described from Gujarat (Pillai, 2006). Siliwal & Molur (2007), published the checklist of spiders of South Asia including the 2006 update of Indian spider checklist. Re description of the Theraphosid species *T. trunculentus* along with notes on the habitat preference and burrow making was given by Siliwal & Molur (2009). Hore & Uniyal (2008) assessed the various dimensions of prescribed fire on spider assemblage in Terai grasslands, India. They pointed out a substantial difference in species composition between fire regimes. Sankari & Tiyagesan (2010) studied the diversity and predatory potential of spiders associated with vegetable growing fields of Nangoor and Moongilithottam in Nagapattinam District, T. Nadu. Eight species were recorded during the study.

Roy et al. (2010) resurrected the very rarely reported bird dung crab spiders, *Phrynarachne*, initially described as *Thomisus tuberosus* (Blackwall, 1864) and *T. peeliana* (Stolickza, 1869) from Dooars of West Bengal. Hippargi et al. (2011) carried out a study on the distribution of spider families in three selected ecosystems of Maharashtra state; Lonar Crater Sanctuary, Melghat Tiger Sanctuary, Southern Tropical Thorn Forest ecosystem. A total of 19, 25 and 31 spider families were recorded respectively from these three sites.

Patil (2011) updated the list of spiders described from Jabalpur district of Madhya Pradesh. The updated list includes 117 spider species under 20 families and 58 genera. Archana (2011) surveyed the diversity of spiders in Toranmal Sanctuary, Maharashtra. Study recorded 117 spider species from 20 families and 55 genera. Nalini Bai & Ravindranatha (2012), conducted a survey of the spider fauna of Indian Institute of Science (IISc.), Bangalore. A total of 40 species of spiders belonging to 33 genera under 14 families were recorded. Araneidae was the most dominant family.

Hadole & Wankhade (2012) studied the potential of spiders in eradication of vector borne diseases. They discussed the scope of using Tetragnathids and Pisaurids for preying upon mosquito larvae. Wankhade et al. (2012) studied the spider diversity in various habitats of University of Pune. 32 species of spiders belonging to 7 families were reported. A generalized re description of *Chilobrachys assamensis* (Theraphosidae) was being carried out by Keswani & Wankhade (2013).

Saha et al. (2016) prepared a comprehensive checklist of spiders based on extensive explorations of reserve forests of N. Bengal. Lawania et al. (2013) studied spider diversity in and around Deeg town, Rajasthan. 24 species from 10 families under 16 genera were reported. Araneidae and Salticidae dominated the agriculture fields. More recorded the diversity of spiders from Radhanagari Wildlife Sanctuary (2015a), Chandoli National Park (2015b) and Koyna Wildlife Sanctuary (2015c). They reported a total of 247 species belonging to 119 genera and 28 families. The dominant families of the study area were Araneidae, Salticidae and Lycosidae.

Bhat et al. (2013) surveyed the spider diversity in cashew plantations of Directorate of Cashew Research, Puttur, Karnataka. The survey yielded a total of 104 species of spiders belonging to 13 families. Detailed season-wise analysis indicated a maximum of 85 species during monsoon, while 28 were present in summer. First description of the females of *Chilobrachys hardwickei* and *Chilobrachys khasiensis* from Gourmara national park, and Mahananda wildlife sanctuary in West Bengal were provided by Mirza et al. (2014). Patil et al. (2013) carried out studies on the spider fauna of Singhori Wildlife Sanctuary, Madhya Pradesh, India. Detailed study revealed 29 species belonging to 18 genera under 10 families. The study resulted in the following spiders reported for the first time from the state; *Oxyopes chitrae, Peucetia viridana, Heteropoda venatoria, Telamonia dimidiata, Tetragnatha mandibulata* and *Thomisus pooneus*.New species under the genus, *Stenaelurillus* was described from Andhrapradesh (Caleb & Mathai, 2014). Later on, a new species under the same genus was explained from Gujarat (Prajapati et al., 2016).

Parmar et al. (2015), studied the diversity of spiders in islands and coastal areas of Rann of Kutch and reported 123 species of spiders belonging to 81 genera and 25 families. Survey conducted by Quasin (2011) in Nandha Devi Biosphere reserve, Uttarakhand reported a new species in *Himalmartensus* (Amaurobiidae).

More (2015d) surveyed spider diversity from parts of Western Ghats (Rundiv, Sidheshwar and Ramnadi) included in Chandoli National Park. 58 species belonging to 38 genera and 16 families were recorded.From Maharashtra new species under the genus *Tigidia* (Barychelidae) was described (Mirza et al., 2016). Studies conducted by Roy et al. (2016), in tea estates of Dooars, West Bengal, India recorded 23 species of salticids in 20 genera. One of the species obtained, *Cheliceroides brevipalpis* was new to science; two first reports from India were also associated with the study; *Cocalus murinus* and *Phaeacius fimbriatus*. *Lyssomanes sikkimensis* was declared as considered as the junior synonym of *Telamonia festiva*.

Researchers have always found it difficult to work on purely morphology-based systematics of spiders, as they exhibit high degree of diversity, even among opposite sexes of the same species. Deshpande & Paul (2016) conducted a preliminary study on spiders of Gulbarga, Karnataka State. Spiders belonging to 10 different families have been recorded. Gaikwad et al. (2017) made pioneer attempts to generate DNA barcodes for 60 species of spiders for the first time from India as a taxonomic tool. DNA barcoding could correctly discriminate 99% of the species studied. Exceptionally high level of intraspecies nucleotide divergence was noticed in *Plexippus paykulli* indicating cryptic diversity.

Pandit & Pai (2017), documented spider fauna from the Taleigao plateau, Goa. 74 species of spiders belonging to 17 families were reported. The collected spiders belonged to 9 foraging guilds.In 2017, a Titanoecid species *Pandava* *laminata* was reported from Gujarat by a team comprising Solanki, Siliwal and Kumar (2017).

Dharmaraj et al. (2017) documented diversity of spiders (Arachnida: Araneae) in Nilgiris, Tamilnadu. They attempted to identify the spider assemblages with respect to their diversity and distribution in the forest area of the Nigiris. A total of 40 species of spiders belonging to 36 genera and 11 families were recorded. Keys published by Tikader (1970) were mainly used for identification. De & Palita (2018), prepared a checklist of spiders from six sacred groves, Koraput district in Southern Odisha, India. During this study, 81 species of spiders under 51 genera from 19 families were recorded. A maximum of 67 species were recorded from Kanta Bausuni sacred grove.

Marusik & Nadolni (2018), redescribed the spider genus *Stoliczka*, based on type species. It was transferred to family Pisauridae from Lycosidae. Only two extant species known from the Western Himalayas described so far. Sharma & Singh (2018) studied the biodiversity and guild structure of spiders in North Eastern Uttar Pradesh.13,662 individuals were collected from 4 districts, viz. Gorakhpur, Kushinagar, Maharajganj and Siddharthnagar. Raiz et al. (2018) assessed the spider diversity and composition associated with the Thungabhadra irrigation channel at Ballari, Karnataka. 50 species belongs to 19 family identified in and around the Vijayanagara Sri Krishnadevaraya University, Ballari.

Jangid et al. (2019) surveyed spider diversity from Central Aravalli Ranges, Rajasthan, India. Study area were distributed in two districts, Pali and Ajmer of central Rajasthan. Altogether 116 species of 22 families were found. Kokilamani et al. (2019) carried out a preliminary study on spider diversity of Tumkur University campus, Tumakuru, Karnataka. 46 species belonging to 34 genera of 13 families were reported. This accounted for 2.72% of Indian spider species, 7.76% and 21.66% of Indian spider genera and families respectively. The spiders collected belonged to six feeding guilds. Among these Orb weavers (52.17%) were most dominant group.

Shraddha & Chaturvedi (2019), conducted study on diversity of spiders at Malavagoppa village, in Shimoga District, Karnataka. 51 species belonging to 42 genera of 16 families were recorded. Malhotra et al. (2019), surveyed spider fauna of four different habitats of the northern Rajasthan; Semi-arid grassland, Scrubland, Open forest land, and Riparian land. *Neoscona mukerjei* was found as highly adaptive one, occurring in 3 habitats out of 4 under consideration. Density of spiders was highest in riparian land, while lowest in semi-arid grassland.

Sankaran et al. (2020a) provided taxonomic notes on *Makdiops* (Selenopidae) based on the type specimen located at ZSI Kolkata. Sankaran et al., (2020b) revised all the five species included in the genus *Plator* (Trochanteriidae) based on the type specimens available with ZSI, Kolkata. The species under description are; *Plator himalayaensis, P. indicus, P. kashmirensis, P. pandeae* and *P. solanensis.* Sankaran et al. (2020c) revised Indian species under the genus *Phaeocedus.* Type specimen deposited at ZSI Kolkata and the Oxford University Museum of Natural History, Oxford. They synonymised *Phaeocedus poonaensis* with *Poecilochroa taborensis* and *Phaeocedus nicobarensis* with *Pandava laminate*. Also, *Phaeocedus mosambaensis* described from Nepal was synonymised with *Drassodes lutescens*.

Goyal & Malik (2020) reported the first record of *Oxyopes kohaensis* (Oxyopidae) from Sirsa, Haryana, India. It was first described from Melghat Tiger Reserve, Maharashtra in 2012 based on two female specimens examined. Caleb

(2020a) described a new genus of jumping spiders; *Orientattus.* He assigned four species under this genus, *O.aurantius* (previously *Schenkelia*), *O. bicuspidatus* (previously *Evarcha*), *O. hongkong* (previously *Pancorius*) and *O. minutus*. Caleb (2020b) described three new species of the genus *Carrhotus. C. andhra* (from Andhra Pradesh), *C. assam* (from Assam) and *C. silanthi* (T. Nadu).

Survey conducted in the scrub jungles of Madras Christian College Campus, Chennai (Caleb, 2020c) reported 108 species of spiders belonging to 84 genera and 25 families. The study also provided the first-time report of *Pagida salticiformis* from India. During this study, *Langona tigrina* was rediscovered after 135 years. Seasonal updation of distribution records of many species was done. First reports of 31 species were made available from Tamil Nadu State.Caleb & Acharya (2020) described a new species of jumping spider from North- Eastern India; *Phintelloides manipur*. They also proposed two new combinations: *Phintelloides singhi* transferred from *Marpissa* and *Phintelloides undulata* transferred from *Cosmophasis*. Nafin et al. (2020) provided the first description of males of Indian jumping spider *Piranthus planolancis,* collected from Western Ghats, Karnataka.

Goyal & Malik (2020) gave the first description of *Oxyopes haryanensis* from western part of Haryana, India. The newly reported species is characterised by a highly coiled epigynum and large sized spermatheca. Kashmeera et al. (2020) studied the diversity of spiders from rocky desert of Kailana, Rajasthan. The study yielded 59 species of spiders in 12 families and 30 genera. Twelve new species were recorded from Rajasthan. Parmar (2021) surveyed spiders around five sites of Dharoi Reservoir, North Gujarat. 981 samples were collected from various habitats like Natural Forest, Grassland, Hilly area, and agriculture area. 142 species of spiders belonging to 86 genera and 25 families were obtained.

Singh et al. (2020) compiled a checklist of mygalomorph spiders recorded from different states and union territories of India, up to August, 2020. 118 species under 31 genera belonging to 8 families, distributed in 23 states and 4 union territories were listed. So far, no reports of these groups of spiders are available from Haryana, Madhya Pradesh, Nagaland, Rajasthan, Delhi, Ladakh, Lakshadweep, Daman and Diu. Their maximum diversity was reported from Tamil Nadu. More than 50% of the species diversity is recorded in Theraphosidae. A comprehensive list of araneo fauna of the reserve forests of North Bengal is also available (Raychaudhuri & Saha, 2015). Based on a male specimen, collected from KIIT Campus Bhubaneswar, Prasad, et al. (2020) provided the first report of *Coleosoma blandum* (Theridiidae), from India. Detailed illustration of the palp along with a checklist of the genus *Coleosoma* was also prepared.

Choudhury et al. (2020) reported two rare species of spiders belonging to Cithaeronidae from India; *Inthaeron rossi* from Kalahandi district, Odisha in the east and *Cithaeron indicus* from Solapur district, Maharashtra in the south. Prathihar et al. (2020) described a new species of the trapdoor spider *Idiops perty* from West Bengal. First time report of the genus *Vailimia* from India was done by Basumatary et al. (2020a). Two new species, *Vailimia ajmerensis* from Rajasthan and *V. jharbari* from Assam are described in detail. Basumatary et al. (2020b) described a new species of jumping spider, *Chinattus prabodhi* based on female specimens collected from Assam. Basumatary et al. (2020c) redescribed *Asianopis goalparaensis* (Deinopidae) based on fresh specimens collected from mixed shrub vegetation and bamboo patches of Assam, India. Prajapati & Kamboj (2020) provided a redescription of *Phintelloides undulatus* (Salticidae) along with the first description of its female from Western coast of India.

Tiwari et al. (2021) worked on the faunal diversity of Family Oonopidae in India. In our country, reports of 52 species in 15 genera are available, spread in 15 states and 2 union territories. Asima et al. (2021) updated the distribution status of the genus *Maripanthus* from South India. Sankaran (2021) studied Indian Palpimanidae and furnished the first record of the genus *Boagrius* from South Asia. He also transferred *Sarascellis namratae* from *Palpimanus.*

2.3. Studies on rivers and riparian habitats

2.3.1. Related to Bharatapuzha

Kumar (2006) surveyed the avifauna of the Bharatapuzha river basin from Parali to Purathoor estuary region, Kerala. 140 species of birds in 49 families were sighted. Birds like the Darter, the Painted Stork, the Oriental White Ibis and the Black-bellied Tern, recorded during the study, are ranked as Near Threatened.

Raj & Azeez (2009) assessed the spatiotemporal fluctuations in quality and quantity of water in basin of Bharatapuzha river employing multivariate statistical analysis tools. They reported a consistent level of discharge, irrespective of seasons, in less disturbed basin. In highly disturbed basin, monsoonal discharge was the highest. Rapidly changing land use patterns added with the impact of dams are suggested to be the factors behind spatiotemporal variations. Seena (2021) investigated the diversity and species composition of riparian vegetation along the lower reaches of the Bharatapuzha River. 110 plants, included in three Pteridophyte and 38 Angiosperm families were recorded. About 25% of the plants recorded in this study were invasive weeds pointing towards a deteriorating status of the ecosystem.

Magesh et al. (2013) conducted a morphometric analysis of river basin of Bharatapuzha incorporating state of the art geoprocessing techniques in GIS.

Strahler's system of classification was adopted for classifying extracted drainage networks. They concluded that remote sensing data (SRTM–DEM) coupled with geoprocessing techniques can be used for management of river basins and other hydrological studies in future.

Renjithkumar et al. (2016) conducted regular surveys to quantify the non-native fishes of Bharatapuzha River. Approximately 13.93% of the fishery of Bharatapuzha was found to be contributed by the non-native species of fishes. They also investigated the pattern of fish exploitation of River Bharatapuzha (2021). On an annual scale around 112.56 tonnes of fish landing occurs in Bharatapuzha. Highest landing occurred in post – monsoon season. Major fishing gears used were gill nets, seine nets, and hooks and lines.

Vrinda & Fabiola (2021) documented the fish diversity of Kannadipuzha River, one of the tributaries of Bharatapuzha Palakkad District, Kerala. A total of 19 species (9 orders, 13 families) were collected. Cyprinidae was the most dominant family.

2.3.2. Riparian habitats

The energy flow and energy transfer pathways in a riparian habitat remains highly complex. The direction, quantity and community interactions with respect to energy flow between the flanking ecosystems are often determined by the size of the river and the extent and nature of boundary between the ecosystems involved (Power & Rainey, 2000; Kato et al., 2003; Baxter et al., 2005). Bendix & Hupp (2000) studied the resultant alterations in riparian ecosystems following floods, and reported drastic change in dominant vegetation. Wiens (2002) observed that floods are capable of altering the energy flow patterns existing in riparian ecosystems. According to him, the energy transfer across the boundaries of the ecosystems is worst affected.

Randhir & Ekness (2013) assessed the impact of changes occurring in water quality and how it affects the habitat potential, especially in riparian ecosystems. The study was being conducted in the Massachusetts (Westfield River Watershed). The role of riparian habitats along both dimensions, viz., lateral and longitudinal ones of the watershed system were analysed. GIS enabled spatial analysis and simulation of interactions in riparian habitats were the tools used to evaluate the dynamics of riparian habitats

Griotti et al. (2017) demonstrated the link between vegetation structure and spider diversity based on the studies conducted in river systems of Chacoan subregion of central Argentina. The comparison was done at two conceptual levels; assemblage (species diversity) and ensemble (guild diversity). Richmond et al. (2018) discussed the various aspects of contamination caused by pharmaceuticals in stream and riparian food webs. This work highlighted the probable exposure of aquatic and riparian biota to a diverse array of pharmaceuticals. Jansen & Robertson (2001) studied the effect of livestock management practices on the ecological conditions with respect to riparian habitats associated with an Australian floodplain river. An investigation was being carried out regarding the effect of grazing and other livestock management practices on riparian habitats defined by Murrumbidgee river in south-eastern Australia. The study revealed that there was a negative impact of grazing on riparian condition and it got further reduced with distance upstream in the upper half of the floodplain.

Ramey et al. (2017) studied the mechanisms defining elevated levels of invertebrate diversity in riparian habitats. Invertebrates including spiders serve as dynamic links between the food chains in operation. Caleb (2020c) documented the spider fauna in the vicinity of a suburban lake (Araabath Lake) in Chennai. The study yielded 70 species of spiders belonging to 58 genera and 21 families. Out of these seven species were endemic to India. Family wise, Salticidae was the most dominant one. Seven feeding guilds were found, of which stalkers and orb-web weavers were the dominant ones. Zaimes et al. (2019) evaluated the diversity values of ground- dwelling insects from three different riparian habitat types of Greece. The remarkable variations in diversity indices indicate the potential of ground dwelling insects as indicators of environmental conditions. De et al. (2021) studied the potential of spiders to be used as bio indicators of variety of riparian habitats of river Ganges.

Cole et al. (2015) surveyed the distribution of flowering plants and insect pollinators on riparian buffer strips. They concluded that diversity and abundance of pollinators like bumble bees were greater in wider riparian buffer strips in comparison to neighbouring grasslands. The results are of great significance, especially in a period of global concern regarding reduction in pollinators.

Catford et al. (2013) discussed the probability of emerging novel riparian ecosystems in future climates. With special emphasis on riparian ecosystems, they used specially prepared qualitative process models to predict probable abiotic and biotic changes in four case study systems: tropical coastal floodplains, temperate streams, high mountain streams and urban riparian zones.

2.3.3. Riparian spiders

Spiders occupy a unique and unparalleled position in food webs operating in riparian ecosystems as they play the dual role of a predator and prey in two different ecosystems; consume emerging aquatic insects and in turn are being consumed by birds, lizards and bats (Jackson & Fisher, 1986; Sabo & Power, 2002; Kato et al., 2003). Crews et al. (2020) studied the adaptations found among diverse families of spiders and concluded that aquatic or semi aquatic spiders had a polyphyletic origin. Spiders of at least 21 families were shown to be adapted for aquatic existence. Curiously enough, the study also revealed that not all spiders with adaptations for aquatic existence were associated with such habitats and many lacking such adaptations occupy such habitats as well.

Kelly et al. (2019) worked on evolution of aquatic habitat association in Dictynids and other associated spiders. They also assembled an atlas of morphological traits with potential significance for both ecology and taxonomy. The 'trees' constructed incorporating the data collected during study suggest multiple episodes of origin of aquatic habitat association within Dictynids. Studies conducted by Forster & Forster (1999) in riparian zones of New Zealand revealed that *Dolomedes aquaticus* leads a semi aquatic life and thrives well among pebbles and boulders on riverbanks.

Jackson et al. (2016) worked on the trophic overlap between fish and riparian spiders. They deliberated on the impact of an introduced species of fish on native trophic interactions. The trophic niche of both native and invasive fish, and native spiders in South Africa were being examined by using stable isotope analysis. The results indicated that spiders shared resources with invasive fish, while spiders had a lesser probability of trophic overlap with native fish. Kelly et al. (2019) worked on how urbanization resulted in an increase the proportion of aquatic insects with respect to the diets of riparian spiders. Stable isotope analyses and Bayesian mixing models were being employed to assess trophic transfers among insects and spiders occurring on the riparian zone of an urban area in San Juan, Puerto Rico. They reported an approximately 30% increase in the proportion of aquatic insects in the diets of the orb-weavers in heavily urbanized areas.

A considerable proportion of the diet of riparian spiders is being contributed by insects emerging from adjoining aquatic habitats (Sanzone et al., 2003; Kato et al., 2004). Krell et al. (2015) studied aquatic prey subsidies to riparian spiders in a stream with different land use types. To assess the impact of varying land use patterns on aquatic prey subsidy of riparian spiders, a longitudinal survey was being carried out along a first order stream (Rhine land – palatinate, Germany). Three alternate land use types were considered; forest, meadow and vineyard. Stable isotope analyses of aquatic emergent insects and terrestrial arthropods were performed to determine the fraction of prey contributed by aquatic and terrestrial resources to the diet of web-weaving (*Tetragnatha* sp.) and ground-dwelling (*Pardosa* sp.) riparian spiders.

Akamatsu et al. (2004) studied the food source of riparian spiders using stable isotope ratios in a middle reach of the Chikuma River, Japan. Stable isotope ratios of carbon and nitrogen were being surveyed in this study. Riparian spiders were found to have an intermediate ratio of Carbon and Nitrogen in comparison to the terrestrial and aquatic insects. The results were indicative of the consumption of both terrestrial and aquatic insects as food by the spiders. Sabo & Power (2002) and Kato et al. (2003) studied the food webs operating in riparian habitats and observed that spiders play a pivotal role in maintaining the integrity and complexity of riparian food webs, as they consume aquatic insects and in turn are being eaten by birds, and bats.

Parmar (2021) documented the spider diversity associated with the wetlands of Visnagar Taluka, Mahesana District, Gujarat. 97 species of spiders in 62 genera and 16 families were recorded. About 26.6% of the families recorded so far from India were represented in this collection. A total of 26 species belonging to 10 families of spiders were reported from the surrounding regions of river Narmada in Jabalpur division (Rai, 2016).

Chapter 3.
Materials & Methodology

MATERIALS AND METHODOLOGY

The methodology of a research problem depicts the sequential stages that lead to the satisfactory fulfilment of the objectives envisaged by the researcher. Literally, it is an algorithm designed in a way to meet all demands while the research is being executed. It answers the “what”, “why” and “how” of a research problem. To elaborate, firstly, it enlists the multitude of strategies being pooled in, to be used in various phases of the research work. Next, it justifies the rationale behind each and every strategy being utilised, and finally, a detailed account of implementation of the strategies; including the details of study sites, co- ordinates and other geographical descriptions, topographic and edaphic factors, climatic variables, periodicity and sample collection methods, preservation methods, identification strategies, taxonomic keys, documentation, etc.

3.1 . Study sites

Kerala, ‘The God’s own country’ is a narrow ribbon like strip of land, bound by Western Ghats on the east side and Arabian sea towards the west. Tamil Nadu and Karnataka occupy the other directions. Occupying a total area of 38,864 sq. km. (1.18% of India’s land area), this comparatively tiny state is situated between 8°.17'.30" N /12°. 47'.40" N and 74°.27'.47" E / 77°.37'.12" E., with the width ranging from 35 km to 120 km. Kerala is endowed with 44 monsoon fed rivers, of which Bharatapuzha occupies the second position in terms of length. Other major rivers include Periyar (244 km), Pamba (176 km), Achenkovil (128 km), Kalladayar (121 km), Valapattanam (110 km) and Chaliyar (69 km).

Bharatapuzha also known as 'Nila', and the 'Nile of Kerala' originates in Anamalai hills, at an elevation of 1964 metres in Tamil Nadu region of Western Ghats. In spite of having the largest basin in Kerala, the river has a relatively lesser water flow, owing to its location in comparatively arid regions of Kerala and Tamil Nadu (Figure 1).

The study mainly focussed on collecting spiders from riparian zones adjoining the major tributaries of Bharatapuzha in Kerala (Figure 2). Five sites were earmarked for collection; Malampuzha, Chittur, Ottappalam, Kannadi and Ponnani (Figure 3). Out of these, the first four sites are located in Palakkad district and the remaining one is in Malappuram district of Kerala.

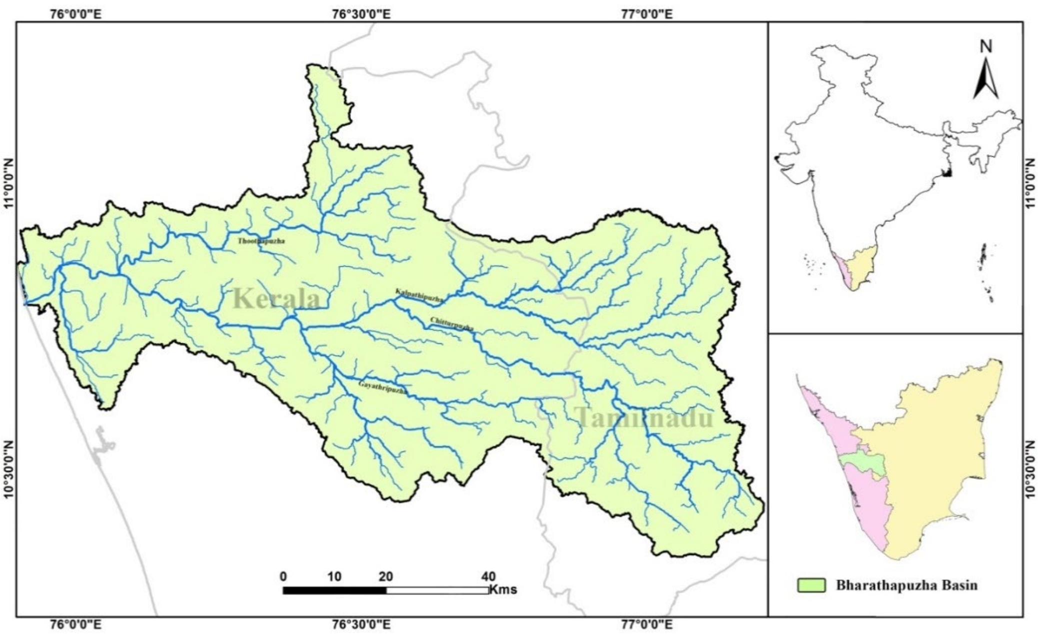


Figure 1. Map showing the basin of Bharatapuzha

3.1.1. Malampuzha (MPZ)

Located 10 km north from Palakkad town (10.8281° N, 76.7368° E), it is a highly renowned tourist destination in Kerala. The sampling site specifically lies within the catchment area of Malampuzha dam and is associated with Kalpathipuzha. From a biodiversity point of view, the site is unlike all others, owing to its close proximity to the Western Ghats.

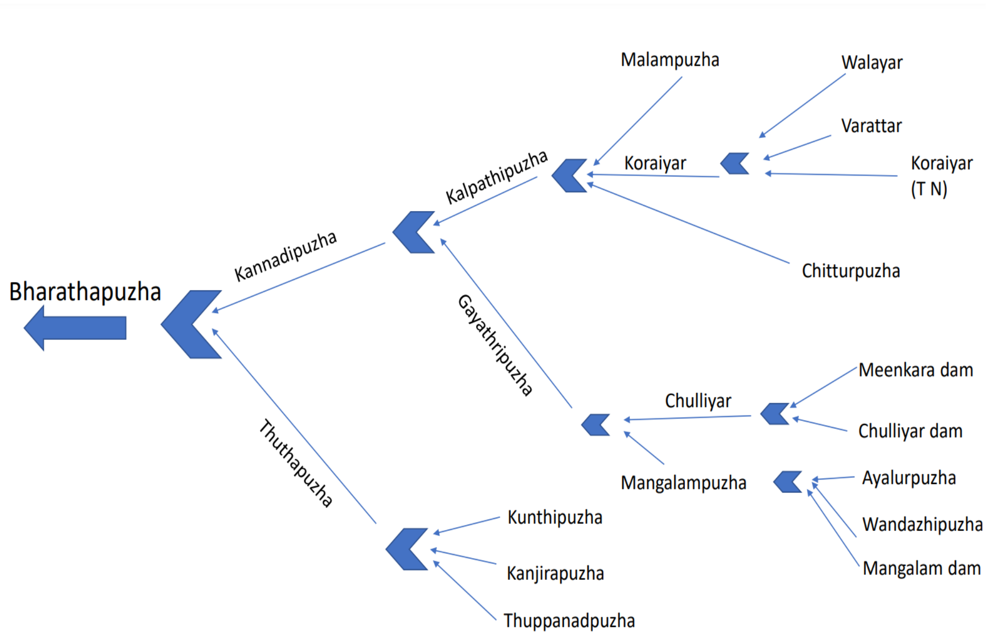


Figure 2. Schematic representation of Bharatapuzha and its tributaries

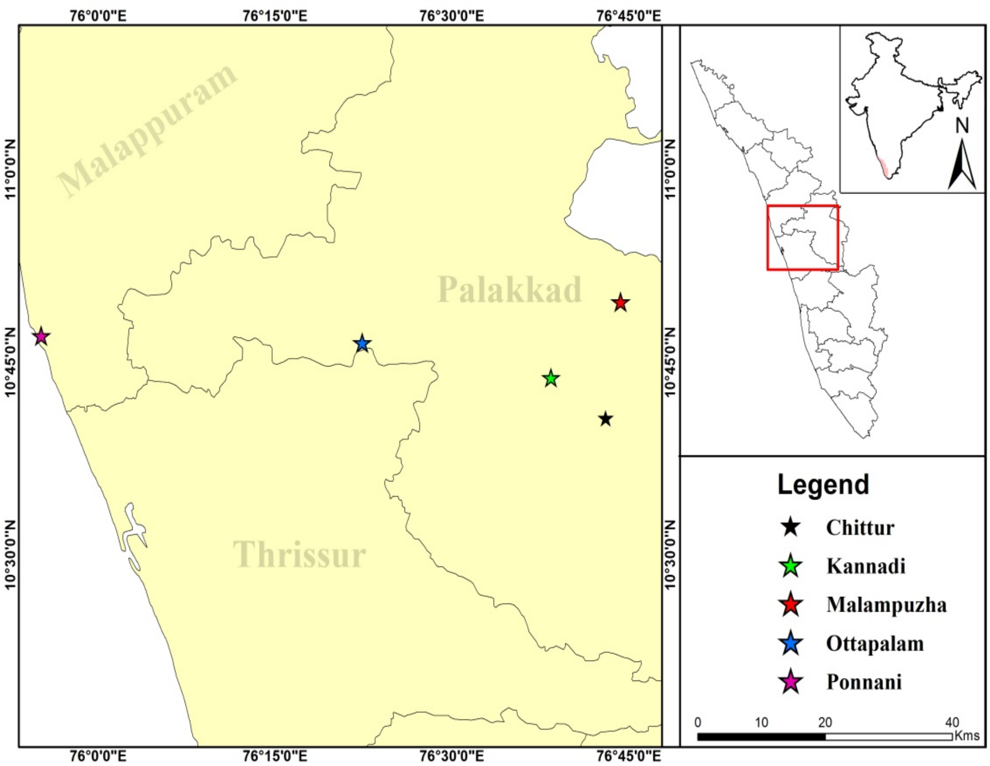


Figure 3. Map showing study sites

3.1.2. Chittur (CTR)

It is situated 15 km. south-east of Palakkad town (10.6772° N, 76.7163° E), on the bank of Chitturpuzha, regionally called as 'Sokanashini' river. The sampling was mainly carried out from the part of river near Chittur Government College.

3.1.3. Ottappalam (OTP)

It is at a distance of 38 km. towards the west of district headquarters and is associated with Kannadipuzha (10.7767° N, 76.3759° E).

3.1.4. Kannadi (KND)

It is a grama panchayat located beside Gayathripuzha (10.7304° N, 76.6403° E). The study site has an irregular terrain of the river due to the presence of plenty of small rocks and pebbles scattered randomly in the basin.

3.1.5. Ponnani (PNI)

Situated 48 km. away from the district headquarters (10.7677° N, 75.9259° E), it is a small village in coastal region of Malappuram district. Sampling site is located beside the 'Bharatapuzha' proper, formed as a result of confluence of all the tributaries and drains to the Arabian sea.

All these tributaries exhibit differences in their perennial nature, water availability across seasons and associated vegetation. Kalpathipuzha, being in proximity to Western Ghat region, and coming under Dhoni forest range, is rich in associated vegetation. Chitturpuzha is lush green on its banks, but mainly bordered by coconut groves and paddy fields. Frequently it receives water released from Aaliyar dam situated in Tamil Nadu. Sites OTP and KND are mainly associated with non- perennial region of Bharatapuzha, where the river undergoes catastrophic variations with the seasons. During extreme summer season (March to May), the river almost gets dried up, leaving behind narrow scattered channels and puddles filled with turbid, stagnant water. Many check dams built in various tributaries also aggravate the situation.

The vegetation cover associated with the tributaries also exhibits high variability. Some of them include 'feather reed grass' (*Calamagrostis acutifera* - Poaceae.), 'cockatoo grass' (*Allopteropis semialata* - Poaceae) , 'sessile joy weed' (*Alternanthera sessilis* -Amaranthaceae), 'Mauritian grass' (*Apluda mutica* - Poaceae), 'sickle senna' (*Senna tora* - Fabaceae), Bengal day flower (*Commelina benghalensis* - Commelinaceae), Bermuda grass (*Cynodon dactylon* - Poaceae), Karanjvel (*Derris trifoliata* - Fabaceae),Sticky lovegrass (*Eragrostis viscosa*- Poaceae), 'cane grass' (*Eleucine indica* - Poaceae), 'goose grass' (*Ipomoea aquatica* - Convolvulaceae), water spinach - (*Ipomea biloba* - Convolvulaceae) and Baby tears (*Lindernia rotundifolia* - Linderniaceae).

These sites experience maximum human interference, in its various forms; ranging from bathing, washing clothes and utensils, sand mining for construction works, dumping of sewage and garbage, etc. PNI has only scanty vegetation associated with it, being located in an estuarine region where the river empties to Arabian sea. This region is also notable for lesser fluctuations in terms of water carried across seasons.

3.2 . Period of study

The study was conducted from 2016 to 2018, for a continuous period of two years. Considering the climatic factors; mainly precipitation, temperature variations and humidity, each year was subdivided into three seasons. **Pre-monsoon** season range from February to May. It is generally arid with scanty rainfall. The day-time temperature shoots very high and majority of the herbaceous plants with superficial fibrous root system dries up. **Monsoon** season extends from June to September, and is characterised by periodic torrential rainfall along with thunder and lightning. The water bodies get filled to their maximum and even leads lo localised floods. The monsoon in Kerala itself is divisible into south-west and north-east categories. The state receives maximum rain fall from south-west monsoon; 43% in southern districts and 83% in northern districts. **Post-monsoon** begins with October and runs up to the end of January. The season experiences moderate temperature, intermittent rain and high humidity.

The annual rainfall data and records of temperature during the study period were obtained from Indian Meteorological department (IMD) website (Table 1).

3.3. Sampling

Organized and unbiased sampling ensures that the researcher gets exposed to a true and reliable cross section of the diversity in whole. Samples were collected mainly in the morning hours; from 7:30 AM to 11:00 AM. Systematic sampling by Line transects was predominantly used for collection.

3.3.1. Line Transect method

This is one of the widely used sampling methods, especially useful when the study area is of larger dimensions, or in some other cases, smaller but difficult for active searching. In biological sampling, this method yields quite different level of outcomes when dealing with sedentary (like plants or some crustaceans) and fast-moving forms (Drummer & McDonald, 1987). For many animal populations, line transects (Figure 4) proved to be comparatively practical, efficient and cheaper method of estimating density. As the river exhibit seasonal fluctuations with respect to the basin coverage and the resultant position of banks, two widely separated transects were fixed in each site, each transect being 100 metres in length, 1.5 metres wide and located at least 5 metres from the shore.

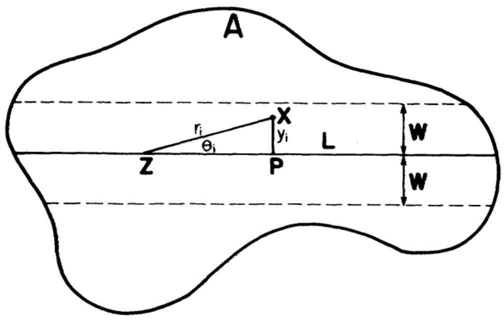


Figure 4. Line transect method (Source: Anderson et al., 1978)

Where,

L - length of the transect, W - width of the transect towards one side, Z - the position of the observer, X - position of the animal, P - point on the line perpendicular to X, r_i - the sighting distance, θ_i - the sighting angle, and y_i- the perpendicular distance from the object to the centreline of the transect.

Four important assumptions form the central pillars of acceptable and valid sampling via line transects (Anderson et al., 1978);

a) A probability value of '1' is assigned to points situated directly on the line, L.
b) Each sighting point is fixed and none of them are counted twice.
c) All distances are measured exactly, so that there exist zero probability of measurement errors.
d) None of the sightings depend on the preceding or proceeding ones.

While dealing with faster, quick moving forms, the following assumptions are usually set to rationalise the discrepancies that may happen;

a) All those animals which are on the line are always visible.
b) They remain visible and do not move before being noticed.
c) An animal is counted only once.
d) The sighting of animals is independent.

3.3.2. Sampling Strategies

1) Sweeping: mainly employed for sampling from thick herbaceous or shrub vegetation cover. Sweep netting is rather a passive method, without employing any sort of attractants or chemicals and without considering the population density or probability of spiders present (Yi et al., 2012). A sweep net (35 cm diameter, 50 cm long handle and 55 cm deep rough conical cotton bag), as used for insect collection was being utilised. After sweeping, the contents of the net were emptied to a white cloth and the spiders were sorted out and transferred to plastic vials of suitable size (Tarsons; 5 ml, 10 ml and 25 ml), using brush dipped in alcohol.

2) Inverted umbrella method: helpful for collecting from branches located high above. An open umbrella (preferably with a white / silver coating inside) was kept in inverted position beneath the branch. Vigorous shaking of the branch dislodged the spiders along with insects and some leaves, spiders were collected from the umbrella using plastic vials. The same method with slight modifications were used in areas dominated by thorny bushes and also in places where the tree branches were densely covered by creepers.

3) Hand picking method: those spiders located on leaves or flowers of isolated plants or on accessible locations were caught with the help of plastic jars or vials. The same method was adopted for collecting spiders located on sandy soil of river banks. This method was found especially suitable for sluggish forms.

4) Litter sifting method: litter dwelling spiders constitute the most important arthropods having a decisive role in the decomposition process (Hou et al., 2019). Here, those ground dwelling spiders or that prey upon the detritus feeders were mainly available. Dry litter was collected with minimum disturbance in a tray. The collected litter was then spread on a long white sheet or cloth and sifted for the presence of spiders, and were subsequently shifted to plastic vials.

3.3 3. Preservation of samples

As far as possible, specimens were photographed in the field itself. The specimen collected by various methods were quickly transferred to a killing jar containing cotton soaked in chloroform. This helps to reduce the chances of breaking the legs, following hyper activity inside the jar. Once killed, the specimens were taken out and sorted out into various petri dishes, along with a preliminary identification effort focussing on the colour patterns and other such cues that may be lost in long term preservation. These petri dishes were filled with 70% ethanol and kept covered by larger sized petri dishes for 3 to 4 hours. By this time the body muscles became relaxed and the body parts were flexible enough for photographic procedures.

3.4 . Identification

The specimens were identified with the help of available books and literature. Unlike insects, in many cases, due to the paucity of standardised keys helpful for species level identification, illustrations and morphological descriptions available in published works were being utilized. Spiders of India (Sebastian& Peter, 2009) and online resources like Araneae of India (Caleb & Sankaran, 2024) were being utilised. Various versions of World spider catalogue (NMBE) were used time to time for assessing the latest taxonomic position and to ensure validity of scientific names. Photography of the specimens were carried out in the laboratory using stereo zoom microscope facility (Leica- M205C) available in Centre for Animal Taxonomy and Ecology (CATE), Christ College, Irinjalakuda. After identification, the specimens were preserved in Audmann's preservative (Tikader, 1987a) containing 70% ethanol, glacial acetic acid and glycerine in 87:8:5 proportions.

3.5 . Documentation of diversity

From the data generated after identification, checklists were prepared for all the five sites, across three seasons; pre-monsoon, monsoon and post-monsoon. These individual checklists were utilised in graphical representation of the data in results section. Later on, these lists were compiled to a single one, so as to get a quick account of species distribution among the study sites.

3.6 . Seasonal variation analysis

Presence and abundance of each species from five study sites, in two consecutive years distributed among three seasons; pre-monsoon, monsoon and post-monsoon was recorded. Both alpha and beta level diversity were calculated. 'R' package (R Core team, 2021) was mainly used for statistical analyses. Following statistical analyses of the tabulated data were carried out;

3.6.1 Rank abundance curve (RAC): depicts some properties of a theoretical or empirical species abundance distribution. The curve is widely used as an indicator of the structure of a multispecies community. The simplest approach to interpret a RAC is to focus on its concave and convex segments.

3.6.2 Hill Numbers (effective number of species): Compile together the three most popularly utilised diversity attributes (Chao et al., 2014). They differ by the parameter 'q'. Values of 'q' equal to 0, 1 and 2 represents species richness, Shannon diversity and Simpson diversity, respectively. Here the Shannon diversity value actually represents the effective number of species that corresponds to Shannon entropy.

3.6.3 Wilcoxon test: is a popular non parametric test helpful in comparing two paired groups (Wilcoxon et al., 1970). The differences between the paired groups are monitored, analysed and expressed as significantly different variations or not.

3.6.4 **Kruskal – Wallis's test**: is a nonparametric equivalent of one-way ANOVA. A significantly different result of this test indicates that at least one of the samples is different from others. The test does not help us to find out the source and location of these differences (Ostertagova et al., 2014).

3.7 . Guild wise diversity of spiders collected

Spider guilds tell us the ways by which they utilise the resources available in their habitats. Various criteria are being utilised for assigning guilds; food preferences, food capture mechanisms, reproductive strategies etc., are some among them. Feeding guilds are exceptionally utilised in spider taxonomy, as they tell us how the prey capturing mechanism is being modified by the specimen under consideration. Accordingly, the major families of spiders are assigned 6 to 8 feeding guilds (as per the systems put forth by various authors). Here we considered the categories proposed by Cardoso et al. (2011), comprising the following guilds;

1. Orb weavers
2. Ground hunters
3. Ambush hunters
4. Sheet web makers
5. Space web makers
6. Sensing web makers
7. Specialists
8. Other hunters

Distribution of families in maximum number of guilds indicate a practically undisturbed habitat, where the spiders could explore the food gathering strategies in all its possibilities. Study of guild structure becomes complete only when it gets quantified. A number of measures are utilized for quantifying the functional diversity and guilds in an ecosystem. Petchey & Gaston (2006) proposed the practice of measuring the total branch length of dendrograms as an alternative to counting the number of guilds. An analysis of similarity (ANOSIM) test was performed to verify that the assigned guilds are statistically supported.

Absence of individuals in certain guilds indicate lesser diversity and occurrence of certain disturbing elements; biotic or abiotic, in the habitat. A highly skewed distribution of individuals in certain guilds only reflects dominance.

Table 1. Climatic factors during the study period

year	District	Rainfall (mm)			Relative humidity			Temperature (in degree Celsius)					
								Minimum			Maximum		
		Pre monsoon	Monsoon	Post monsoon	Pre monsoon	Monsoon	Post monsoon	Pre monsoon	Monsoon	Post monsoon	Pre monsoon	Monsoon	Post monsoon
2016-17	Palakkad	46.43	258.67	34.37	77.84	86.33	76.93	21.5	20.5	20.13	34.57	28.42	31.06
	Malappuram	45.55	312.80	30.55	78.21	87.36	76.24	20.53	19.94	19.53	33.57	27.77	30.63
2017-18	Palakkad	62.72	381.0	44.23	78.46	89.01	77.56	20.92	21.03	20.24	35.22	28.62	31.98
	Malappuram	44.75	482.05	85.95	77.89	89.94	77.05	20.23	19.87	20.08	33.74	28.06	30.45

Chapter 4.
Results

RESULTS

4.1. Spider inventory

Systematic and season bound sampling from the five selected sites; MPZ, CTR, OTP, KND and PNI, yielded considerable diversity of spiders. A total of 7151 adult individuals were identified during this study which could be classified under 27 families, 90 genera and 133 species (Table 2, Figure 5). Considering the number of families recorded, the value reaches an approximate of 44% reported from our country (Caleb & Sankaran, 2024). In terms of diversity in number of genera and species, we could account 18% and 7% respectively of that reported from India. The aggregate data from five habitats spanning three seasons (PRM, MON and POM), indicates that family Salticidae had the maximum value of richness (24 genera and 27 species), followed by Araneidae (13 genera and 25 species) and Tetragnathidae (4 genera and 10 species).

4.1.1. Alpha diversity

Alpha diversity refers to variations in biodiversity on a regional scale. Species richness, equitability together with the spatial and temporal variations of these attributes constitute the cardinal aspects of alpha diversity. Spiders being highly agile and ubiquitous organisms, assessment of their regional diversity and distribution patterns draw special attention. The highly interchangeable trophic roles of spiders; that of predators and preys, make their community interactions more complex. This study focussed on the documentation of spiders in five selected riparian habitats spanning over three seasons of two consecutive years. Besides the preparation of a consolidated checklist (Table 3), assessment of the diversity indices; Shannon index, Simpson's concentration index and Shannon's equitability index also formed a part of study of alpha diversity.

Table 2. Representation of genera and species in different spider families

Sl.No.	Families	No. of genera	No. of species
1.	Amaurobiidae	1	1
2	Araneidae	13	25
3	Cheiracanthiidae	1	3
4	Clubionidae	1	3
5	Corinnidae	2	2
6	Ctenidae	1	1
7	Eresidae	1	1
8	Gnaphosidae	2	2
9	Hahniidae	1	1
10	Hersiliidae	1	1
11	Linyphiidae	2	2
12	Lycosidae	3	7
13	Mimetidae	1	1
14	Nephilidae	1	1
15	Oonopidae	1	1
16	Oxyopidae	3	8
17	Philodromidae	3	3
18	Pholcidae	2	3
19	Pisauridae	1	2
20	Salticidae	24	27
21	Scytodidae	1	3
22	Sparassidae	3	3
23	Tetragnathidae	4	10
24	Theraphosidae	2	2
25	Theridiidae	7	9
26	Thomisidae	5	7
27	Uloboridae	3	3
	Total	90	133

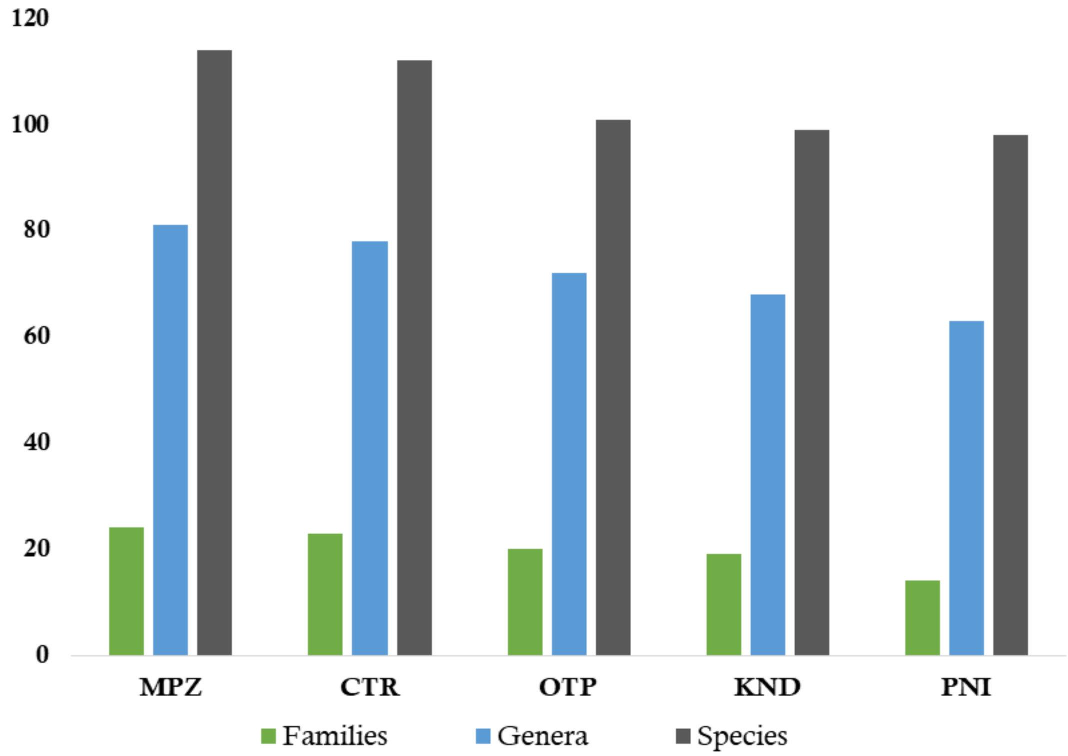


Figure 5. Representation of families, genera and species

Checklist of the families reflects the overall diversity associated with the riparian zones of the river. A highly uneven distribution of individuals and taxonomic units could be met with in the families recorded. Out of the twenty-seven families, only three (Salticidae, Araneidae and Tetragnathidae) had ten or more species. It was also noticed that these families remain to be the main contributors of richness and abundance recorded in all the five habitats and across three seasons. On the contrary, eight families had representatives from single species only and five families were represented by two species each.

Table 3. Checklist of spiders sampled

Sl. No.	Family / Species
I	**Amaurobiidae Thorell 1870**
1	*Amaurobius* sp.1

II	**Araneidae Clerck 1757**
2	*Anepsion maritatum* (O. Pickard-Cambridge, 1877)
3	*Araneus* sp.1
4	*Arachnura angura* Tikader, 1970
5	*Argiope aemula* (Walckenaer, 1841)
6	*Argiope anasuja* Thorell, 1887
7	*Argiope catenulata* (Doleschall, 1859)
8	*Argiope pulchella* Thorell,1881
9	*Argiope* sp.1
10	*Chorizopes* sp.1
11	*Cyclosa bifida* (Doleschall,1859)
12	*Cyclosa confraga* (Thorell, 1893)
13	*Cyclosa hexatuberculata* Tikader,1982
14	*Cyclosa* sp.1
15	*Cyrtophora cicatrosa* Stolickza,1869
16	*Cyrtophora moluccensis* (Doleschall, 1857)
17	*Eriovixia excelsa* (Simon, 1889)
18	*Eriovixia laglaizei* (Simon, 1877)
19	*Eriovixia* sp. 1
20	*Gasteracantha geminata* (Fabricius, 1798)
21	*Gasteracantha kuhli* CL. Koch, 1837
22	*Gea subarmata* Thorell, 1890
23	*Neoscona bengalensis* Tikader & Bal, 1981
24	*Neoscona mukerjei* Tikader, 1980
25	*Neoscona vigilans* Blackwall,1865
26	*Neoscona* sp.1
27	*Parawixia dehaani* (Doleschall, 1859)
III	**Cheiracanthiidae Wagner 1887**
28	*Cheiracanthium danieli* Tikader, 1975
29	*Cheiracanthium melanostomum* (Thorell, 1895)
30	*Cheiracanthium* sp.1
IV	**Clubionidae Simon 1878**
31	*Clubiona drassodes* O. Pickard-Cambridge, 1874

32	*Clubiona nicobarensis* Tikader, 1977
33	*Clubiona tridentata* Dhali et al., 2016
V	**Corinnidae Karsch 1880**
34	*Castianeria zetes* Simon, 1897
35	*Corinnomma* sp.1
VI	**Ctenidae Keyserling 1877**
36	*Bowie cochinensis* (Gravely, 1931)
VII	**Eresidae C L. Koch 1845**
37	*Stegodyphus sarasinorum* Karsch, 1892
VIII	**Gnaphosidae Banks 1898**
38	*Drassodes* sp.1
39	*Scotophaeus blackwalli* (Thorell, 1871)
IX	**Hahniidae Bertkau 1878**
40	*Hahnia mridulae* Tikader, 1970
X	**Hersiliidae Thorell 1869**
41	*Hersilia savignyi* Lucas, 1836
XI	**Linyphiidae Blackwall 1859**
42	*Linyphia* sp.1
43	*Neriene macella* (Thorell, 1898)
XII	**Lycosidae Sundevall 1833**
44	*Hippasa agelenoides* (Simon, 1884)
45	*Hippasa pantherina* Pocock, 1899
46	*Lycosa mackenziei* Gravely,1924
47	*Pardosa birmanica* Simon, 1884
48	*Pardosa pseudoannulata* (Bosenberg & Strand, 1906)
49	*Pardosa sumatrana* (Thorell, 1890)
50	*Pardosa* sp.1
XIII	**Mimetidae Simon 1881**
51	*Mimetus* sp.1
XIV	**Nephilidae Simon 1894**
52	*Nephila pilipes* (Fabricius, 1793)
XV	**Oonopidae Simon 1890**
53	*Triaeris* sp.1

XVI	**Oxyopidae Thorell 1869**
54	*Hamataliwa* sp. 1
55	*Oxyopes birmanicus* Thorell, 1887
56	*Oxyopes javanus* Thorell, 1887
57	*Oxyopes lineatipes* (C. L. Koch, 1847)
58	*Oxyopes shweta* Tikader, 1970
59	*Oxyopes sunandae* Tikader, 1970
60	*Peucetia ananthakrishnani* Murugesan et al., 2006
61	*Peucetia viridana* (Stoliczka, 1869)
XVII	**Philodromidae Thorell 1869**
62	*Philodromus* sp.1
63	*Psellonus planus* Simon, 1897
64	*Thanatus elongatus* (Tikader, 1960)
XVIII	**Pholcidae CL. Koch 1850**
65	*Crossopriza* sp. 1
66	*Pholcus phalangioides* (Fuesslin, 1775)
67	*Pholcus* sp.1
XIX	**Pisauridae Simon 1890**
68	*Dendrolycosa gitae* (Tikader, 1970)
69	*Dendrolycosa* sp.1
XX	**Salticidae Blackwall 1841**
70	*Asemonea tenuipes* (O.P. Cambridge, 1869)
71	*Brettus cingulatus* Thorell,1895
72	*Brettus* sp. 1
73	*Carrhotus viduus* (C. L. Koch, 1846)
74	*Chrysilla volupe* (Karsch, 1879)
75	*Epeus indicus* Prozynski, 1992
76	*Epocilla aurantiaca* (Simon, 1885)
77	*Evarcha* sp.1
78	*Harmochirus brachiatus* (Thorell, 1877)
79	*Hasarius adansoni* (Audouin, 1826)
80	*Hyllus semicupreus* (Simon, 1885)
81	*Indopadilla insularis* (Malamel et al., 2015)

82	*Menemerus bivittatus* (Dufour, 1831)
83	*Myrmaplata plataleoides* (O. P. Cambridge, 1869)
84	*Myrmarachne melanocephala* MacLeay, 1839
85	*Phidippus yashodharae* Tikader, 1977
86	*Phintella vittata* (C. L. Koch, 1846)
87	*Plexippus paykulli* (Audouin, 1826)
88	*Plexippus petersi* (Karsch, 1878)
89	*Portia fimbriata* (Doleschall, 1859)
90	*Rhene flavigera* (C. L. Koch, 1846)
91	*Rhene* sp. 1
92	*Siler semiglaucus* (Simon, 1901)
93	*Stenaelurillus lesserti* Reimoser, 1934
94	*Telamonia dimidiata* (Simon, 1899)
95	*Thiania bhamoensis* Thorell, 1887
96	*Thyene imperialis* (Rossi, 1846)
XXI	**Scytodidae Blackwall 1864**
97	*Scytodes fusca* Walckenaer, 1836
98	*Scytodes pallida* Doleschall, 1859
99	*Scytodes thoracica* (Latreille, 1802)
XXII	**Sparassidae Bertkau 1872**
100	*Heteropoda venatoria* (Linnaeus, 1767)
101	*Thelcticopis* sp.1
102	*Olios milleti* (Pocock, 1901)
XXIII	**Tetragnathidae Menge 1866**
103	*Leucauge decorata* (Blackwall, 1864)
104	*Leucauge dorsotuberculata* Tikader, 1982
105	*Leucauge tessellata* (Thorell, 1887)
106	*Leucauge fastigata* (Simon, 1877)
107	*Tetragnatha cochinensis* Gravely, 1921
108	*Tetragnatha javana* (Thorell, 1890)
109	*Tetragnatha mandibulata* Walckenaer, 1842
110	*Tetragnatha viridorufa* Gravely, 1921
111	*Tylorida striata* (Thorell, 1877)

112	*Tylorida ventralis* (Thorell, 1877)
XXIV	**Theraphosidae Thorell 1869**
113	*Annandaliella* sp.1
114	*Chilobrachys* sp.1
XXV	**Theridiidae Sundevall 1833**
115	*Argyrodes flavescens* O. Pickard-Cambridge, 1880
116	*Argyrodes* sp.1
117	*Ariamnes flagellum* (Doleschall, 1857)
118	*Chikunia nigra* (O. Pickard-Cambridge, 1880)
119	*Chrysso* sp.1
120	*Meotipa* sp.1
121	*Nihonhimea mundula* (L. Koch, 1872)
122	*Phoroncidia septemaculeata* (O. P. -Cambridge, 1873)
123	*Theridion* sp.1
XXVI	**Thomisidae Sundevall 1833**
124	*Camaricus formosus* Thorell 1887
125	*Indoxysticus minutus* (Tikader, 1960)
126	*Oxytate subvirens* (Strand, 1907)
127	*Runcinia insecta* (L.Koch, 1875)
128	*Thomisus lobosus* (Tikader, 1965)
129	*Thomisus projectus* Tikader, 1960
130	*Thomisus pugilis* Stoliczka,1869
XXVII	**Uloboridae Thorell 1869**
131	*Miagrammopes* sp.1
132	*Uloborus krishnae* Tikader, 1971
133	*Zosis geniculata* (Olivier, 1789)

4.1.2. Description of families recorded

1. Family: Amaurobiidae, Thorell 1869.

Common name: Hackled mesh web weavers

Features: Eight pale-coloured eyes, in two rows. Three clawed, cribellate and ground – dwelling forms. Cephalothorax less wide than long. Both pro and retro margins of chelicerae bear teeth. Elongated legs with single row of trichobothria on tarsi. Trochanters un notched. Abdomen oval, covered by dense layer of setae. Epigyne complex, bearing sutures that separate the median and lateral lobes. Presence of simple retro lateral and dorsal tibial apophyses on the male palp. Among the six spinnerets, both the anterior and posterior ones are two segmented. Cribellum full-fledged or variably divided. Predominantly nocturnal in hunting. Irregular, intricate funnel -like webs are constructed at the lower most parts of vegetation.

Species sampled:

Amaurobius sp. 1.

Total number of genus / species reported globally: 26 / 202

Total number of genus / species reported from India: 2/ 2

2. Family: Araneidae, Clerck 1757

Common name: Orb web spiders

Features: Second dominant diverse family in India. An oblique depression demarcating the cephalic and thoracic regions. Two rows comprising eight eyes, wide separation of laterals from medians, medians form a quadrangle. Three tarsal claws and auxiliary foot claws present. Completely or partially sclerotised and complex epigyne with a transverse furrow on its plate. Paracymbium bears a sclerotised hook and is attached to proximal end of cymbium. Strong, non – divergent and vertical chelicera with boss. Labium rebordered. Dorsum covered by serrated setae. Presence of stabilimentum in orb webs of some genera. Exceptionally skilful in weaving perfect orb webs. Majority of Indian members of this family construct orb-webs, except in *Cyrtophora.*

Species sampled:

Anepsion maritatum (O. Pickard-Cambridge, 1877)

Arachnura angura Tikader 1970

Araneus ellipticus (Tikader & Bal , 1981)

Argiope aemula (Walckenaer, 1841)

Argiope anasuja Thorell 1887

Argiope catenulata (Doleschall, 1859)

Argiope pulchella Thorell 1881

Argiope sp.1

Chorizopes sp.1

Cyclosa bifida (Doleschall 1859)

Cyclosa confraga (Thorell 1893)

Cyclosa hexatuberculata Tikader 1982

Cyclosa sp.1

Cyrtophora cicatrosa (Stolickza 1869)

Cyrtophora moluccensis (Doleschall, 1857)

Eriovixia excelsa (Simon 1889)

Eriovixia laglaizei (Simon 1877)

*Eriovixia sp.*1

Gasteracantha geminata (Fabricius 1798)

Gasteracantha kuhli CL. Koch 1837

Gea subarmata Thorell 1890

Neoscona bengalensis Tikader & Bal 1981

Neoscona mukerjei Tikader 1980

Neoscona vigilans Blackwall, 1865

Neoscona sp.1

Parawixia dehaani (Doleschall, 1859)

Total number of genus and species reported globally: 191/ 3128

Total number of genus and species reported from India: 34/ 188

3. Family: Cheiracanthiidae, Wagner 1887

Common name: Sac spiders

Features: Entelegyne ecribellate forms. Two rows of eight eyes widely separated from each other. first pair of legs more elongated, thoracic streak not found; chelicerae quite imposing. Members of this family had a relentlessly drifting history, being a part of Clubionidae, later transferred to Miturgidae, followed by being placed in Eutichuridae and finally to an independent family status.

Species sampled:

Cheiracanthium danieli Tikader 1975

Cheiracanthium melanostomum (Thorell, 1895)

Cheiracanthium sp.1

Total number of genus / species reported globally: 14 / 371

Total number of genus / species reported from India: 2 / 31

4. Family: Clubionidae, Simon 1878

Common name: Sac spiders

Features: Distinctly longer, ovoid cephalothorax. Eight small and uniform sized eyes in two rows, posterior row slightly longer than the anterior one. Long chelicerae bearing 2 to 7 pro marginal and 2 to 4 retro marginal teeth. Convex shaped epigynal plate, occasionally sclerotized. Inconsistent apophysis, embolus and cymbium form parts of the male palp.

Species sampled:

Clubiona drassodes O. Pickard-Cambridge, 1874

Clubiona nicobarensis Tikader, 1977

Clubiona tridentata Dhali et al., 2016

Total number of genus / species reported globally: 18 / 665

Total number of genus / species reported from India: 3 / 31

5. Family: Corinnidae, Karsch 1880

Common name: Ant mimicking sac spiders

Features: Generally, inhabit the debris or humus on the shaded region of the forest floor. Eight eyes arranged in two asymmetric rows. Posterior row of eye straight or strongly curved. The book lung region of abdomen heavily sclerotised. In males, the spinnerets are devoid of spigots. Highly complex and variable epigyne. Males of most genera have bulbus lacking median apophysis. Many of the members are ant-mimics; the front legs are raised in the air resembling the antenna of insects. They build silk – lined retreats in rolled up leaves.

Species sampled:

Castianeria zetes Simon, 1897

Corinnomma sp.1

Total number of genus/ species reported globally: 76 / 867

Total number of genus / species reported from India: 8 / 18

6. Family: Ctenidae, Keyserling 1877

Common name: False lycosids / Wandering spiders

Features: Eight eyes arranged in three rows; 2 4 2. Strongly recurved row of anterior eyes. Size of the anterior median eyes many times smaller than that of laterals. Inner margin of chelicera possesses four or five teeth. Ovoid cephalothorax with a deep depression, epigyne complex with lateral horns, first two pairs of legs bear strong bristles towards the lower side. Litter- dwelling, aggressive, nocturnal hunters often confused with Lycosids.

Species sampled: *Bowie cochinensis* (Gravely, 1931)

Total number of genus /species reported globally: 49 / 612

Total number of genus / species reported from India: 5 / 20

7. Family: Eresidae, C L Koch 1845

Common name: Social spiders

Features: Cephalic region wider and usually raised, sunken clypeus. Eight eyes, four median eyes forming a quadrangle, anterior laterals shifted to the side of the head, posterior laterals exist high up on the posterior portion of the head. Oval shaped abdomen bearing large sized cribellum. Large number of individuals occupy large sheet – like or sac- shaped nests and feed together; hence social in nature.

Species sampled:

Stegodyphus sarasinorum Karsch, 1892

Total number of genus / species reported globally: 9 / 106

Total number of genus / species reported from India: 1 /4

8. Family: Gnaphosidae, Banks 1898

Common name: Mouse spiders

Features: Eight small sized eyes in two transverse rows, irregularly shaped and flattened posterior medians, Tarsi I and II with dense scopulae, preening comb present in metatarsi IV of some species, highly complex epigyne with prominent cuticular margins.

Species sampled:

Drassodes sp. 1

Scotophaeus blackwalli (Thorell, 1871)

Total number of genus / species reported globally: 153 / 2474

Total number of genus / species reported from India: 28 / 140

9. Family: Hahniidae, Bertkau 1878

Common name: Comb- tailed spiders

Features: Two procurved rows of eight equal sized eyes. Sternum is anteriorly truncated, but posteriorly pointed. A series of ridges found on lateral side of chelicera; used for sound production in males. Tracheal spiracles open midway between the genital opening and the base of spinnerets.

Species sampled:

Hahnia mridulae Tikader, 1970

Total number of genus / species reported globally: 29/ 240

Total number of genus/ species reported from India: 3/ 4

10. Family: Hersiliidae, Thorell 1869

Common name: Two tailed spiders / bark spiders

Features: Two highly recurved rows of eight eyes large tubercle, larger sized anterior medians. Sternum heart shaped, exceptionally elongated posterior spinnerets, complex epigyne with broad central septum, tibial apophysis lacking in male palp.

Species sampled:

Hersilia savignyi Lucas, 1836

Total number of genus/ species reported globally: 16/ 188

Total number of genus / species reported from India: 3/ 12

11. Family: Linyphiidae, Blackwall 1859

Common name: Sheet web spiders / money spiders

Features: Height of the clypeus generally exceeds that of median ocular region, two rows of eight heterogeneous eyes, slightly darker coloured anterior medians, sternum usually heart shaped, legs three clawed, constructs sheet webs that can be flat, domed or hammock shaped, isolated threads form a scaffolding web above the sheet.

Species sampled:

Linyphia sp.1

Neriene macella (Thorell, 1898)

Total number of genus /species reported globally: 634 / 4858

Total number of genus /species reported from India: 31/ 66

12. Family: Lycosidae, Sundevall 1833

Common name: Wolf spiders

Features: Sternum oval shaped, eight dark coloured unequal eyes arranged in three rows; 4 2 2, legs three clawed, normal type spinnerets without colulus, generally complex epigyne with highly sclerotized median septum, no tibial apophysis on male palp, embolus of varying types. Mothers carry the newly hatched spiderlings on their back till the second moult. They are highly aggressive and active hunters with excellent eyesight.

Species sampled:

Hippasa agelenoides (Simon, 1884)

Hippasa pantherina Pocock 1899

Lycosa mackenziei Gravely 1924

Pardosa birmanica Simon, 1884

Pardosa pseudoannulata (Bosenberg & Strand, 1906)

Pardosa sumatrana (Thorell, 1890)

Pardosa sp.1

Total number of genus / species reported globally: 134/ 2473

Total number of genus /species reported from India: 20/ 120

13. Family Mimetidae, Simon 1881

Common name: Pirate spiders

Features: Cephalothorax with sloping thoracic region. Eight eyes, AME largest, laterals equal sized and well demarcated from the medians. Chelicerae with peg teeth. Tibia and metatarsi I and II with a pro marginal row of long slightly curved, regularly spaced spines. Prey exclusively on other spiders. Exhibits unusual behaviour to ensure successful predation from the web of prey species.

Species sampled: *Mimetus* sp.1

Total number of genus /species reported globally: 8/ 162

Total number of genus /species reported from India: 2/ 3

14. Family Nephilidae, Simon 1894

Common name: Long – legged orb weavers

Features: Variably sized, ecribellate, three- clawed spiders with eight eyes placed in two rows; contiguously arranged lateral eyes. Long, lean, three clawed legs with numerous spines. Tricobothria restricted to tibial segment. Shape of the abdomen highly variable. Size of the anterior and posterior spinnerets highly dissimilar. Simple epigyne. Flat or rectangular paracymbium, large and globular tegulum, subtegulum well developed. Embolus elongated with conspicuous embolic conductor. Sexual dimorphism very prominent; females many times larger than the males.

Species sampled:

Nephila pilipes (Fabricius, 1793)

Total number of genus /species reported globally: 7/ 58.

Total number of genus / species reported from India: 4 / 4.

15. Family: Oonopidae, Simon 1890

Common name: Dwarf hunting spiders / goblin spiders

Features: Tiny haplogyne spiders. Possess six compact eyes or eyes absent in some cases, larger sized median eyes. Tarsus with onychium. Epigyne simple, with a sclerotised slit. Posterior pair of tracheae with spiracles situated behind epigastric folds. Nocturnal ground dwellers, actively pursue the prey.

Species sampled:

Triaeris sp.1

Total number of genus /species reported globally: 115/ 1953

Total number of genus / species reported from India: 14/ 47

16. Family: Oxyopidae, Thorell 1869

Common name: Lynx spiders

Features: Eight eyes arranged in a hexagonal shape in two rows, anterior medians very small sized, male palp with paracymbium, cheliceral margin short and equipped with one tooth on each side, legs long, with three claws and prominent spines, clypeus very high and vertical.

Species sampled:

Hamataliwa sp.1

Oxyopes birmanicus Thorell, 1887

Oxyopes javanus Thorell, 1887

Oxyopes lineatipes (C. L. Koch, 1847)

Oxyopes shweta Tikader, 1970

Oxyopes sunandae Tikader, 1970

Peucetia ananthakrishnani Murugesan et al., 2006

Peucetia viridiana (Stoliczka, 1869)

Total number of genus / species reported globally: 9/ 443

Total number of genus/ species reported from India: 4 / 89

17. Family: Philodromidae, Thorell 1869

Common name: Elongated crab spiders

Features: Eight eyes arranged in two recurved rows, chelicerae toothless, long slender laterigrade legs, leg II exceptionally longer and legs I, III and IV almost equal sized, kidney shaped spermatheca.

Species sampled:

Philodromus sp.1

Psellonus planus Simon 1897

Thanatus elongatus (Tikader 1960)

Total number of genus / species reported globally: 29/ 528

Total number of genus / species reported from India: 7/ 43

18. Family: Pholcidae, C L Koch 1850

Common name: Daddy- long- leg spiders

Features: The entire width of carapace is occupied by 6 to 8 eyes, very small sized anterior medians and the rest are larger and forms a pair of triads, intimately fused sternum and labium, long thin extremely long and highly fragile legs, large triangular anal tubercle, in females the epigyne is represented by a swollen thickened area.

Species sampled:

Crossopriza sp.1

Pholcus phalangioides (Fuesslin, 1775)

Pholcus sp.1

Total number of genus /species reported globally: 97 / 1979

Total number of genus / species reported from India: 7 / 16

19. Family: Pisauridae, Simon 1890

Common name: Nursery web spiders

Features: Two or three rows of dark homogenous eyes, long tapered three clawed legs, generally elongate abdomen wider towards the pedicel, abdomen covered with dense plumose setae, epigyne highly complex and equipped with two folds of integument.

Species sampled:

Dendrolycosa gitae (Tikader, 1970)

Dendrolycosa sp.1

Total number of genus / species reported globally: 56/ 365

Total number of genus / species reported from India: 9/ 21

20. Family: Salticidae, Blackwall 1841

Common name: Jumping spiders

Features: Most diverse family in India. Unequal sized eyes arranged in three or four rows, anterior medians exceptionally large, two clawed legs with claw tufts, long plate like maxillae, variable number of teeth on both margins of chelicerae. They are equipped with colour vision and can locate prey from a distant point. Dorsal side of the abdomen usually covered with hairs, contributing variable designs; helpful in identification. They are expert hunters and sometimes occupy the webs of other spiders as well.

Species sampled:

Asemonea tenuipes (O. P. Cambridge, 1869)

Bianor sp.1

Brettus cingulatus Thorell ,1895

Brettus sp.1

Carrhotus viduus (C. L. Koch, 1846)

Chrysilla volupe (Karsch, 1879)

Epeus indicus Prozynski, 1992

Epocilla aurantiaca (Simon, 1885)

Harmochirus brachiatus (Thorell, 1877)

Hasarius adansoni (Audouin, 1826)

Hyllus semicupreus (Simon, 1885)

*Indopadilla insulari*s (Malamel et al., 2015)

*Menemerus bivittatu*s (Dufour, 1831)

Myrmaplata plataleoides (O. P. Cambridge, 1869)

Myrmarachne melanocephala MacLeay, 1839

Phidippus yashodharae Tikader, 1977

Phintella vittata (C. L. Koch, 1846)

Plexippus paykulli (Audouin, 1826)

Plexippus petersi (Karsch, 1878)

Portia fimbriata (Doleschall, 1859)

Rhene flavigera (C. L. Koch, 1846)

Rhene sp.1

Siler semiglaucus (Simon, 1901)

Stenaelurillus lesserti Reimoser, 1934

Telamonia dimidiata (Simon, 1899)

Thiania bhamoensis Thorell, 1887

Thyene imperialis (Rossi, 1846)

Total number of genus /species reported globally: 683 / 6697

Total number of genus / species reported from India: 110/ 325

21. Family: Scytodidae, Blackwall 1864

Common name: Spitting spiders

Features: Six small sized eyes in three widely separated dyads, long slender three clawed legs, highly elongated metatarsi devoid of spines, female palp also with claws, specially equipped with prosomal silk glands; they spit the mixture of venom and silk on the prey.

Species sampled:

Scytodes fusca Walckenaer, 1836

Scytodes pallida Doleschall, 1859

Scytodes thoracica (Latreille, 1802)

Total number of genus / species reported globally: 4/ 253

Total number of genus / species reported from India: 2 / 11

22. Family Sparassidae, Bertkau 1872

Common name: Giant crab spiders

Features: Two rows of differently sized eyes, medians larger. Elongated slender laterigrade legs, III and IV smaller. Highly sclerotised complex epigyne.

Species sampled:

Heteropoda venatoria (Linnaeus, 1767)

Thelcticopis sp.1.

Olios milleti (Pocock, 1901)

Total number of genus /species reported globally: 97/ 1488

Total number of genus / species reported from India: 12/ 89

23. Family Tetragnathidae, Menge 1866

Common name: Long jawed spiders

Features: Eight eyes arranged in two rows, lateral eyes arranged close together or widely separated in some. Epigyne is complex and possess unsclerotized genital plate, motile and distinct paracymbium. Anterior and posterior spinnerets similar in size.

Species sampled:

Leucauge decorata (Blackwall, 1864)

Leucauge dorsotuberculata Tikader 1982

Leucauge tessellata (Thorell, 1887)

Leucauge fastigata (Simon, 1877)

Tetragnatha cochinensis Gravely 1921

Tetragnatha javana (Thorell, 1890)

Tetragnatha mandibulata Walckenaer, 1842

Tetragnatha viridorufa Gravely 1921

Tylorida striata (Thorell, 1877)

Tylorida ventralis (Thorell, 1877)

Total number of genus / species reported globally: 45/ 987

Total number of genus / species reported from India: 11/ 55

24. Family: Theraphosidae, Thorell 1869

Common name: Tarantulas

Features: Two clawed Mygalomorph spiders. Legs with well-developed scopulae and claw tufts, tarsi with clavate trichobothria. Cephalothorax profusely hairy. Eight eyes in two rows, as a compact group. Legs two clawed, Legs II and IV with reduced spines. Epigyne simple with paired unbranched spermatheca. Male palp with a second haematodocha.

Species sampled:

Annandaliella sp.1

Chilobrachys sp.1

Total number of genus / species reported globally: 168 / 1109

Total number of genus / species reported from India: 11/ 59

25. Family: Theridiidae, Sundevall 1833

Common name: Comb- footed Spiders

Features: Eight eyes arranged in two more or less parallel rows, all except anterior medians paler in colour. Occasionally chelicerae elongated and lacks cheliceral teeth. Larger members possess a specialised structure called tarsal comb on tarsi IV.

Species sampled:

Achaearanea sp.1

Argyrodes flavescens O. Pickard-Cambridge 1880

Argyrodes kumadai Chida et al., 1999

Ariamnes flagellum (Doleschall, 1857)

Chikunia nigra (O. Pickard-Cambridge 1880)

Chrysso sp.1

Nihonhimea mundula (L. Koch, 1872)

Phoroncidia septemaculeata (O. Pickard-Cambridge 1873)

Theridion sp.1

Total number of genus / species reported globally: 129/ 2568

Total number of genus / species reported from India: 34/ 90

26. Family: Thomisidae, Sundevall 1833

Common name: Crab spiders

Features: Two rows of eight equal sized dark coloured eyes fringed with white borders, laterals slightly elevated, medians comparatively large. Laterigrade legs, I, II longer. Chelicera teethless. In general, no webs are constructed.

Species sampled:

Amyciaea forticeps O. P. Cambridge 1873

Camaricus sp.1

Indoxysticus minutus (Tikader, 1960)

Runcinia insecta (L.Koch, 1875)

Thomisus lobosus (Tikader 1965)

Thomisus projectus Tikader 1960

Thomisus pugilis Stoliczka 1869

Total number of genus / species reported globally: 171/ 2165

Total number of genus / species reported from India: 41/ 173

27. Family: Uloboridae, Thorell 1869

Common name: Hackled web spiders

Features: Number and arrangement of eyes highly variable; eight homogenous eyes in two rows or a single posterior row of four eyes. Undivided cribellum in front of spinnerets. They lack a venom gland, but add strong digestive enzymes on their prey.

Species sampled:

Miagrammopes sp.1

Uloborus krishnae Tikader 1971

Zosis geniculata (Olivier, 1789)

Total number of genus / species reported globally: 19/ 285

Total number of genus / species reported from India: 5/ 26

4.1.3. Taxonomic identification key to the families collected from the study area

1a. Two pairs of book lungs, fangs closing in longitudinal axis (paraxial) **Mygalomorphae** ……………………..………………**THERAPHOSIDAE**

1b. One pair of book lungs or absent; fangs closing in transverse axis (diaxial) (**Araneomorphae**)………..………..……..……………………………..**2**

2a. Cribellum and calamistrum present, sometimes absent in males (Section Cribellate)... **3**

2b. Cribellum and calamistrum absent (Section Ecribellate) …………………**5**

3a. Femora with rows of long trichobothria, metatarsi IV compressed and curved under the line of the calamistrum, first pair of legs clearly longer than the second pair…………………………………………..…**ULOBORIDAE**

3b. Femora without rows of long trichobothria, metatarsi IV not compressed and curved, first pair of legs not clearly longer…………………………………….. **4**

4a. Carapace rectangular, ocular area long, anterior lateral eyes and posterior lateral eyes more than 4 times their diameter apart……..……... **ERESIDAE**

4b. Carapace narrowed in front, ocular area shorter, anterior lateral eyes and posterior lateral eyes less than 4 times their diameter apart…………………………………………….…..**AMAUROBIIDAE**

5a. With less than eight eyes……………………………………………….… **6**

5b. With eight eyes………………………………………………………. . **8**

6a. Eyes in two well separated triads……………..……………… **PHOLCIDAE**

6b. Eyes arranged otherwise…………………………………………………....**7**

7a. Carapace domed towards thoracic region …………………**SCYTODIDAE**

7b. Carapace differently shaped……………………………… **OONOPIDAE**

8a. Tarsus with two claws……………………………………………........ .**9**

8b. Tarsus with three claws………………………………………………….. .**17**

9a. Eyes in three rows, anterior median eyes very large…………**SALTICIDAE**

9b. Eyes arranged differently……………………………………………… .**10**

10a. Legs laterigrade, directed towards side or forwards…………………….. ..**11**

10b. Legs prograde, 1 and 2 directed forwards, 3 and 4 backwards……...……. .**13**

11a. Tarsi and metatarsi without scopulae, legs I and II usually much longer than legs III and IV ………………………………………….. **THOMISIDAE**

11b. Tarsi and sometimes metatarsi with scopulae, legs different………......**12**

12a. Small to medium-size spiders, chelicerae without teeth or at most one on retromargin, tarsus-metatarsus joint allowing movement in one plane only…. ……………………………………………………**PHILODROMIDAE**

12b. Medium-size to large spiders, chelicerae with at least two teeth on retromargin, membranous connection to metatarsus permits free movement of tarsus…………………………………………………...**SPARASSIDAE**

13a. Spinnerets long and cylindrical, far apart……….........**GNAPHOSIDAE**

13b. Spinnerets conical, not wide apart…….…………………. ………………**14**

14a. Eyes in three rows (2:4:2), epigyne with lateral horns, male palp with dorsally concave median apophysis…..…………………………**CTENIDAE**

14b. Eyes in two rows (4:4), epigyne without lateral horns, male palp with different median apophysi ……….……………………………………….. **15**

15a. Male palp pear-shaped with short distal embolus, square-shaped epigyne with spherical spermathecae, median spinnerets of female with three and posterior spinneret with two large cylindrical gland spigots…………………………………………..…… **CORINNIDAE**

15b. Genitalia differently shaped, median and posterior spinnerets of female without such spigot ………………………………….……………… **16**

16a. Median spinnerets of females laterally flattened, with at least one row of large spigots………..…………………………**CHEIRACANTHIIDAE**

16b. Median spinnerets of females not flattened, without rows of large spigots……..………………………………………….. **CLUBIONIDAE**

17a. Tarsi with trichobothria, often in a row…………………………………….**18**

17b. Tarsi without trichobothria…………………………………..……..…. **21**

18a. Eyes in two rows……………………………………………………..… **19**

18b. Eyes either in three to four rows or in three groups……………………… **20**

19a. Posterior spinnerets long and two-segmented …………...….**HAHNIIDAE**

19b. Posterior spinnerets not particularly long or with one segment only ……………………………………………………………**PISAURIDAE**

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, eyes in three rows, tibiae and metatarsi only with usual spines……………………………..…………… …..……**LYCOSIDAE**

21a. Posterior spinnerets very long, last segment at least three times longer than wide...**HERSILIIDAE**

21b. Posterior spinnerets not unusually long…………………………………… **22**

22a. Anterior tibiae and patellae with a prolateral row of alternating long and short curved spines, chelicerae with peg teeth .……………. .**MIMETIDAE**

22b. Legs without such spines……………………………………………….. **23**

23a. Paracymbium is a separate sclerite, tarsi usually cylindrical or sometimes fusiform, chelicerae often with stridulating file …………..…**LINYPHIIDAE**

23b. Paracymbium fused to cymbium or rudimentary, no cheliceral stridulating file, tarsi variable….…………………………………………………… **24**

24a. Tarsi IV with ventral comb of serrated hairs, brownish rings around the eyes……………………………………...………….....**THERIDIIDAE**

24b. Tarsi without ventral comb of serrated hairs, eyes without brownish rings…………………………………………………………………**25**

25a. Male palp complex, with median apophysis, embolus not wrapped by conductor, paracymbium often hook-shaped, chelicerae often swollen but not modified for courtship, epigyne often with scape….……….. **ARANEIDAE**

25b. Male palp fairly simple without median apophysis but with conductor wrapping the embolus, paracymbium elongate or short, chelicerae usually long or swollen, modified for courtship in males, epigyne usually indistinct …………… …….……………………………………………………..**26**

26a. Large to very large spiders, carapace with a pair of tubercles, web huge, made of yellow silk………..………………..………………… .**NEPHILIDAE**

26b. Smaller spiders with colourless web, carapace without paired tubercles…………………………………………**TETRAGNATHIDAE**

4.2. Population attributes of spiders

Present study intended to characterize various aspects of population ecology of spiders, including the diversity and richness, abundance, equitability and similarities and dissimilarities in distribution of spiders along the sites under consideration.

Sampling along line transects was the predominant strategy adopted to work out the above-mentioned objectives. Five sampling sites were ear marked for collection along the banks of different tributaries of Bharatapuzha; MPZ, CTR, KND, OTP and PNI. Even though a random selection of sites were made, care has been taken to include sites with some dissimilar features; like those associated with permanent vegetation cover versus those with transitory cover of vegetation, or those with perennial phase of the river versus those with fluctuating phases of the river, etc. To ensure a uniform sampling, the study period was divided into 3 seasons; PRM, MON and POM.

4.2.1. Habitat-wise diversity; Abundance

A well-marked difference in diversity was observed among the habitats. Out of the five habitats under consideration, MPZ had the maximum diversity, immediately followed by CTR. Considering abundance, a maximum value of 2156 was recorded from MPZ, while the lowest was from OTP, 990 individuals. Other sites had abundance values between these two sites; CTR (1756), KND (1173) and PNI (1076), (Table 4). The following observations could be made from the box plot representation of the abundance values corresponding to five habitats (Figure 6). In MPZ, a wider box occurred above the median line, positively skewed distribution, whiskers higher above and widely distributed outliers. In CTR, comparatively symmetrical distribution, here also, positively skewed, but whiskers lower and lesser number of outliers. Considering OTP, the boxes were symmetrical on both parts of mean, no lower whiskers, outliers lesser in number and lie closer to whiskers. In KND, symmetrical boxes, whiskers highly condensed and outliers closer. In PNI, the boxes were symmetrical on either side of the median line, no lower whiskers, and outliers clustered.

Mean abundance value was highest at MPZ, 102.67 ± 26.54 (mean ± SD), the remaining positions being occupied by CTR (92.42 ± 23.56), PNI (89.67 ± 14.32), KND (82.50 ± 13.93) and OTP (78.20 ± 14.79) respectively. Araneidae and Salticidae were the most numerically abundant families in all sites (Figure 7).

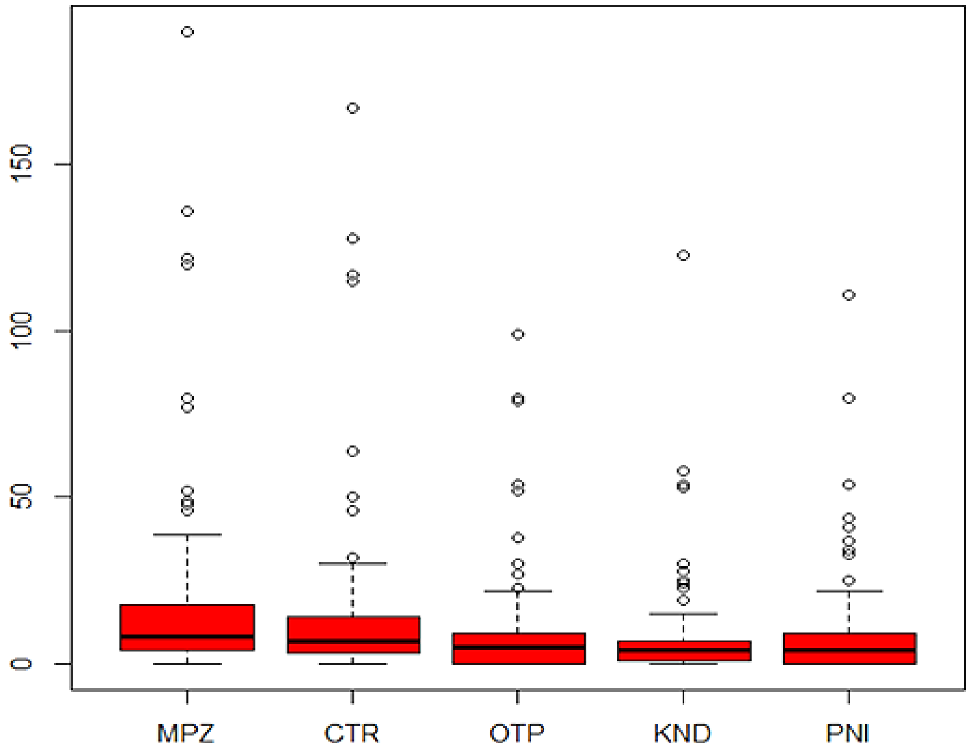


Figure 6. Box plot site wise

Table 4. Total number of individuals and mean abundance

PARAMETER	MPZ	CTR	KND	OTP	PNI
Individuals	2156	1756	1173	990	1076
Mean Abundance ± S D	102.67± 26.54	92.42 ± 23.56	78.20 ± 14.79	82.50 ± 13.93	89.67 ± 14.32
No. of samples (n)	21	19	15	12	12

4.2.2. Habitat-wise diversity; Richness

Among the total diversity of 133 species recorded in this study, MPZ had representatives from 114 species. A very close value was also recorded from CTR, 112 species. Diversity values from OTP was 99 species, from PNI it was 98 species. The lowest among the values was recorded from KND; 96 species. Slightly varying values were being predicted by species richness estimators like Chao1, Chao1bc, iChao1, ACE and ACE1(Table 5). The species estimators provide estimated values of richness against the observed values. Chao1 named after Anne Chao, is a non-parametric richness estimator and mainly assumes that in a random sample, some species may be rare and may not be included. Chao takes into consideration both the above-mentioned categories and provides a correction factor for under sampling of any. Chao1bc stands for a bias corrected modified version of the basic Chao estimator, specifically built for dealing with extremely small sized samples. ACE-represents Abundance based Coverage Estimator; again, a non-parametric richness estimator, where incompletely sampled data is extrapolated to provide estimate of the species richness in the habitat.

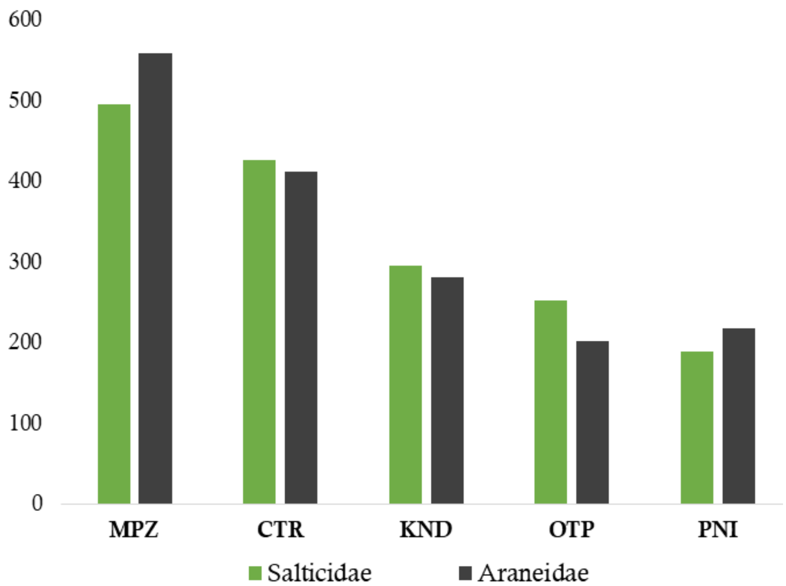


Figure 7. Comparative abundance of Salticidae and Araneidae

Table 5. Observed and estimated richness in habitats

Sites	Observed richness	Richness values predicted by estimators				
		Chao1	Chao1bc	iChao1	ACE	ACE1
MPZ	114	114.4 ± 0.9	114.2 ±0.5	114.4±0.9	114.4±0.7	114.4±0.7
CTR	112	112.1±0.3	112.0±1.4	112.1±0.3	112.2±0.5	112.2±0.5
OTP	101	102.6±1.9	102.2±1.6	102.6±1.9	102.7±1.6	102.7±1.6
KND	99	99.1±0.3	99.0±1.3	99.1±0.3	99.2±0.5	99.2±0.5
PNI	98	98.4±0.9	98.3±0.7	98.5±0.3	98.7±1.0	98.7±1.0

Diversity in terms of genera also followed a similar pattern; MPZ (81), CTR (78), OTP (72), KND (68) and PNI with a lowest value of 63. At the level of family, the sites recorded varying distribution; MPZ had representatives from 24 families, while 23 families were reported from CTR. 20 families recorded from OTP, 19 from KND and only 14 from PNI.

Salticidae was the most diverse family in three sites MPZ, CTR and OTP with 17 genera and 17 species, 16 genera and 17 species and 14 genera and 14 species respectively. In KND and PNI, Araneidae was more diverse with 12 genera and 14 species, and 11 genera and 14 species respectively. Maximum number of singletons were reported from KND, while maximum doubletons were from OTP (Table 6). It could be noticed that the first two sites had a very high and almost equal richness and the remaining three sites had lower but almost comparable species richness.

Table 6. Total number of species, singletons and doubletons

PARAMETER	MPZ	CTR	KND	OTP	PNI
Total number of species	114	112	99	101	98
Singletons	1	1	5	1	3
Doubletons	5	8	6	10	5

4.2.3. Diversity indices; site-wise

Diversity indices provide a quantified view of diversity of species within a habitat. They offer an easier way to compare population attributes of ecological units or to track changes occurring within a single ecological unit over time. As a part of this study, we considered Shannon index (H), Simpson's index (D) and Shannon's Equitability index (E_H) to record the three main attributes of populations; richness, dominance, and evenness.

Shannon index considers both species richness and relative abundance. Out of the five habitats under consideration, MPZ had a distinctly higher H value (62.862). CTR and KND had very closer values (59.094 and 58.588 respectively). Only negligible difference was found to exist between the values of OTP and PNI (55.494 and55.802 respectively) (Table 7).

Simpson's index indicates the relative community interactions in a habitat. The value provides a clue regarding the decisive role played by specific groups of organisms in the ecosystem. Highest value was recorded from MPZ (36.325), while OTP had the lowest (29.698). Equitability values ranged from 0.874 (MPZ & KND) to 0.918 (PNI). Higher values indicate dominance by a small fraction of individuals and hence non- equitable sharing of resources.

Table 7. Diversity indices in five habitats

Site	Shannon Index	Standard error	Simpson's Index (D)	Standard error	Shannon's Equitability Index (E_H)
MPZ	62.862	1.452	36.325	1.578	0.874
CTR	59.094	1.696	31.595	1.460	0.864
OTP	55.494	1.421	29.698	1.834	0.882
KND	58.588	1.869	35.020	2.173	0.874
PNI	55.802	1.733	32.331	2.199	0.918

Average observed values of both Shannon and Simpson's indices were found out by calculating the Index values for each sample, followed by obtaining the mean value of the same. These values help to check the trend followed by these indices through the course of sampling procedure. The highest values of both average observed Shannon diversity and Simpson's index were reported from KND (33.731 and 27.618 respectively) (Figure 8).

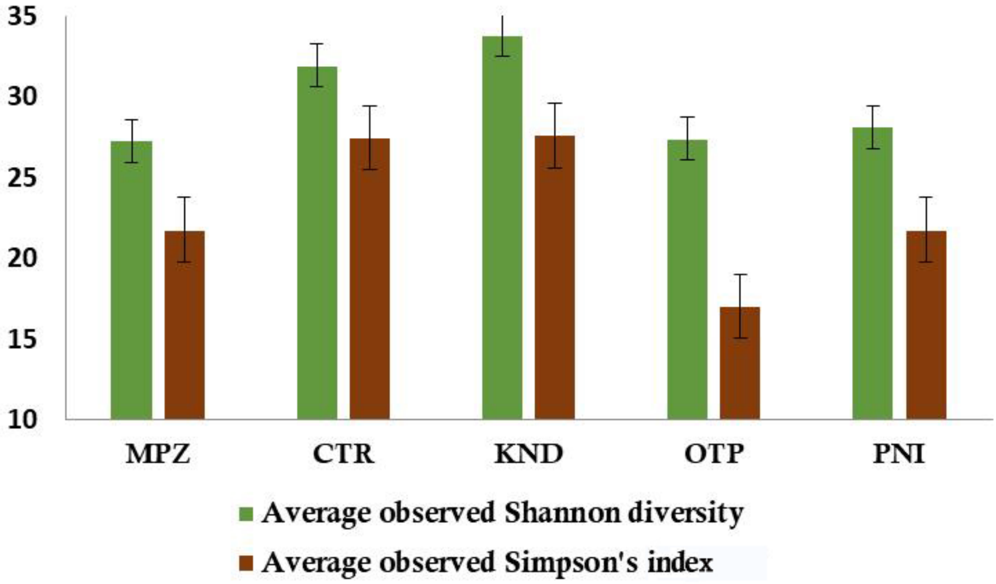


Figure 8. Average observed values of Shannon and Simpson indices

4.2.4. Relative abundance of spiders among habitats

Relative abundance values offer a reliable index of ecosystem functioning. The value depicts the proportion of occurrence of a particular species compared to the total number of organisms of various species inhabiting the same ecosystem. Ecologists often prefer to classify the organisms to various categories like dominants, subdominants, common, rare, etc. Such a classification helps to get a vivid view of ecosystem dynamics.

Relative abundance values (Table 8) calculated indicate a maximum value of 12.42 % for *Hyllus semicupreus* in KND, followed by *Dendrolycosa gitae* (10.32 %) in PNI, *Hyllus semicupreus* (9.46%) in CTR, *Hyllus semicupreus* (8.81%) in MPZ and *Anepsion maritatum* (8.44%) in OTP. Aggregate relative abundance values are taken into consideration for assigning the spiders to various categories. Organisms with relative abundance values equal to or greater than 10% are designated as "eudominant", those having 5 to 10% are "dominant", 2 to 5 % "subdominant", 1 to 2% "recedent" and less than 1% are "sub recedent". Accordingly, we have *Hyllus semicupreus* (8.94%), *Oxyopes javanus* (5.87%) and *Anepsion maritatum* (6.28%) as the 'dominants' while *Dendrolycosa gitae* (4.87%) and *Tetragnatha javana* (4.24%), *Hippasa agelenoides* (2.52%) and *Oxyopes birmanicus* (2.13%) are designated as 'sub-dominants' (Figure 9).

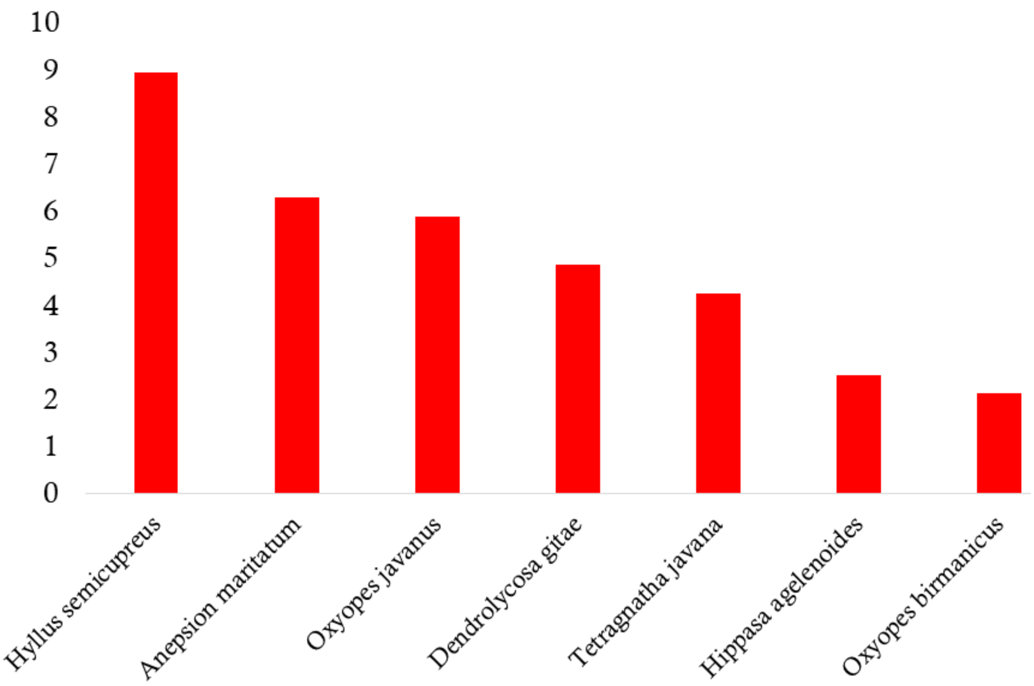


Figure 9. Representation of dominant and subdominant species

4.2.5 Descriptions of dominant and sub-dominant species.

(i) *Hyllus semicupreus* Simon, 1885

Common name: Heavy bodied jumper

Distribution: India, Sri Lanka.

Dark brown or dull black cephalothorax bearing sandy yellow hairs. Abdomen of male covered by golden yellow flat setae; while females have oval abdomen covered with chevrons in white and brown hairs. Preys on insects and other spiders.

(ii) *Oxyopes javanus* Thorell,1887

Common name: Striped Lynx spider

Distribution: India, Nepal, Bangladesh, Thailand, Indonesia (Java), Philippines, China

Cephalothorax longer than wide. Dorsum with a broad v- shaped pale mark. Lateral margins with brownish patches. Anterior row of eyes strongly recurved, posterior row procurved. Ocular quadrangle longer than wide. Middle portion of maxillae dilated to an angular end. Clypeus yellowish brown with a pair of dark brown lines. Ventral side of lines with blackish lines. Abdomen longer than wide, middle region whitish, lateral sides dark brown, posterior end with a median dark patch.

(iii) *Anepsion maritatum* O. Pickard-Cambridge, 1877

Common name: Grass jewel spider

Distribution: India, Sri Lanka, Thailand, Japan, China to Indonesia (Sulawesi)

Cephalothorax yellowish, convex, as long as wide. Eyes darker than normal, anterior row straight, posterior row slightly procurved. Posterior median eyes larger than anterior medians. Abdomen convex, dorsum of the abdomen decorated with black and white patches. Ventrum pale, the region between epigyne and spinnerets blackish.

(iv) ***Dendrolycosa gitae*** Tikader, 1970

Common name: Nursery web spider

Distribution: India (mainland, Andaman Is.)

Cephalothorax longer than broad, anterior part narrower, broadest about middle, yellowish – brown in colour with two pairs of thin longitudinal white stripes. Fovea longitudinal and situated in the posterior half. Eyes eight, anterior eye row shorter and less recurved, posterior eye row longer and more recurved. Anterior median eyes shorter than anterior laterals, posterior medians shorter than posterior laterals. Eyes encircled by black margins. Legs long and hairy. Tarsus three clawed. Abdomen yellowish- brown, longer than broad. Dorsum brown, bears a mid – longitudinal pale band at the anterior half, two pairs of thin longitudinal white stripes present. Spins a three-dimensional web with a platform at the bottom.

(v) ***Tetragnatha javana*** (Thorell, 1890)

Common name: Tailed tetragnathid spider

Distribution: India, Africa to Japan, Philippines, Indonesia.

A pair of reddish-brown C- shaped fovea on cephalothorax. Eye margins deep black in colour. Out of eight eyes arranged in two rows, the anterior one is longer than the strongly recurved posterior one. Reddish – brown coloured labium, adorned with a deep yellow terminal margin. Chelicera extending up to half the length of carapace. Yellowish- brown abdomen with silver spots.

(vi) ***Hippsa agelenoides*** (Simon, 1884)

Common name: Funnel web spider

Distribution: India, Myanmar, Taiwan.

Cephalothorax profusely pubescent, light brown. Slightly procurved row of anterior eyes, medians and laterals almost similar sized. Sternum heart-shaped. Thin and long legs with plenty of spines and hairs. Presence of greenish -brown irregular patches on the legs. Mid- dorsal region of abdomen bears greenish -brown irregular patches.

(vii) *Oxyopes birmanicus* Thorell, 1887

Common name: Crossed lynx spider

Distribution: India, China to Sumatra.

Cephalic region marked by light and dark striations originating from central brown coloured fovea. Fawn- coloured ocular area. Maxillary lobes carrying prominent pad of hairs on top of each. Long, strong, and highly spiny legs, tip of tibia IV visibly black. A peculiar pattern exists on dorsal aspect of abdomen.

Table 8. Relative abundance values

Sl.No.	Species	Relative abundance (%)
1	*Amaurobius* sp. 1	0.06
2	*Anepsion maritatum* (O. Pickard-Cambridge, 1877)	6.28
3	*Araneus* sp.1	0.38
4	*Arachnura angura* Tikader, 1970	0.88
5	*Argiope aemula* Walckenaer, 1842	0.31
6	*Argiope anasuja* Thorell, 1887	0.69
7	*Argiope catenulata* Doleschall, 1859	0.63
8	*Argiope pulchella* Thorell, 1891	1.38
9	*Argiope* sp.1	0.43
10	*Chorizopes* sp.1	0.76
11	*Cyclosa bifida* Doleschall, 1859	0.45
12	*Cyclosa confraga* Thorell, 1892	0.52
13	*Cyclosa hexatuberculata* Tikader, 1982	0.31
14	*Cyclosa* sp. 1	0.70
15	*Cyrtophora cicatrosa* Stolickza, 1869	1.58

16	*Cyrtophora moluccensis* (Doleschall,1857)	1.03
17	*Eriovixia excelsa* (Simon, 1889)	0.67
18	*Eriovixia laglaizei* (Simon, 1877)	0.42
19	*Eriovixia* sp. 1	0.24
20	*Gasteracantha geminata* (Fabricius, 1798)	0.99
21	*Gasteracantha kuhli* CL. Koch, 1837	0.32
22	*Gea subarmata* Thorell,1890	0.45
23	*Neoscona bengalensis* Tikader & Bal, 1981	0.49
24	*Neoscona mukerjei* Tikader, 1980	0.43
25	*Neoscona vigilans* Blackwall, 1865	1.86
26	*Neoscona* sp.1	0.59
27	*Parawixia dehaani* (Doleschall,, 1859)	0.50
28	*Cheiracanthium danieli* Tikader, 1975	0.48
29	*Cheiracanthium melanostomum* (Thorell, 1895)	0.80
30	*Cheiracanthium* sp.1	0.59
31	*Clubiona drassodes* O. Pickard-Cambridge, 1874	0.25
32	*Clubiona nicobarensis* Tikader, 1977	0.28
33	*Clubiona tridentata* Dhali et al., 2016	0.24
34	*Castianeria zetes* Simon, 1897	0.14
35	*Corinnomma* sp. 1	0.64
36	*Bowie cochinensis* (Gravely, 1931)	0.22
37	*Stegodyphus sarasinorum* Karsch, 1891	0.10
38	*Drassodes* sp.1	0.22
39	*Scotophaeus blackwalli* (Thorell, 1871)	0.22
40	*Hahnia mridulae* Tikader, 1970	0.11
41	*Hersilia savignyi* Lucas, 1836	0.01
42	*Linyphia sp.*1	0.67
43	*Neriene macella* (Thorell, 1898)	0.17
44	*Hippasa agelenoides* (Simon, 1884)	0.18
45	*Hippasa pantherina* Pocock, 1899	2.52
46	*Lycosa mackenziei* Gravely, 1924	0.41
47	*Pardosa birmanica* Simon, 1884	0.63
48	*Pardosa pseudoannulata* (Bosenberg & Strand, 1906)	0.39

49	*Pardosa sumatrana* (Thorell, 1890)	0.45
50	*Pardosa* sp.1	1.34
51	*Mimetus* sp.1	0.29
52	*Nephila pilipes* (Fabricius, 1793)	0.07
53	*Triaeris* sp.1	0.15
54	*Hamataliwa* sp. 1	0.34
55	*Oxyopes birmanicus* Thorell, 1887	2.13
56	*Oxyopes javanus* Thorell, 1887	5.87
57	*Oxyopes lineatipes* (C. L. Koch, 1847)	1.87
58	*Oxyopes shweta* Tikader, 1970	1.12
59	*Oxyopes sunandae* Tikader, 1970	0.80
60	*Peucetia ananthakrishnani* Murugesan et al., 2006	0.22
61	*Peucetia viridana* (Stoliczka, 1869)	1.37
62	*Philodromus* sp.1	0.35
63	*Psellonus planus* Simon, 1897	0.14
64	*Thanatus elongatus* (Tikader, 1960)	0.17
65	*Crossopriza* sp. 1	0.57
66	*Pholcus phalangioides* (Fuesslin, 1775)	0.71
67	*Pholcus* sp. 1	0.36
68	*Dendrolycosa gitae* (Tikader, 1970)	4.87
69	*Dendrolycosa* sp. 1	1.08
70	*Asemonea tenuipes* (O.P.Cambridge, 1869)	1.19
71	*Brettus cingulatus* Thorell, 1895	0.43
72	*Brettus* sp. 1	0.39
73	*Carrhotus viduus* (C. L. Koch, 1846)	0.34
74	*Chrysilla volupe* (Karsch, 1879)	0.64
75	*Epeus indicus* Prozynski, 1992	0.17
76	*Epocilla aurantiaca* (Simon, 1885)	0.49
77	*Evarcha* sp.1	0.29
78	*Harmochirus brachiatus* (Thorell, 1877)	0.45
79	*Hasarius adansoni* (Audouin, 1826)	8.94
80	*Hyllus semicupreus* (Simon, 1885)	1.87
81	*Indopadilla insularis* (Malamel et al., 2015)	0.17

82	*Menemerus bivittatus* (Dufour, 1831)	0.31
83	*Myrmaplata plataleoides* (O. P. Cambridge, 1869)	0.56
84	*Myrmarachne melanocephala* MacLeay, 1839	0.29
85	*Phidippus yashodharae* Tikader, 1977	0.39
86	*Phintella vittata* (C. L. Koch, 1846)	1.33
87	*Plexippus paykulli* (Audouin, 1826)	1.64
88	*Plexippus petersi* Karsch, 1878	0.67
89	*Portia fimbriata* (Doleschall, 1859)	0.25
90	*Rhene flavigera* (C. L. Koch, 1846)	0.34
91	*Rhene* sp. 1	0.20
92	*Siler semiglaucus* (Simon, 1901)	0.22
93	*Stenaelurillus lesserti* Reimoser, 1934	0.17
94	*Telamonia dimidiata* (Simon, 1899)	1.01
95	*Thiania bhamoensis* Thorell, 1887	0.22
96	*Thyene imperialis* (Rossi, 1846)	0.27
97	*Scytodes fusca* Walckenaer, 1837	0.46
98	*Scytodes pallida* Doleschall, 1859	0.46
99	*Scytodes thoracica* (Latreille, 1802)	0.29
100	*Heteropoda venatoria* (Linnaeus, 1767)	0.84
101	*Thelcticopis* sp.1	0.27
102	*Olios milleti* (Pocock, 1901)	0.42
103	*Leucauge decorata* (Blackwall, 1864)	0.50
104	*Leucauge dorsotuberculata* Tikader, 1982	0.28
105	*Leucauge tessellata* (Thorell, 1887)	0.15
106	*Leucauge fastigata* (Simon, 1877)	0.41
107	*Tetragnatha cochinensis* Gravely, 1921	1.31
108	*Tetragnatha javana* (Thorell, 1890)	4.24
109	*Tetragnatha mandibulata* Walckenaer, 1842	0.78
110	*Tetragnatha viridorufa* Gravely, 1921	0.17
111	*Tylorida striata* (Thorell, 1877)	0.99
112	*Tylorida ventralis* (Thorell, 1877)	0.28
113	*Annandaliella* sp.1	0.01
114	*Chilobrachys* sp. 1	0.01

115	*Argyrodes flavescens* O. Pickard-Cambridge, 1880	0.32
116	*Argyrodes kumadai* Chida et al., 1999	0.21
117	*Ariamnes flagellum* (Doleschall, 1857)	0.31
118	*Chikunia nigra* (O.P.Cambridge, 1880)	0.20
119	*Chrysso* sp.1	0.28
120	*Meotipa* sp.1	0.29
121	*Nihonhimea mundula* (L. Koch, 1872)	0.31
122	*Phoroncidia septemaculeata* O. P. -Cambridge, 1873	0.36
123	*Theridion* sp.1	0.34
124	*Camaricus formosus* Thorell, 1887	0.41
125	*Indoxysticus minutus* (Tikader, 1960)	0.52
126	*Oxytate subvirens* (Thorell, 1891)	1.54
127	*Runcinia insecta* (L.Koch, 1875)	0.59
128	*Thomisus lobosus* Tikader, 1965)	1.08
129	*Thomisus projectus* Tikader, 1960	0.56
130	*Thomisus pugilis* Stoliczka ,1869	0.43
131	*Miagrammopes* sp.1	0.07
132	*Uloborus krishnae* Tikader, 1972	0.18
133	*Zosis geniculata* (Olivier, 1789)	0.01

Table 9. Site-wise relative abundance values of dominant and sub dominant species

Species	MPZ	CTR	OTP	KND	PNI
Anepsion maritatum	6.31	6.63	8.44	5.35	4.09
Dendrolycosa gitae	5.66	6.52	0	0	10.32
Hippasa agelenoides	2.23	2.83	3.24	2.53	1.77
Hyllus semicupreus	8.81	9.46	6.73	12.42	7.43
Oxyopes birmanicus	1.62	1.81	1.88	3.03	3.07
Oxyopes javanus	5.57	7.25	6.82	5.86	3.16
Tetragnatha javana	3.57	3.63	4.6	5.45	5.02

4.2.6. Hill numbers in habitats

In MPZ, observed species richness, Shannon index and Simpson index (Hill numbers for q=0,1 and 2) were 114.00, 62.862 and 36.325 respectively (Table 10).

In CTR, Hill numbers corresponding to q=0,1 and 2 were 112.00, 59.094 and 31.959 respectively. OTP; 101.00,56.050 and 31.959, KND;99.00, 58.588 and 35.053, PNI;98.00,55.802 and 32.331 respectively.

Diversity profile curves of all the five habitats followed a general trend showing uneven distribution of members. The curves represent a decreasing function of ‘q’ with negative slope values. In MPZ, the empirical curve declined from 114.400 (q=0) to 25.961 (q=3) while estimator curve closely followed and ran from 114.400 to 26.280 (Figure 10). In CTR, the curve was less steep. The empirical curve was between 112.000 and 22.502 while estimator curve was between 112.056 and 22.789 (Figure 11). In OTP, the empirical curve had 101.000 and 19.620 as the upper and lower values respectively while estimator curve was closely applied and ran between 102.635 and 19.979 (Figure 12).

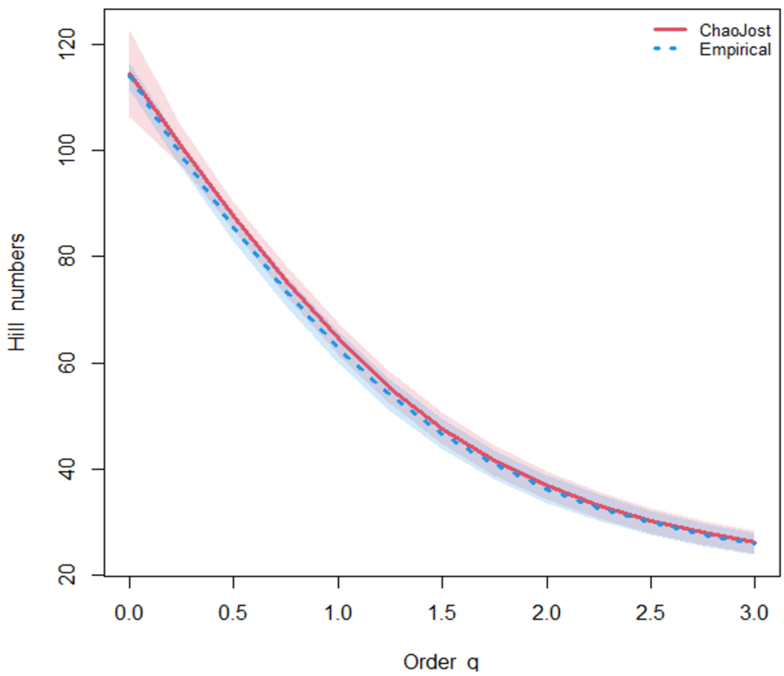


Figure 10. Diversity profile curve of MPZ

Considering KND, the curve was shallow and empirical extended between 99.000 and 25.434 while estimator was between 99.026 and 26.010 (Figure 13). In

PNI, the estimator and empirical curves were deep. The empirical was between 98.000 and 22.730 while the estimator was between 98.450 and 23.182 (Figure 14).

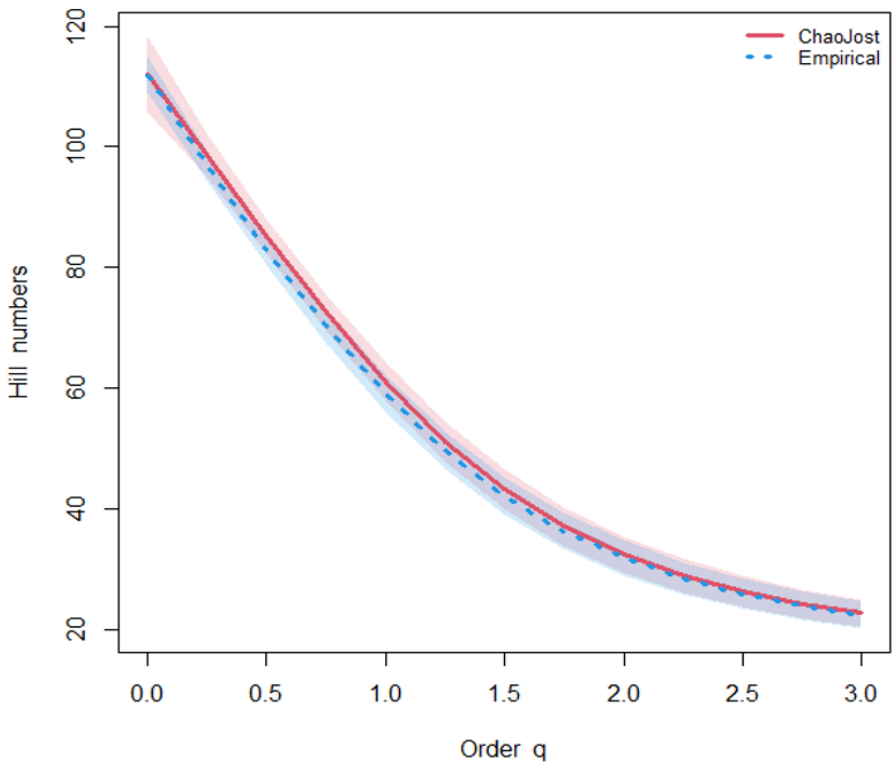


Figure 11. Diversity profile curve of CTR

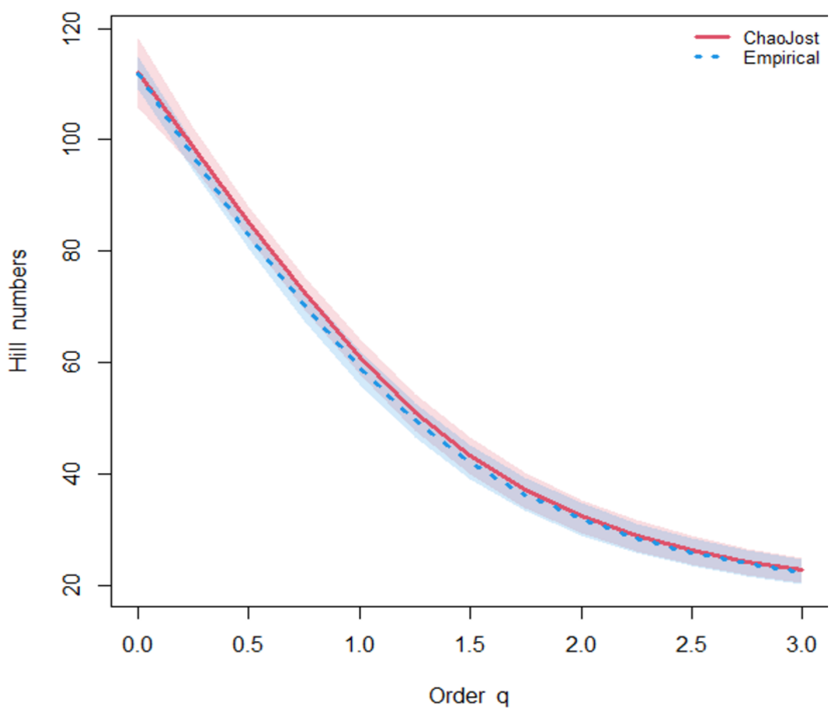


Figure 12. Diversity profile curve of OTP

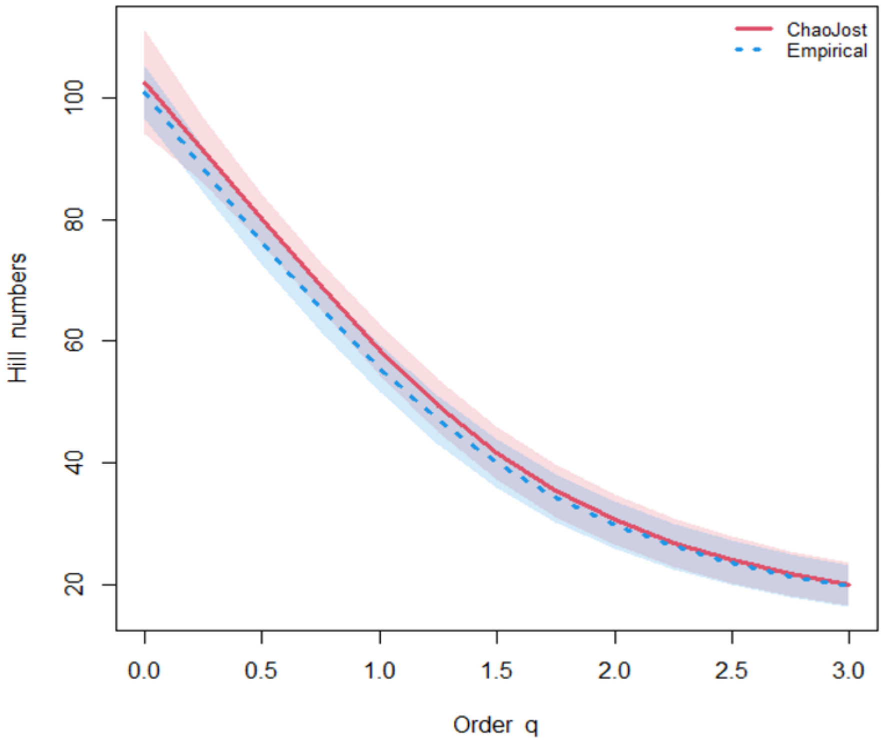


Figure 13. Diversity profile curve of KND

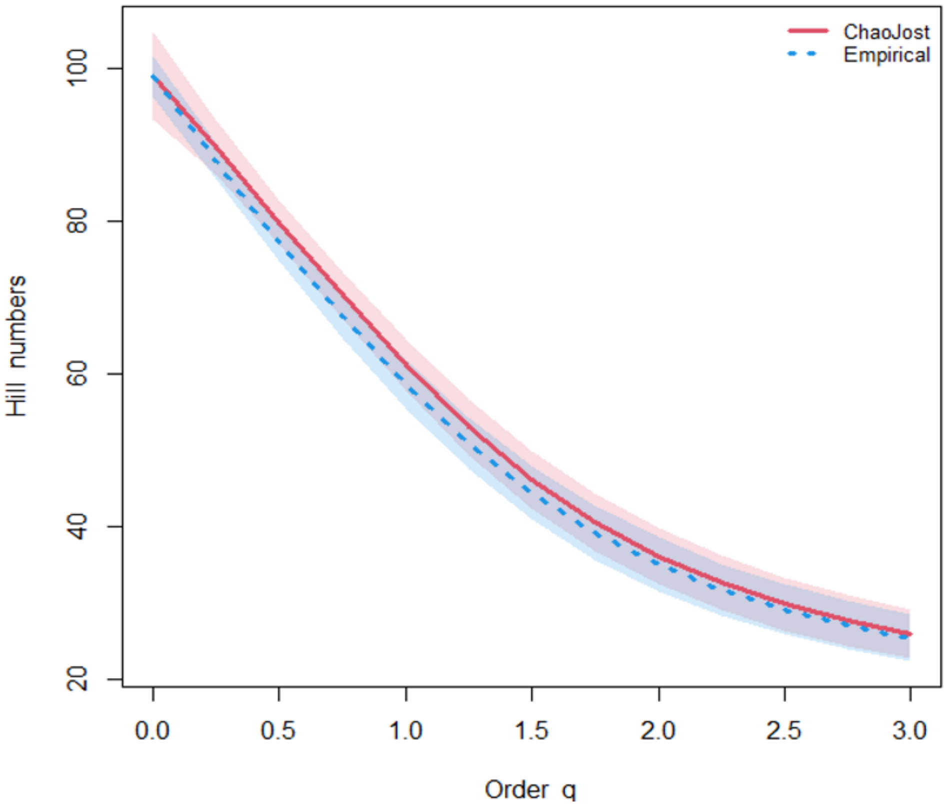


Figure 14. Diversity profile curve of PNI

Table 10. Site-wise consolidated list of Hill numbers

Sites	'q' values	Hill numbers Empirical	Hill numbers ChaoJost
MPZ	0	114.00	114.400
	1	62.862	64.581
	2	36.325	36.931
CTR	0	112.00	112.056
	1	59.094	61.046
	2	31.959	32.533
OTP	0	101.00	102.635
	1	56.050	58.569
	2	31.959	30.586
KND	0	99.00	99.062
	1	58.588	61.168
	2	35.053	36.102
PNI	0	98.00	98.450
	1	55.802	58.490
	2	32.331	33.302

4.2.7. Season wise abundance and diversity

Study of the correlation between species diversity and seasons revealed a clear-cut variation of diversity with varying seasons. Considering abundance, POM had the highest representation with 3885 individuals, followed by PRM; 1867 individuals. The abundance of spiders was found to be least during MON season comprising only 1399 individuals. A very well demarcated difference in abundance values could be noticed between the highest and lowest recorded values. This indicates the variability in spider population in conjunction with varying seasons and hence with the changing environmental and climatic gradients (Figure 15). Mean abundance value was found to be higher in POM (Table 11); 777.0 ± 313.95 (mean ± SD), followed by PRM (373.4 ± 131.23) and least in MON (279.8 ± 71.69). Maximum singleton species was recorded in PRM while maximum doubleton occurred in MON. Number of unique species was in the order MON>PRM>POM. Percentage value of rare species was also in the order MON>PRM>POM. Season- wise data show *Hyllus semicupreus* (220) as the dominant one during pre-monsoon, *Tetragnatha javana* (226) in monsoon and *Hyllus semicupreus* (371) in post-monsoon.

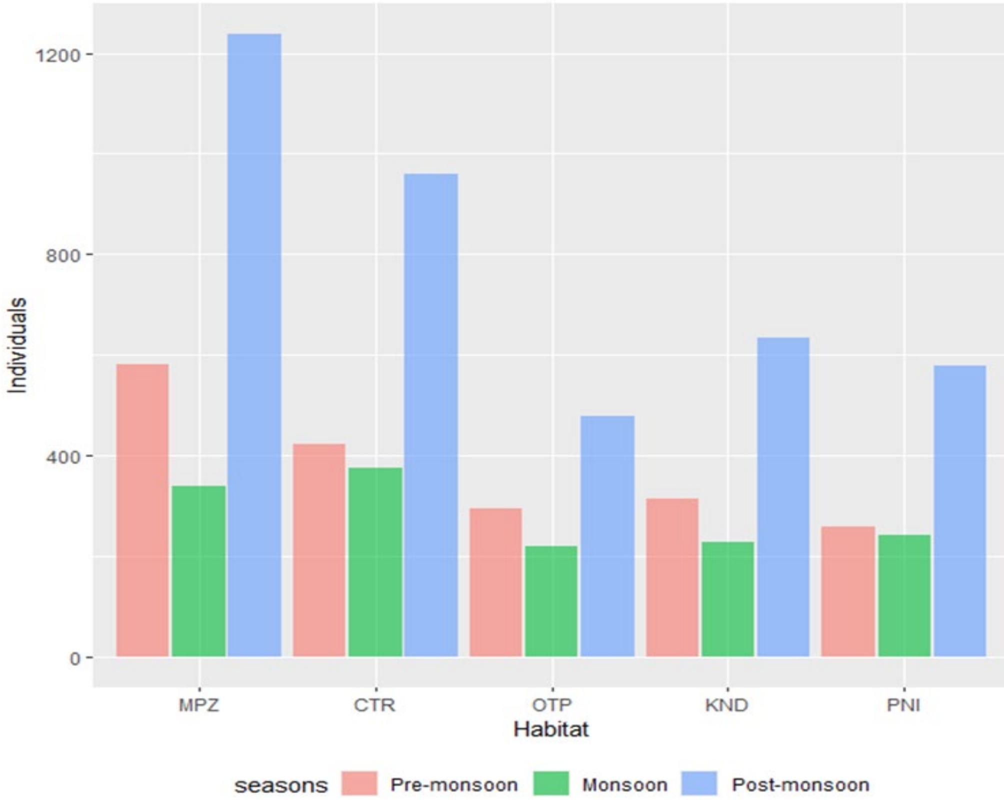


Figure 15. Seasonal abundance of spiders in five habitats

Table 11. Abundance, number of singletons, doubleton, unique and rare across seasons

	PRM	MON	POM
Individuals	1867	1399	3885
Mean ±	373.4	279.8	777.0
SD	131.23	71.69	313.95
Total No. of Species	107	96	127
Singleton	4	3	2
Doubleton	3	9	1
Unique Species	37	46	25
Rare species %	57.01	69.79	25.98

Shannon index was found to be higher in POM (Table 12) and least in MON. Similarly, Simpson index was maximum in POM and minimum in MON.

Table 12. Diversity indices; season-wise

Seasons	Shannon index ± s e	Simpson index ± s e
PRM	54.135 ± 1.500	28.875 ± 1.128
MON	42.294 ± 1.556	19.796 ± 1.160
POM	71.346 ± 1.413	39.300 ± 1.312

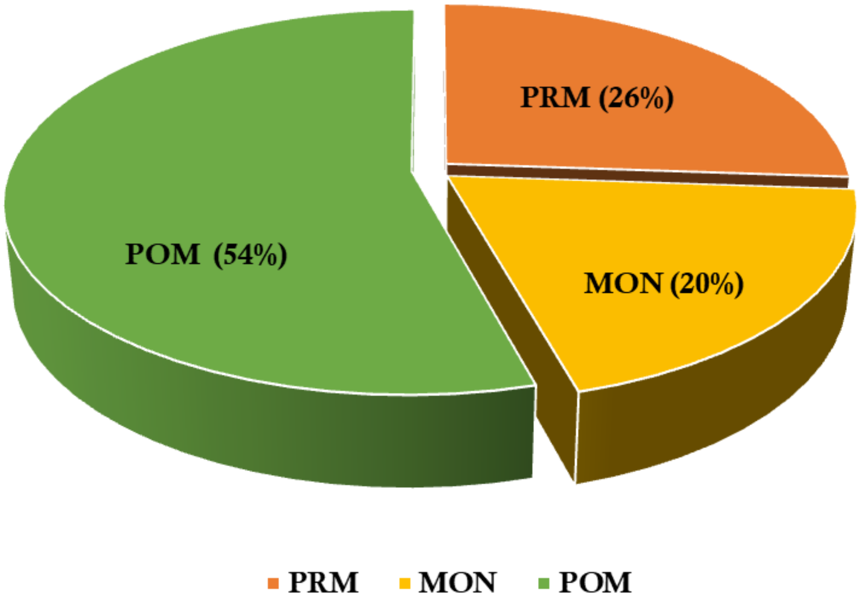


Figure 16. Seasonal distribution of overall abundance (%)

On a comparative mode, it could be observed that there existed a wide gap between the abundance values of the three seasons; especially between PRM – POM and MON – POM pairs. The percentage -wise abundance of the three seasons were; PRM (26%), MON (20%) and POM (54%), (Figure 16). Undoubtedly the POM season happened to be the best one for species abundance. The percentage abundance of POM is more than double the that of other two seasons. Monsoon season was found to support the lowest number of individuals. Even though, the classification of our study period was mainly based on monsoon rainfall, in actual sense, there are a host of topographic, climatic, and biotic factors having decisive roles in these diversity values. Majority of the spiders being predators, the seasonal fluctuation may also be accelerated by fluctuations in their prey populations.

The distribution of species richness and abundance in conjunction with the seasons were represented by Box plots. They are graphical tools for displaying the nature of the distribution of components of a data set. Interpretation is based on shape of the box (narrow / wide), nature of whiskers and outliers, etc. The box represents interquartile range. The line running inside the box represents the median value (Figure 17).

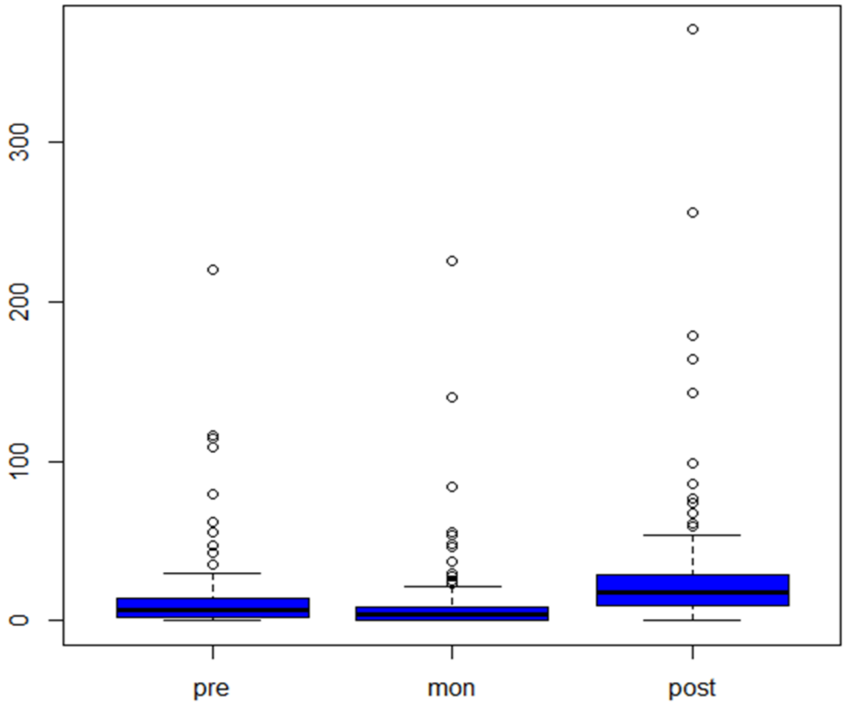


Figure 17. Box plot for seasonal data

Separate box plots for the seasonal variations in each of the five habitats were made and the width of the box, symmetry with respect to the median line and length of whiskers etc. were found to be highly varying. In MPZ, the three boxes representing the seasons were entirely different. The box corresponding to PRM had an upper skewed distribution; majority of the distribution lying above the median line. The whisker was short and the out-liers were limited in number and majority were seen nearer the whisker. MON had a very narrow box with extremely short whisker and out-liers concentrated on the whiskers. During POM, the plot was almost symmetrical, with longer whiskers (Figure 18).

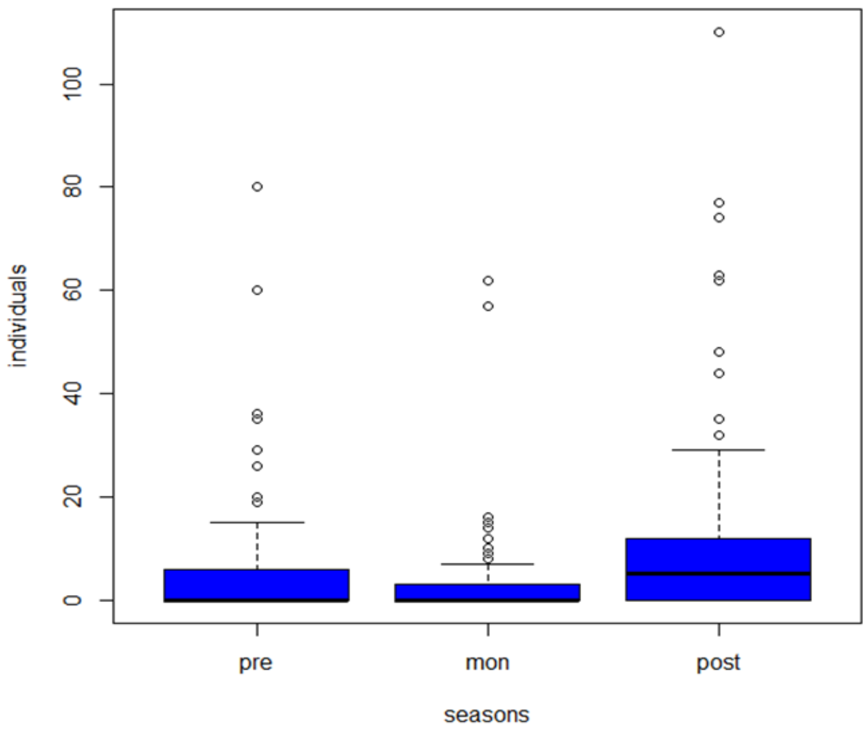


Figure 18. Box plot of MPZ

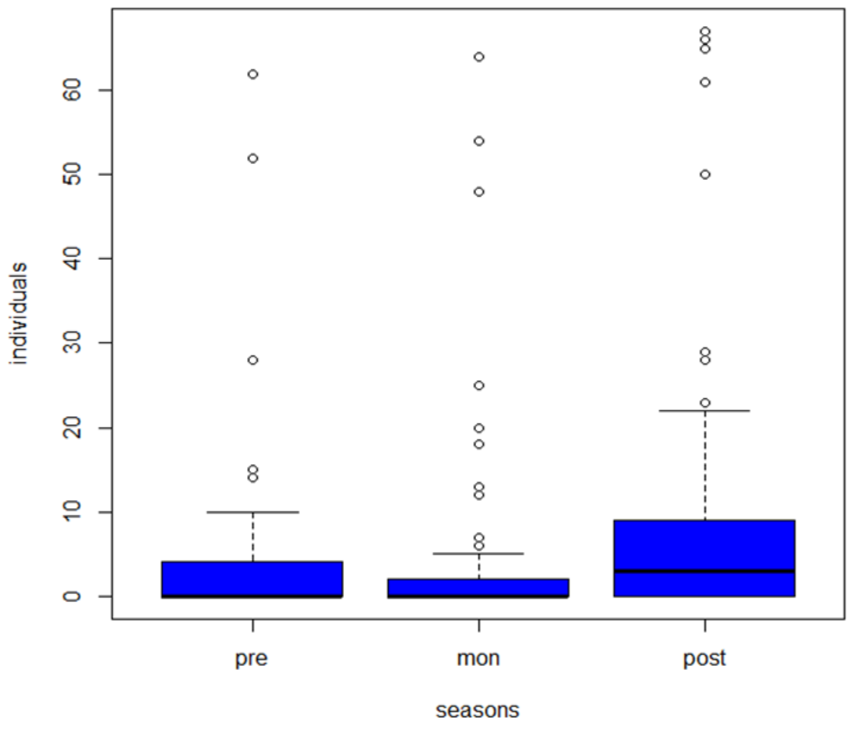


Figure 19. Box plot of CTR

In CTR, all the three plots were asymmetrical to varying degrees. Both PRM and MON seasons had upper clustered values with very short whiskers and highly scattered out-liers. Comparatively symmetrical distribution was observed during POM season. The out-liers represented some of the highly diverged members (Figure 19).

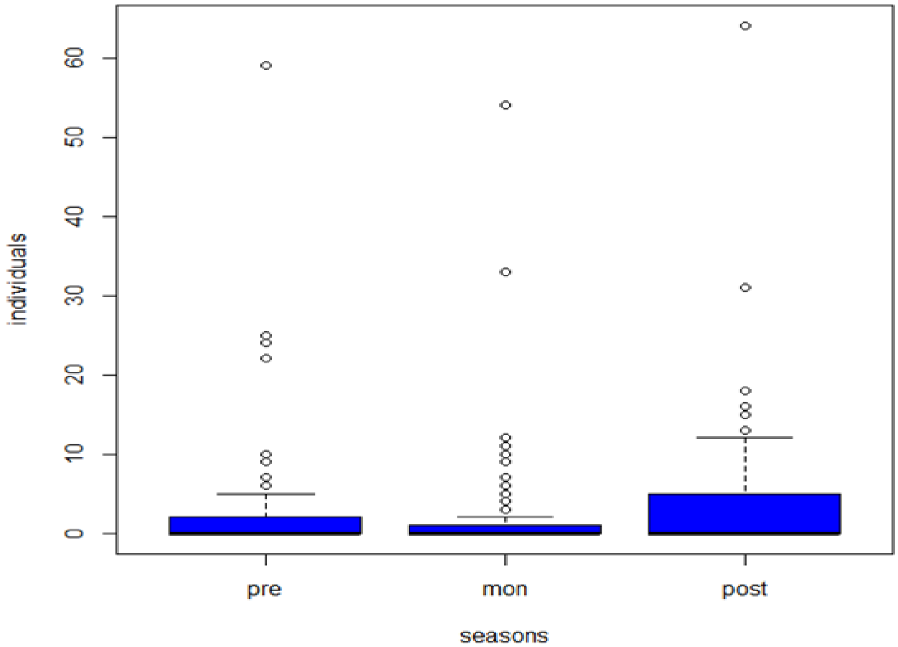


Figure 20. Box plot of OTP

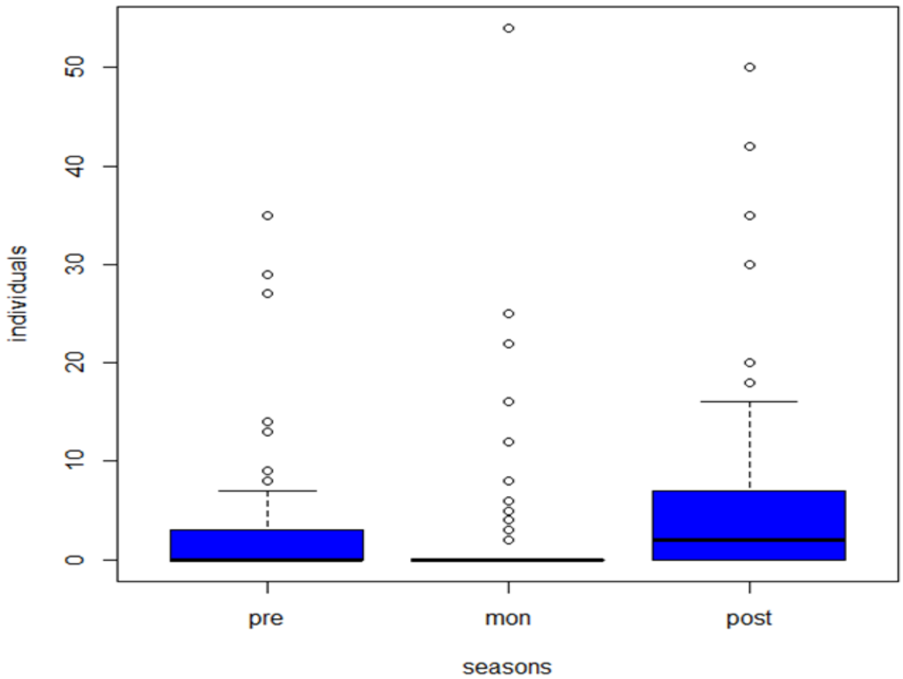


Figure 21. Box plot of KND

The box plots related to OTP (Figure 20), were highly asymmetrical and upper clustered. MON season had an extremely narrow box and very small whisker with outliers clumped above it.

In KND, also a marked difference in the distribution of spiders was recorded. During MON season, the richness values were concentrated on the median line. In POM, the values were asymmetrically distributed (Figure 21). Similarly, in PNI, all the seasons had asymmetrically distributed richness, very short whiskers and the outliers were highly concentrated during MON (Figure 22).

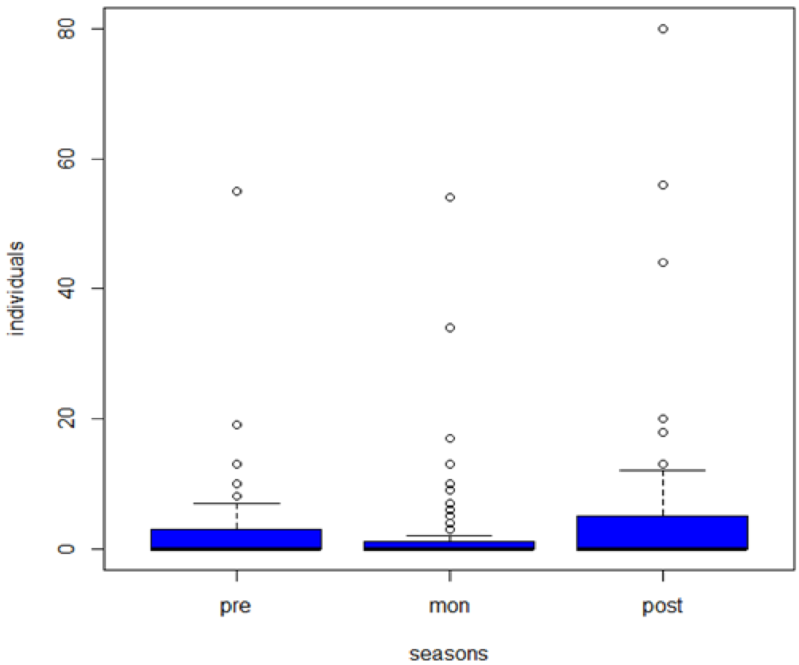


Figure 22. Box plot of PNI

4.2.8. Hill numbers in seasons

Hill numbers for q=0,1 and 2 were calculated (Table13). For PRM, the empirical values for q=0, 1 and 2 were 107.00, 54.135 and 28.875 respectively. During MON, slightly lower values of 96.00,42.294 and 19.797 were recorded. Highest among these values were obtained during POM; 127.00, 71.346 and 38.917 (for q=0, 1 and 2) respectively. For all the three seasons, the respective empirical values were found to be slightly lower than that of the estimator (ChaoJost).

Table 13. Hill numbers; season-wise

'q' values	Hill numbers PRM		MON		POM	
	Empirical	ChaoJost	Empirical	ChaoJost	Empirical	ChaoJost
0	107.00	108.99	96.00	96.500	127.00	128.99
1	54.135	55.78	42.294	43.820	71.346	72.552
2	28.875	29.313	19.797	20.067	38.917	39.301

Diversity profile curves corresponding to the three seasons were subjected to detailed analysis. In PRM, the empirical curve (blue, broken lines) extended from y= 107.00 (x value/ q value =0) to y= 19.876 (q = 3) as a gradually decreasing function with negative slope values. Simultaneously, the estimator curve (red curve, ChaoJost estimator) followed the same path from y=108.999 to y= 20.080. Shape of the curve denotes an early attainment of saturation (Figure 23). During MON, the empirical curve ran between 96.000 and 13.232. The estimator curve lain between 96.500 and 13.344. Shape of the curve was almost like that of PRM (Figure 24). In POM, the deciding values of empirical curve were 127.000 and 26.014, while estimator curve was between 128.999 and 26.179 (Figure 25).

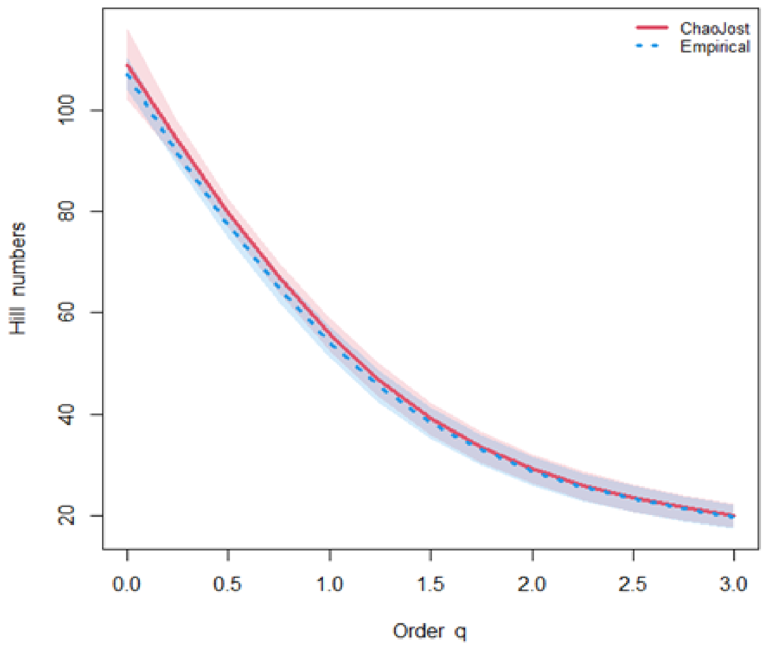


Figure 23. Diversity profile curve of PRM

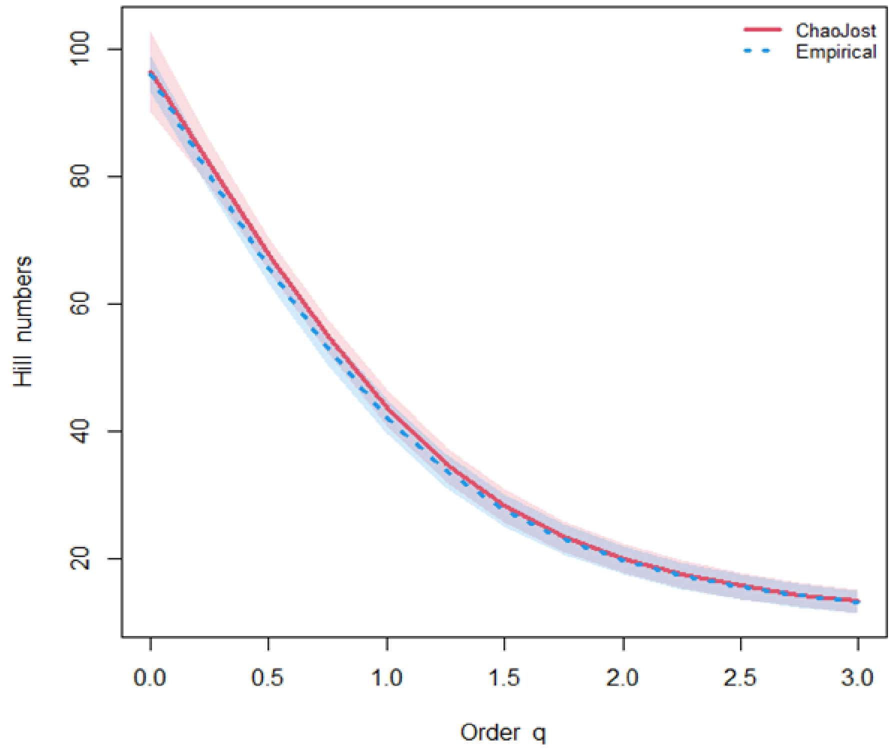


Figure 24. Diversity profile curve of MON

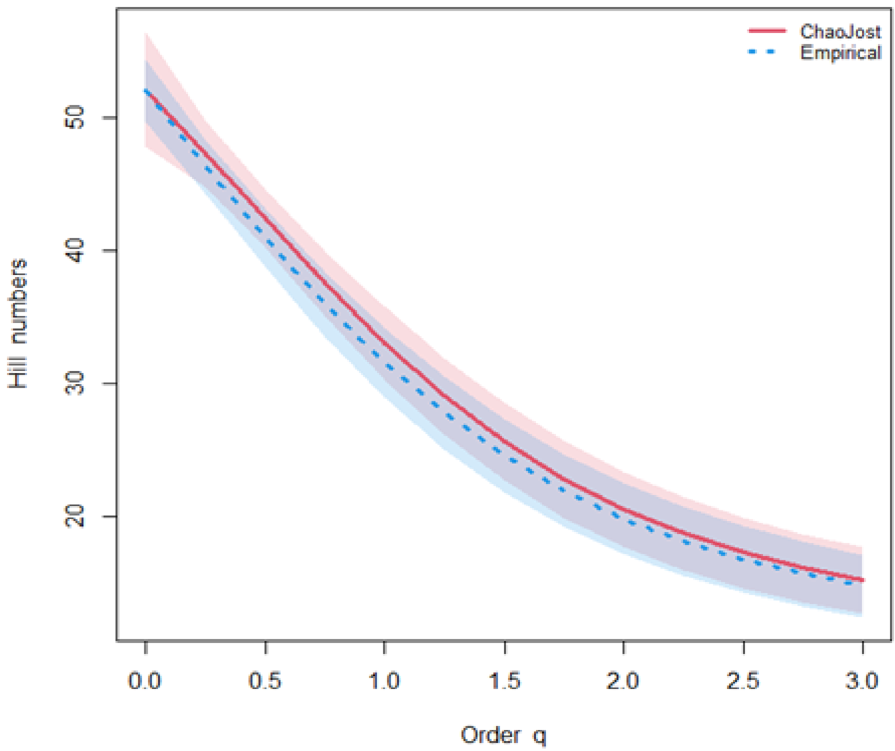


Figure 25. Diversity profile curve of POM

4.2.9. Season wise richness

Maximum diversity of spiders was recorded during the post monsoon season (127 species). The next highest value of diversity was recorded during pre-monsoon with 107 species, while monsoon recorded the lowest value with only 96 species. Corresponding estimated values of the same are 124, 127 and 135 respectively; indicating probability of reporting more species in each season. (Table 14).

Table 14. Actual and estimated richness among seasons

Diversity indices	PRM	MON	POM
Richness	107	96	127
Est.richness	124	127	135

A comparative analysis of the distribution of genera and species across seasons demonstrate an undulating account; the values decreasing during MON, and then having a sudden increase in POM (Figures 26, 27 & 28). For the sake of convenience, the number of species in each site per season were converted to corresponding percentage values. Maximum percentage of species in PRM was recorded in CTR (54.2%), which increased to 57.4% during POM. In MPZ, the value increased from 47.6% (PRM) to 62.9% (POM). In OTP, the value increased from 39.25% to 53.5%. In KND, there was an increase from 42% to 47.2%. Finally, in PNI the value increased from 41.1% to 46.4% (Figure 29).

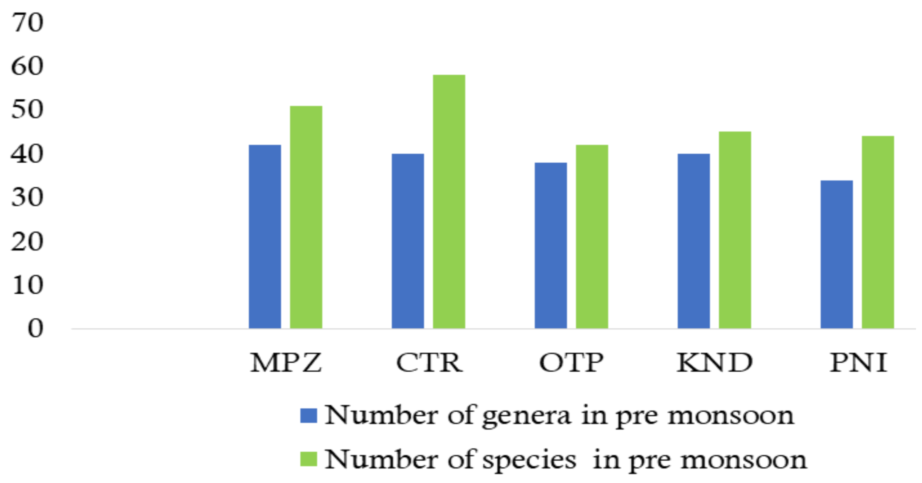


Figure 26. Variation in genera and species during PRM

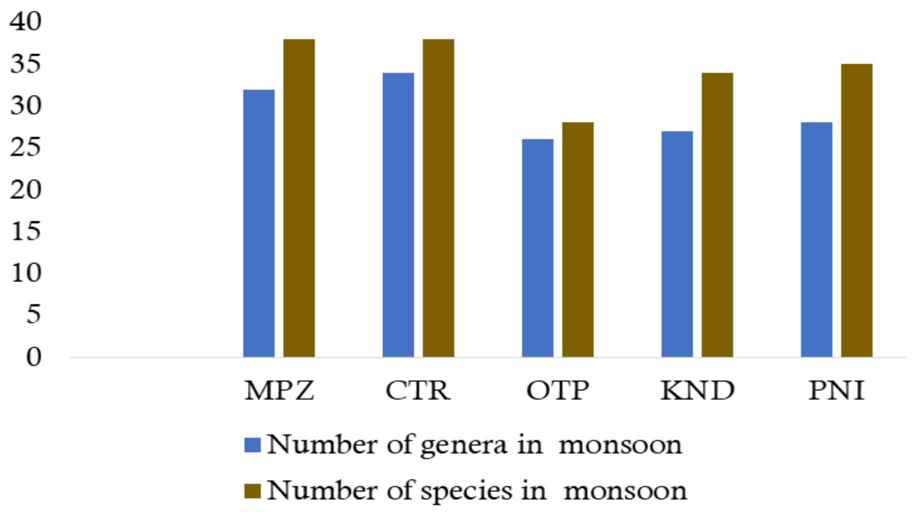


Figure 27. Variation in genera and species during MON

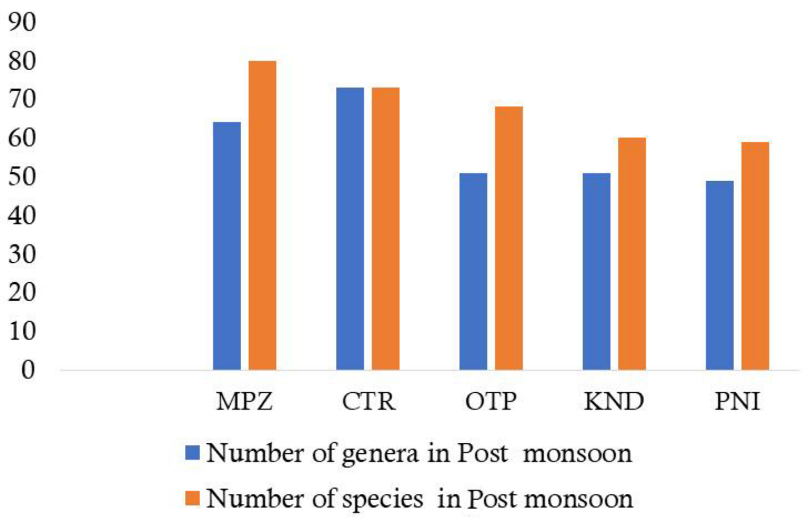


Figure 28. Variation in genera and species during POM

Figure 29. Variability of species per seasons

4.3. Beta Diversity

Beta diversity refers to the comparative analysis of individual diversities measured on a regional basis. It tries to show case the inherent similarities and dissimilarities in various attributes of diversity among two or more ecological units.

On a peripheral level, comparison of seasonal and habitat wise abundance and richness values could arbitrarily be done without any complicated practices. Out of 7151 individuals sampled, 1867 were recorded during PRM, which contributes to 26.11%, while during MON, 1399 spiders occurred, contributing 19.56% and in POM, 3885 individuals constituted a bulk value of 53. 90%. Obviously, the seasonal abundance value hierarchy emerges to be POM > PRM > MON.

Habitat -wise abundance comparison shows MPZ with 2156 spiders constituted 30.14%, CTR (1756) – 24.55%, KND (1173) – 16.40%, OTP (990) – 13.84% and PNI (1076) amounts to 15.04%. The hierarchy of habitat-wise abundance was MPZ > CTR > KND > PNI >OTP.

Considering species richness, MPZ could report 114 out of the127 species recorded during the study (89.7%), CTR (112)- 88.1%, KND (99) – 77.9%, OTP (101) – 79.5% and PNI (98) – 77.1%; thereby indicating high species turn over in all sites under consideration.

To assess the nature of distribution of the values, Shapiro – Wilk Test was performed and the result was displayed as a Q-Q plot (Figure 30). As the observed effect size, KS – D was large, we could conclude that the magnitude of the difference between the sample distribution and the normal distributions is large and the distribution deviates from a normal one.

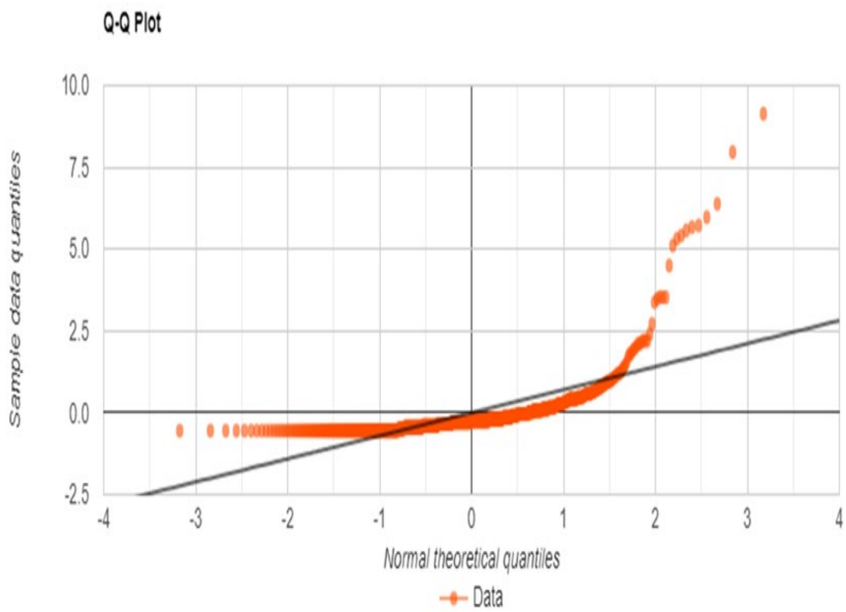


Figure 30. Q - Q plot of pooled data

Kruskal Wallis' H test was performed to find out the nature of relationships among the five sites under study. Results of post – hoc Mann Whitney U test revealed varying degrees of relationship among the sites with respect to abundance.

Considering the 'p' and 'z' values, the following conclusions were drawn; in comparison to the fixed α value, 0.05, some of the pairs of sites were found to have p values lower than α, hence qualifying the rejection of H_0. A statistically significant difference was found to exist among MPZ-KND, MPZ-OTP, MPZ – PNI, CTR-KND, CTR-OTP and CTR-PNI. The calculated p and z values were not in the desirable range to reject H_0 and sites MPZ-CTR, KND-OTP, KND- PNI and OTP – PNI were not found to have statistically significant difference.

Kruskal Wallis H test was conducted to investigate the difference in distribution of spiders among seasons. The results indicated that there is a significant difference in the dependant variables between the seasons; $\chi^2 (2) = 79.38$, $p < 0.001$ with a mean rank score of 181. 95 for PRM, 148.2 for MON and 269.85 for POM.

Results of post – hoc Wilcoxon signed rank test indicated varying relations between seasons and abundance values.

- Only a significant medium difference was found out between PRM and MON.
- A significant large difference exists between MON and POM.
- A significant large difference was also found to exist between PRM and POM.

Table 15. Wilcoxon ranked sum test

Seasons	'Z'value	'p' value	'r' value
PRM & MON	-3.3	=0.001	-0.3
MON & POM	8.7	< 0.001	0.8
PRM & POM	7.4	< 0.001	0.7

Analysis of similarities (ANOSIM) results also supported the existence of varying degree of similarities among the habitats (Figure 31).

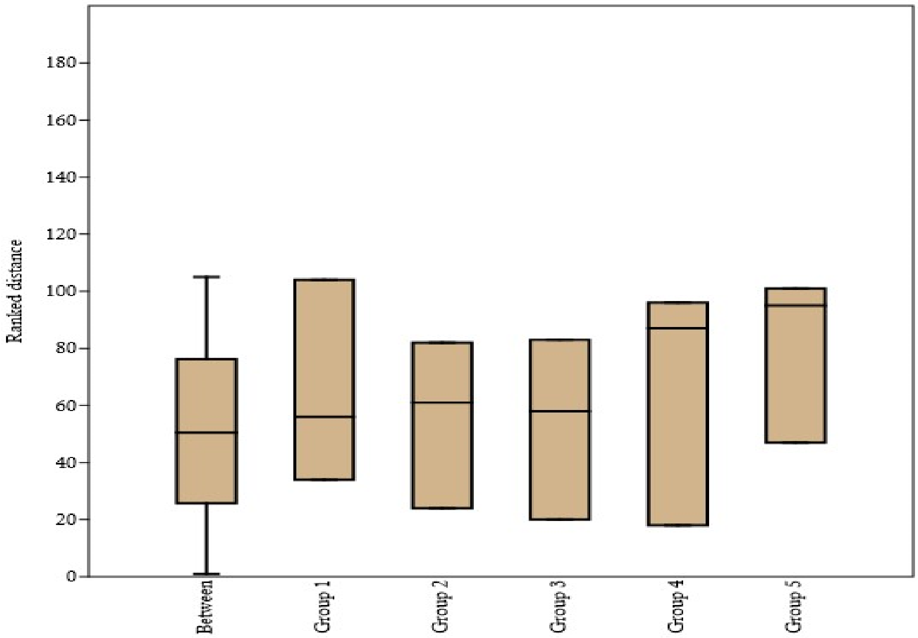


Figure 31. ANOSIM results

To find out which species contributed most to the dissimilarity values reported between a pair of habitats, SIMPER (Similarity Percentage) analysis was carried out using Vegan package of R. The overall average dissimilarity value of pooled data was 67.73. *Hyllus semicupreus* was the species with maximum value of average dissimilarity (4.65).

Table 16. SIMPER analysis values

Sl. No.	Sites		Overall average dissimilarity
1.	MPZ	CTR	39.80
2.	MPZ	OTP	63.52
3.	MPZ	KND	50.37
4.	MPZ	PNI	52.48
5.	CTR	OTP	58.28
6.	CTR	KND	50.00
7.	CTR	PNI	48.31
8.	OTP	KND	48.38
9.	OTP	PNI	45.08
10.	KND	PNI	45.12

In pair – wise comparison of the habitats, maximum overall average dissimilarity was found between MPZ &OTP (63.52) (Table 16). *Tetragnatha javana* was the species that contributed maximum average dissimilarity value (4.48). Remaining pairs of habitats and the species with maximum average dissimilarity are as follows; MPZ & CTR, *Tetragnatha javana* (3.50), MPZ & KND, *Tetragnatha javana* (4.11), MPZ & PNI*, Tetragnatha javana* (4.25), CTR & KND, *Dendrolycosa gitae* (4.59), CTR & OTP, *Dendrolycosa gitae* (4.59), CTR & PNI, *Dendrolycosa gitae* (4.29), KND & OTP, *Oxyopes javanus* (3.15), KND & PNI, *Oxyopes javanus* (4.63), OTP & PNI, *Oxyopes javanus* (5.30).

The overall average dissimilarity value of pooled data of seasons was 38.73. *Hyllus semicupreus* was the species with maximum value of average dissimilarity (3.73). Pair wise comparison of seasons; overall average dissimilarity between PRM & MON was 47.09. Maximum average dissimilarity was 6.92 by *Tetragnatha javana.* In PRM &POM pair, overall average dissimilarity was 43.01 and maximum average dissimilarity was 2.62 by *Hyllus semicupreus*. Pair-wise MON & POM; overall average dissimilarity was 55.15, with *Hyllus semicupreus* contributing maximum average dissimilarity value (6.11).

The dissimilarity aspects in species distribution were represented with the help of n MDS (non-metric multi- dimensional scaling) plot, using vegdist ( ) function of vegan package. A dissimilarity matrix derived from Bray – Curtis was utilised as the reference. The plot displays the large-scale clustering of major proportion of individuals of different taxa with two distinct symbols (Figure 32).

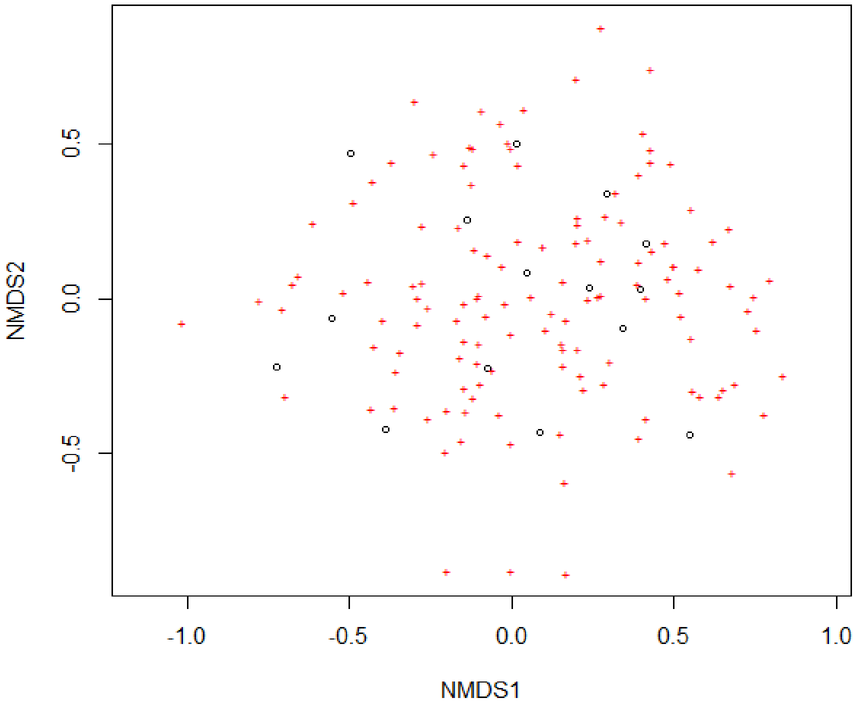


Figure 32. n MDS plot of pooled data

4.4. Overall diversity

A total of 7151 individuals belonging to 133 species, 90 genera under 27 families were recorded during the study. Out of these, 106 could be identified up to species level (79.6%) and the remaining 27 could be identified up to genus level only. The sample coverage was 0.999 and coefficient of variance was 1.568. Empirical values of species richness, Shannon index and Simpson's index (Hill numbers for q=0, 1 and 2) were 133.0, 70.94 ± 0.89, and 38.26 ± 0.99 respectively (Table 17). Species richness estimator ChaoJost provided the corresponding values as 138.99, 71.63 ± 0.90 and 38.46 ± 0.99.

Table17. Hill numbers, overall data

'q' values	Empirical (MLE)	Predicted (ChaoJost)
0	133.00	138.99
1	70.94	71.63
2	38.26	38.46

Diversity profile curve corresponding to the pooled data represented a gradually decreasing function. The empirical curve extended from y=133.000 (q=0) to y=26.310 (q=3). Similarly the estimator curve extended from y=138.999 to y=26.405. The empirical and estimator curves followed the same path almost throughout, except at the beginning, where the estimator curve indicated a higher value almost equal to 140, indicating the probability of reporting a richness value greater than the actual 133 (Figure 33).

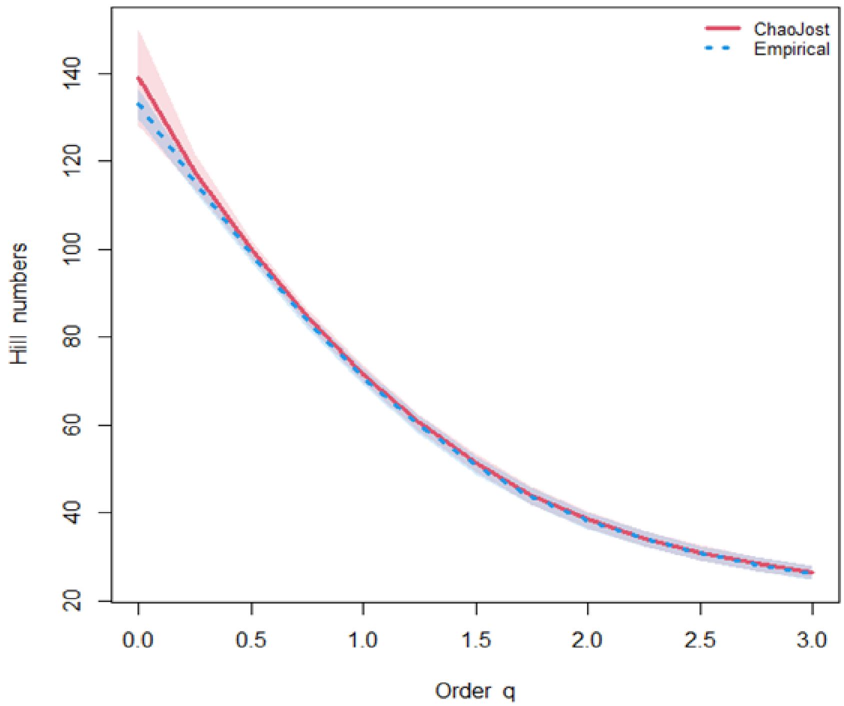


Figure 33. Diversity profile curve of overall data

4.5. Deduction of abundance and richness from curves

To reaffirm the numerical values of abundance and richness we came across with in the previous parts, three different categories of curves were chosen; species accumulation curve, rank abundance curve and rarefaction curve. Representation of the data via these curves will reflect the general trends in distribution of richness and abundance, among the habitats and across the seasons. Some extra revelations are also expected as the curves chosen here represent three entirely different categories and hence are based on exclusive algorithms.

4.5.1. Species accumulation curves

Species accumulation curves depict the number of species in a particular area with increasing sampling efforts (Figures 34 to 39). A hypothetical assumption that 'all species have equal chances of being detected' forms the cardinal aspect of species accumulation curves (Deng et. al, 2015). A curve with suddenly increasing steep slope indicates considerable number of species added per each sampling effort; a shallow slope curve points towards asynchronous relation between sampling efforts and finding of additional species (Colwell et al., 2004).

The four component curves of a species accumulation curve are; collector curve, exact curve, random curve, and rarefaction curve (Thompson & Withers; 2003).

Species accumulation curves corresponding to the three seasons of study also followed a similar trend as to that of habitats. In general, the curves represent moderate sampling effort as they have not reached the uppermost asymptote (Figures 40, 41 & 42).

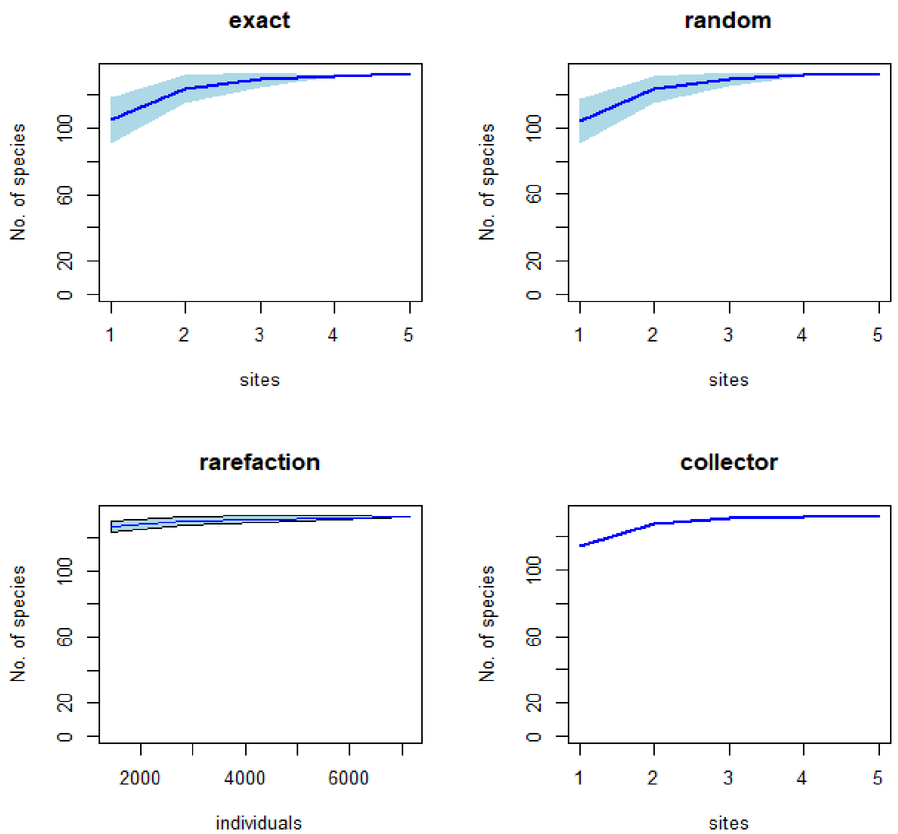


Figure 34. Species accumulation curves of the pooled samples

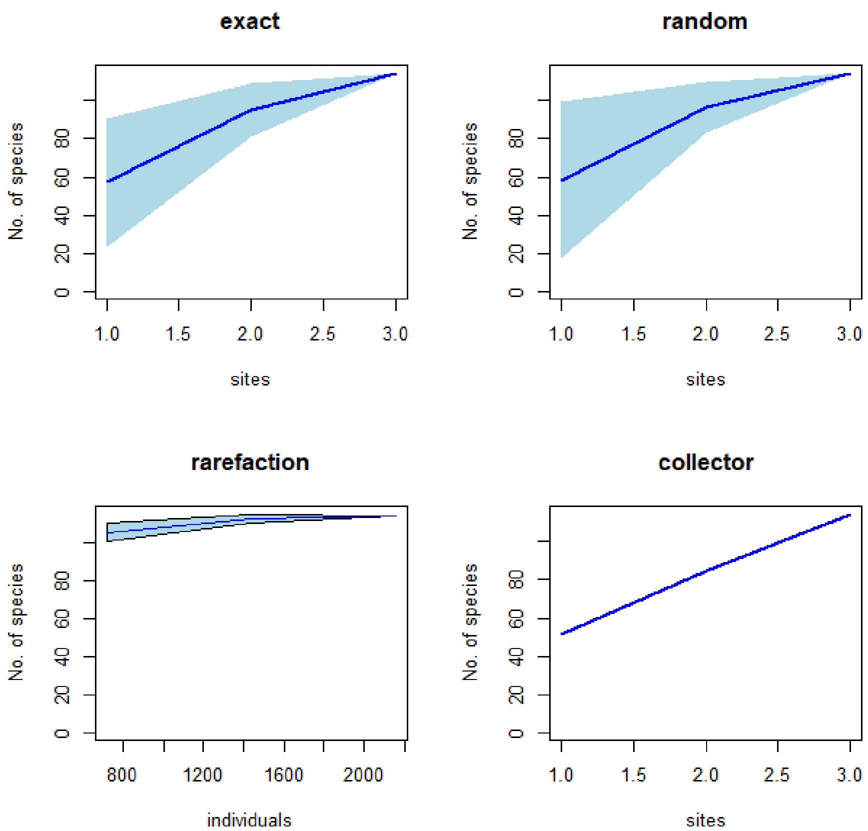


Figure 35. Species accumulation curve of MPZ

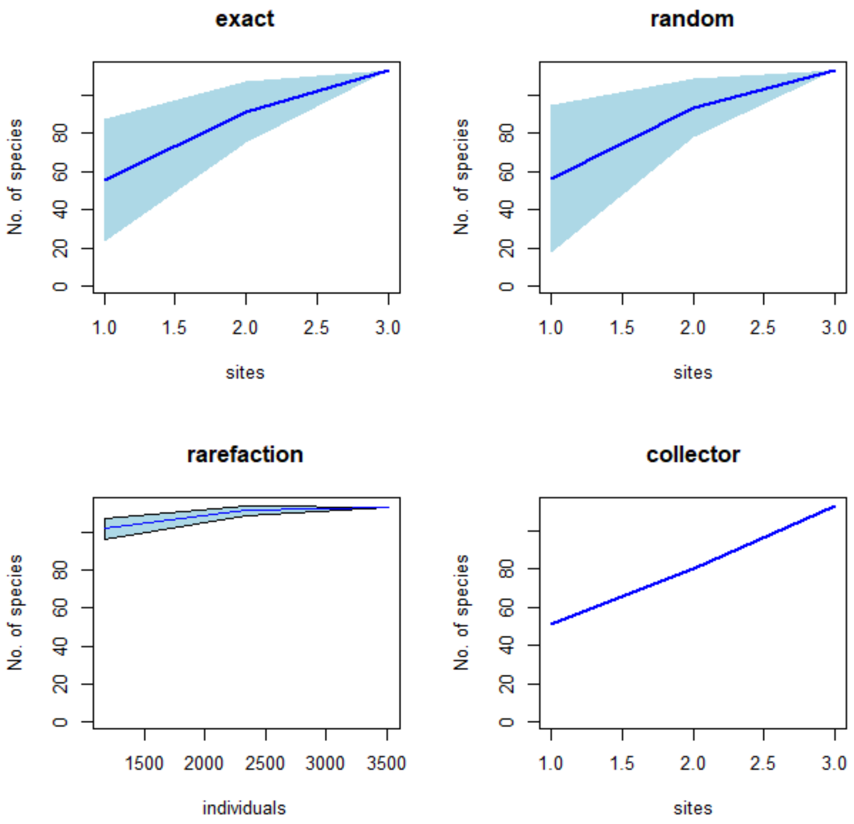


Figure 36. Species accumulation curve of CTR

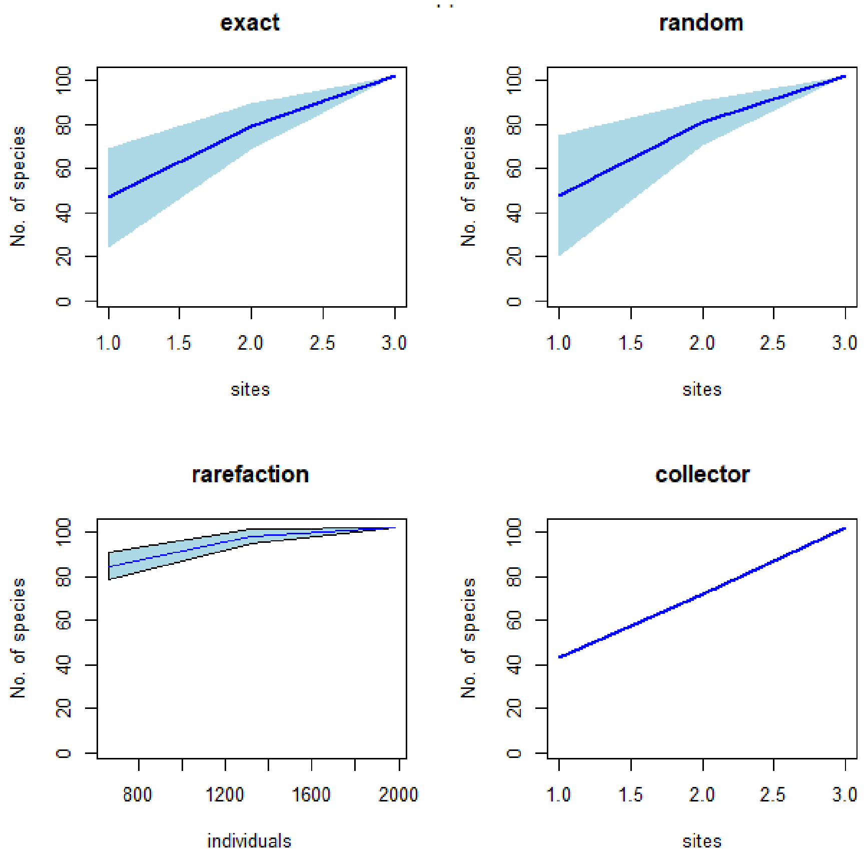


Figure 37. Species accumulation curve of OTP

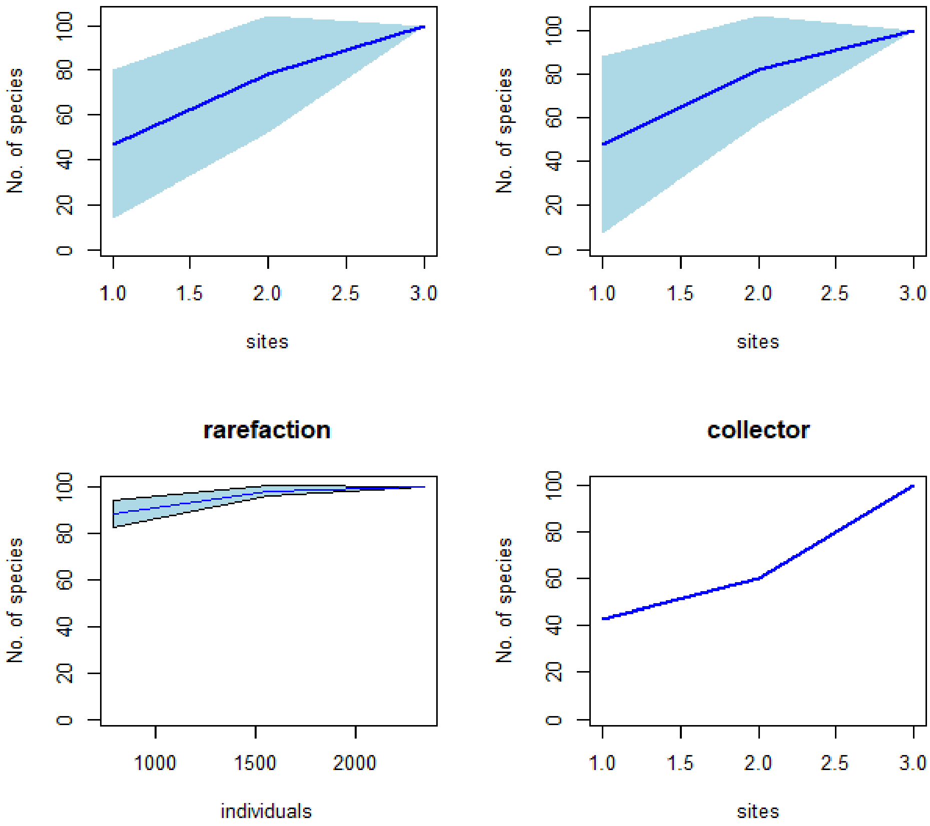


Figure 38. Species accumulation curve of KND

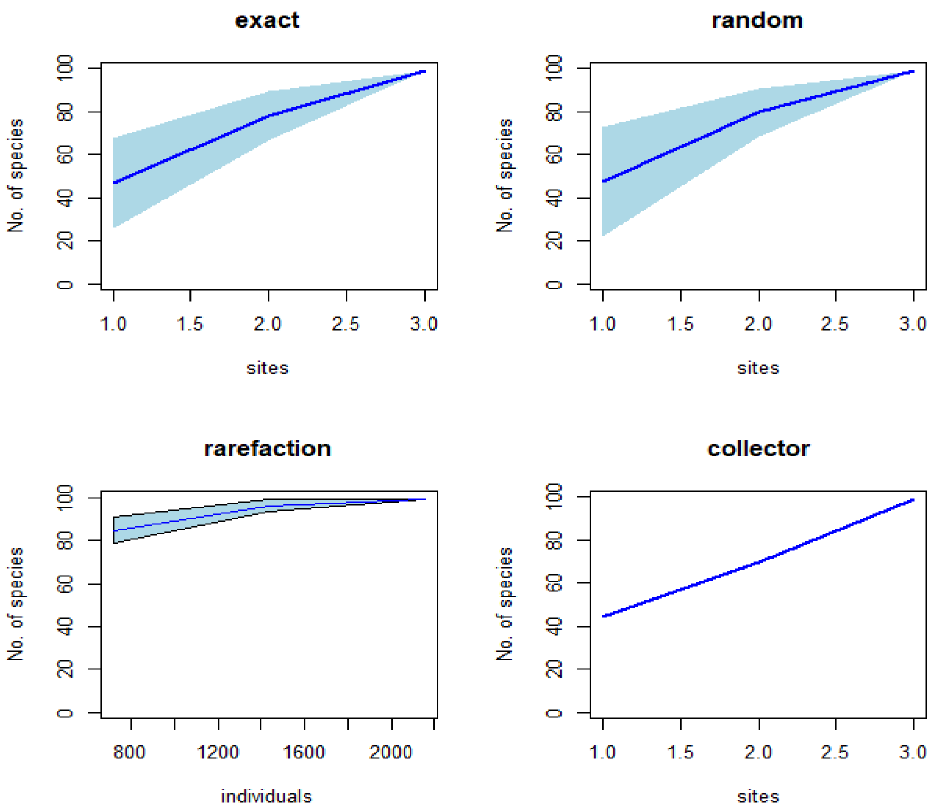


Figure 39. Species accumulation curve of PNI

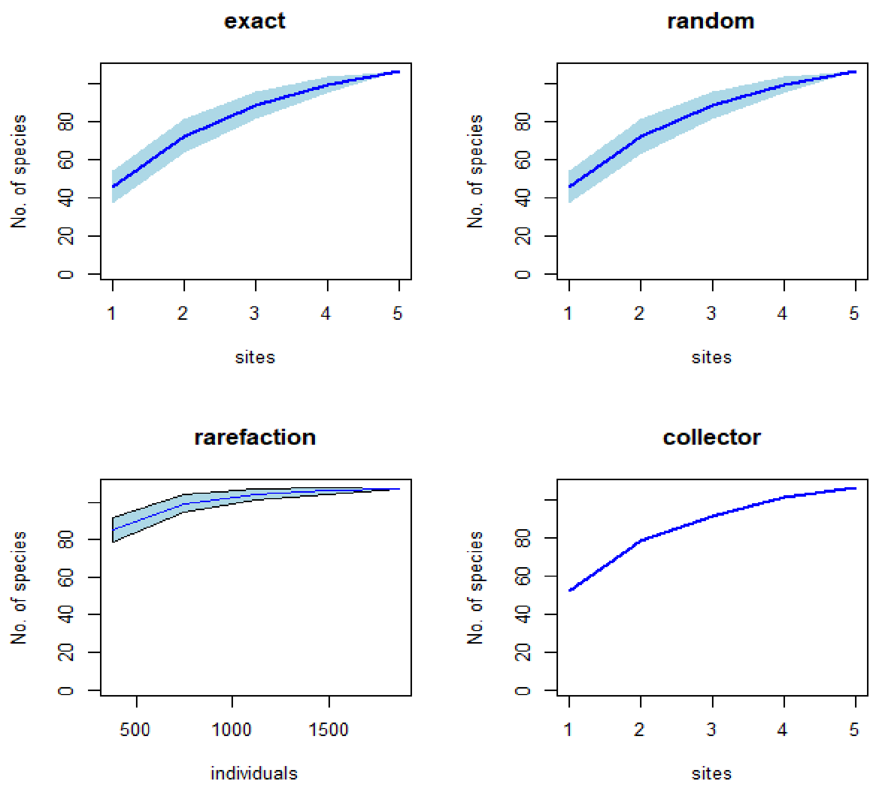


Figure 40. Species accumulation curve of PRM

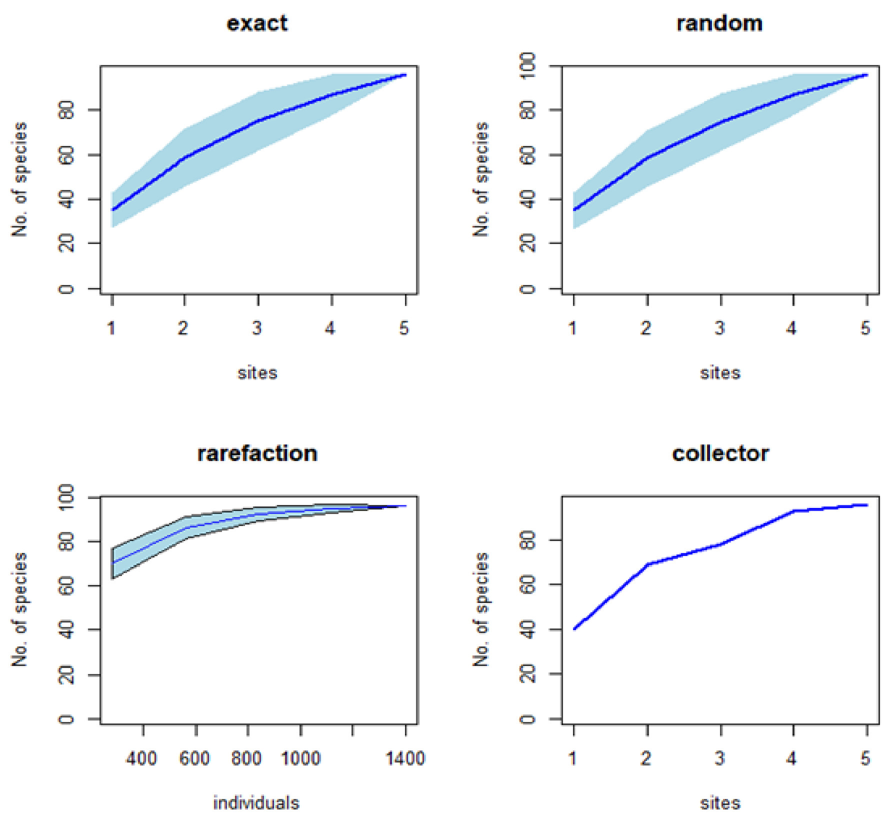


Figure 41. Species accumulation curve of MON

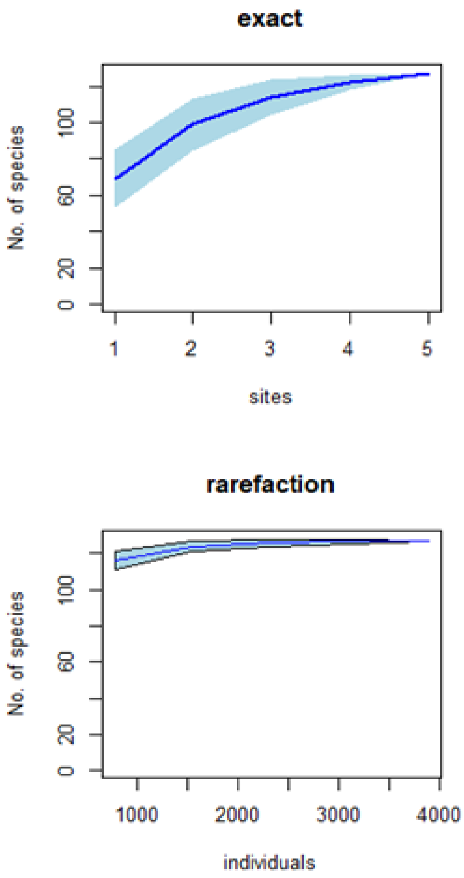


Figure 42. Species accumulation curve of POM

4.5.2. Best fit model and Rank abundance curves

The structure of a multispecies community and its ecological status can be effectively displayed by Rank Abundance Curves (RAC). They depict both the spatial and temporal changes in ecological communities. RAC denotes a ranked vector of species abundance derived from simplex models. They plot the rank of species (X axis) against relative abundance of each species (Y axis). A steep curve represents dominance by a few members. Greater the area under the graph, greater is the number of species in the community. Comparison of shapes and slopes of different samples provide a hint towards species turn over; highly dissimilar curves indicate high rate of turn over. Outliers or bumps occurring in the curve indicates rare species (Clarke, 1990).

Avolio et al. (2019) updated the "codyn" library of R package V.2.0.0, by introducing new functions. They concluded that a not only species turnover in the form of gains or losses, but also re ordering of species contributes to significant changes in the appearance of RAC.

Dozens of models are extensively used to explain the uneven shape of RACs. The following five models were being considered in this study.

- **Null model**: lacks any fitted parameters.
- **Pre – emption model**: has a single parameter, pre-emption coefficient, α denotes the rate of decay of abundance per rank. This model assumes the exploitation of a considerable fraction of resources by a high ranked species followed by one having an immediately lower rank and so on.
- **Log normal model**: assumes that the logarithmic abundances are normally distributed. A log normal model is typically found suitable for a data showing right – skewed distribution; there are many small values and a few large values.
- **Zipf model**: underlies that the abundance of a species in RAC is inversely proportional to the rank. Zipf is mainly useful in describing distributions where a few elements are extremely common while majority of them are relatively rare.
- **Zipf- Mandelbrot model**: explains complex communities where apart from biological interactions, the abundance are also determined by multi fold factors acting sequentially (Magurran, 2003).

Akaic Information Criterion (AIC) and Bayesian Information Criterion (BIC) are measures of goodness of fit of a model. Lower AIC and BIC values are indicative of best fit models (Magurran, 1988, 2007). The values of various models, the best fit model, and the corresponding Rank Abundance curves with respect to habitats are appended (Tables 18 to 22, Figures 43 to 47).

Analyses of the AIC values suggest Zipf – Mandelbrot model as the most suitable one to deal with species rank distributions. Out of the three parameters being considered in the tables, Parameter 1 represents the fitted abundance of the most abundant species (Akaike, 1979). Parameter 2 (also denoted as parameter β) stands for potential niche diversity of the environment (Burnham & Anderson, 2004). Parameter 3 (Parameter γ) indicates the average probability of the appearance of a species.

Three major assumptions are involved in consideration of AIC values; first one considers that the same process underlies in drawing all the datasets (Foster & Sober, 1994). Second one considers size of the sample as large enough in determining the asymptotic properties. Finally, there is an assumption that the data follows a multivariate normal distribution.

Out of the five sites, MPZ had the highest value of parameter 1 (0.3421) and parameter 2, (-1.075). Site KND had a parameter value closer to 1, indicating comparatively even distribution. The lowest AIC and BIC values were recorded from KND.

Table 18. Values of various models - MPZ

	par1	par2	par3	AIC	BIC
Null				755.935	755.935
Preemption	0.035788			876.512	879.248
Lognormal	2.3344	1.1162		544.133	549.605
Zipf	0.11991	-0.80595		591.241	596.713
Mandelbrot	0.34212	-1.0751	2.5747	538.030	546.239

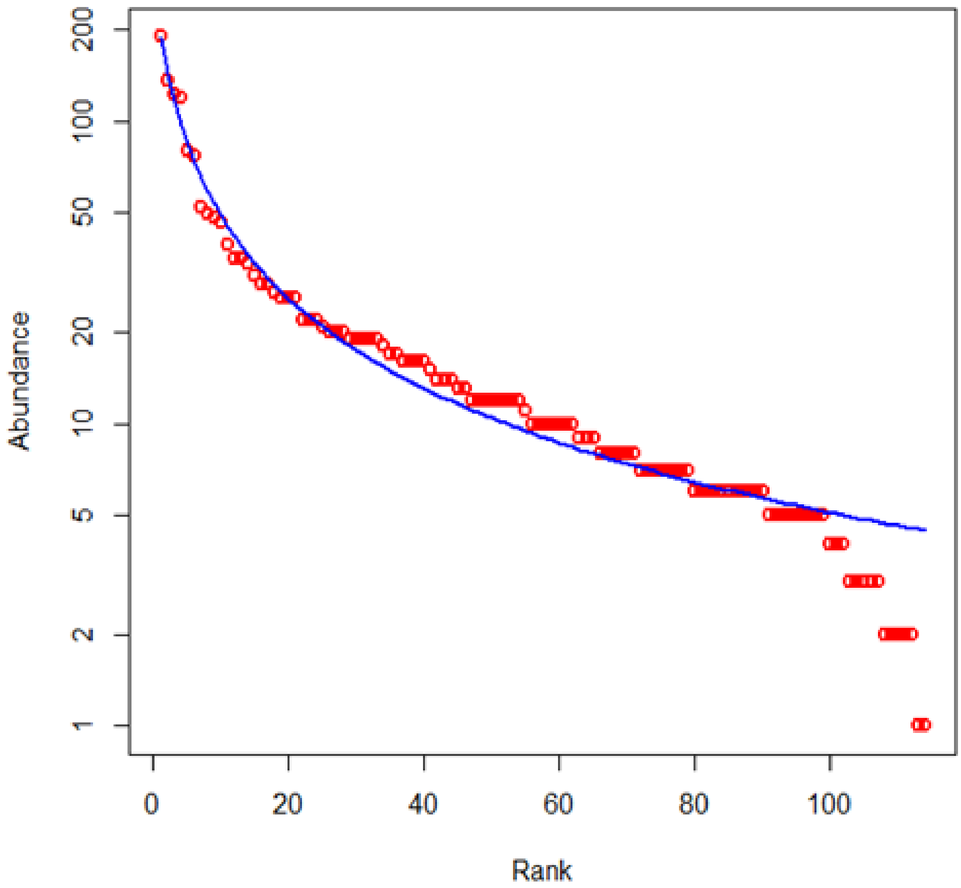


Figure 43. Rank abundance curve of MPZ

Table 19. Values of various models - CTR

	par1	par2	par3	AIC	BIC
Null				767.394	767.394
Preemption	0.037067			882.564	882.583
Lognormal	2.1125	1.1483		549.376	554.813
Zipf	0.12835	-0.83107		549.820	555.257
Mandelbrot	0.26302	-1.0196	1.548	521.970	530.125

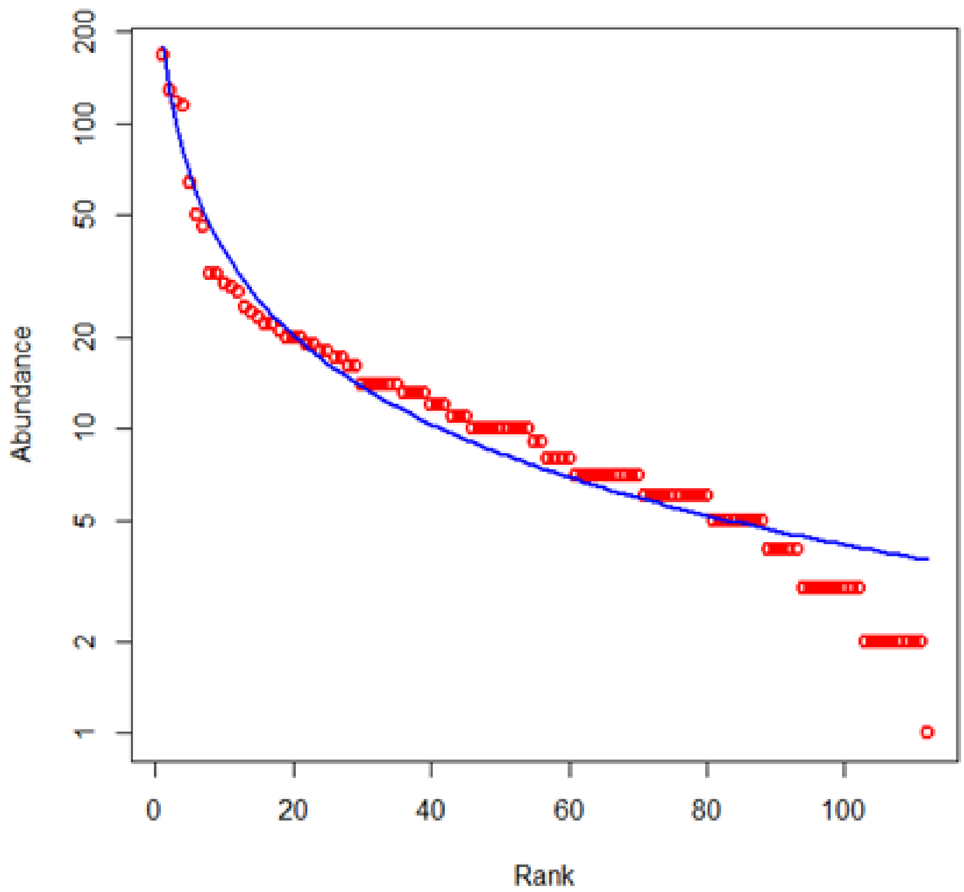


Figure 44. Rank abundance curve of CTR

Table 20. Values of various models - OTP

	par1	par2	par3	AIC	BIC
Null				533.249	533.249
Pre-emption	0.037303			594.929	597.524
Lognormal	1.9485	1.0384		433.561	438.751
Zipf	0.11751	-0.78051		431.551	436.742
Mandelbrot	0.2804	-1.0096	2.0915	410.018	417.804

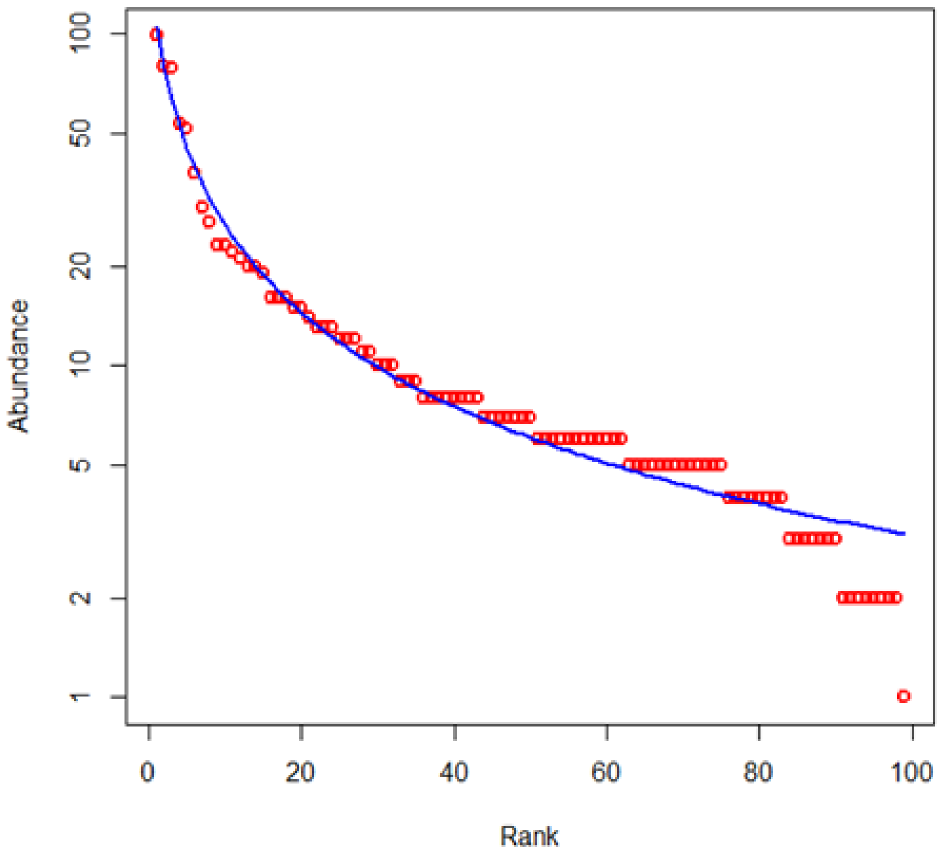


Figure 45. Rank abundance curve of OTP

Table 21. Values of various models - KND

	par1	par2	par3	AIC	BIC
Null				520.281	520.281
Preemption	0.03928			593.178	595.793
Lognormal	1.6764	1.1185		406.318	411.548
Zipf	0.13023	-0.82486		402.154	407.384
Mandelbrot	0.18551	-0.92063	0.69013	400.233	408.078

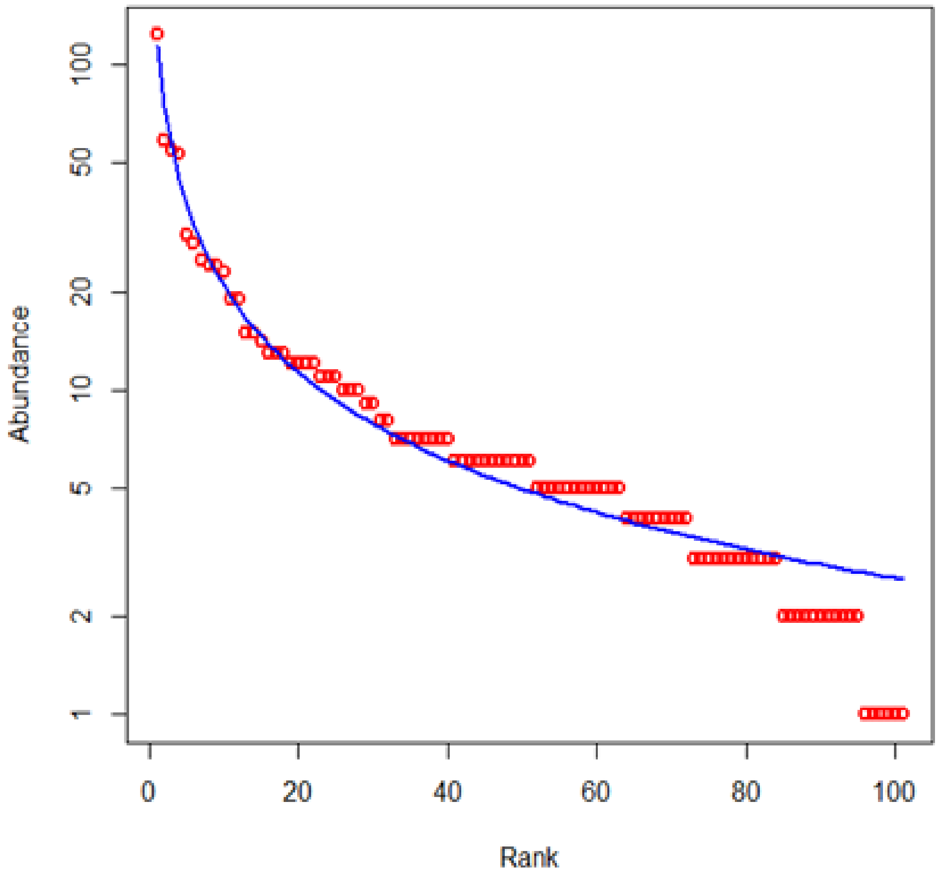


Figure 46. Rank abundance curve of KND

Table 22. Values of various models - PNI

	par1	par2	par3	AIC	BIC
Null				503.551	503.551
Preemption	0.0397			564.848	567.433
Lognormal	1.822	1.0876		399.577	404.747
Zipf	0.12601	-0.80759		404.149	409.319
Mandelbrot	0.2698	-1.0104	1.696	390.778	398.533

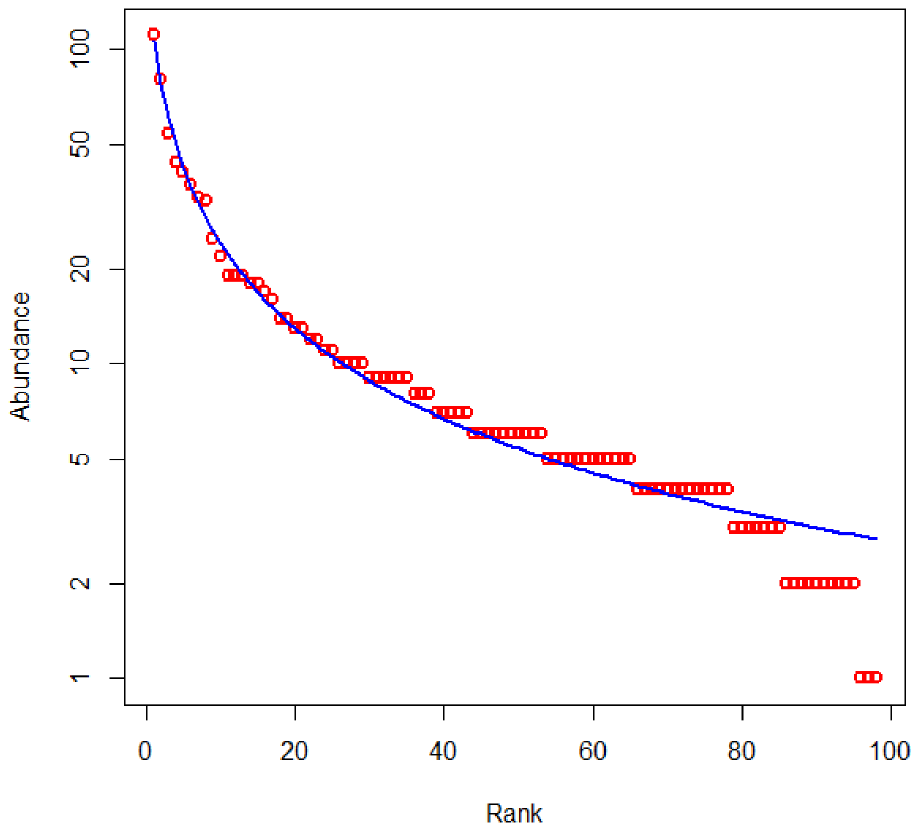


Figure 47. Rank abundance curve of PNI

Analysis of the tables (Tables 23, 24 & 25, Figures 47, 48 & 49) corresponding to best fit model of the seasons, Zipf-Mandelbrot was found to be the best one in all three seasons. PRM had the highest values for parameter 1 (0.301), POM had the highest value of parameter 2 (-0.897). POM itself had the value of parameter 3 closer to 1 (0.936). The lowest AIC value occurred in MON (398.35).

Table 23. Values of various models - PRM

	par1	par2	par3	AIC	BIC
Null				776.359	776.359
Preemption	0.041			878.890	881.563
Lognormal	2.163	1.201		502.948	508.298
Zipf	0.139	-0.861		520.948	526.294
Mandelbrot	0.301	-1.065	1.571	493.116	501.135

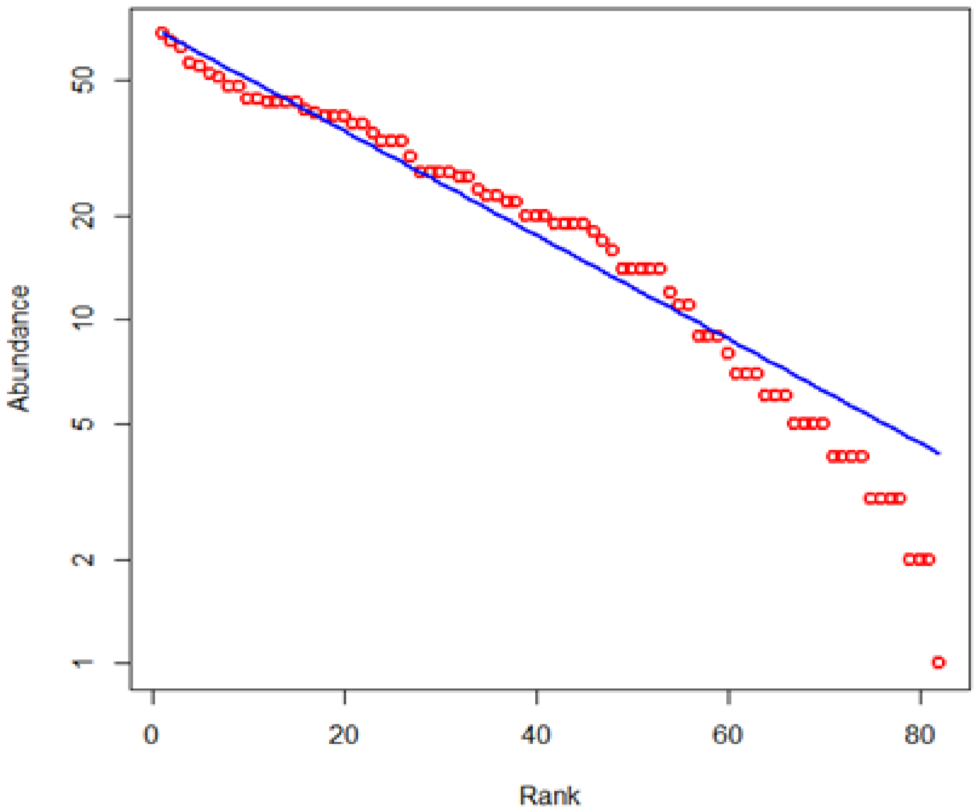


Figure 48. Rank abundance curve of PRM

Table 24. Values of various models - MON

	par1	par2	par3	AIC	BIC
Null				792.669	792.669
Preemption	00.050			843.878	846.442
Lognormal	1.8306	1.33		440.393	445.522
Zipf	0.175	-0.951		401.130	406.259
Mandelbrot	0.236	-1.035	0.455	398.351	406.044

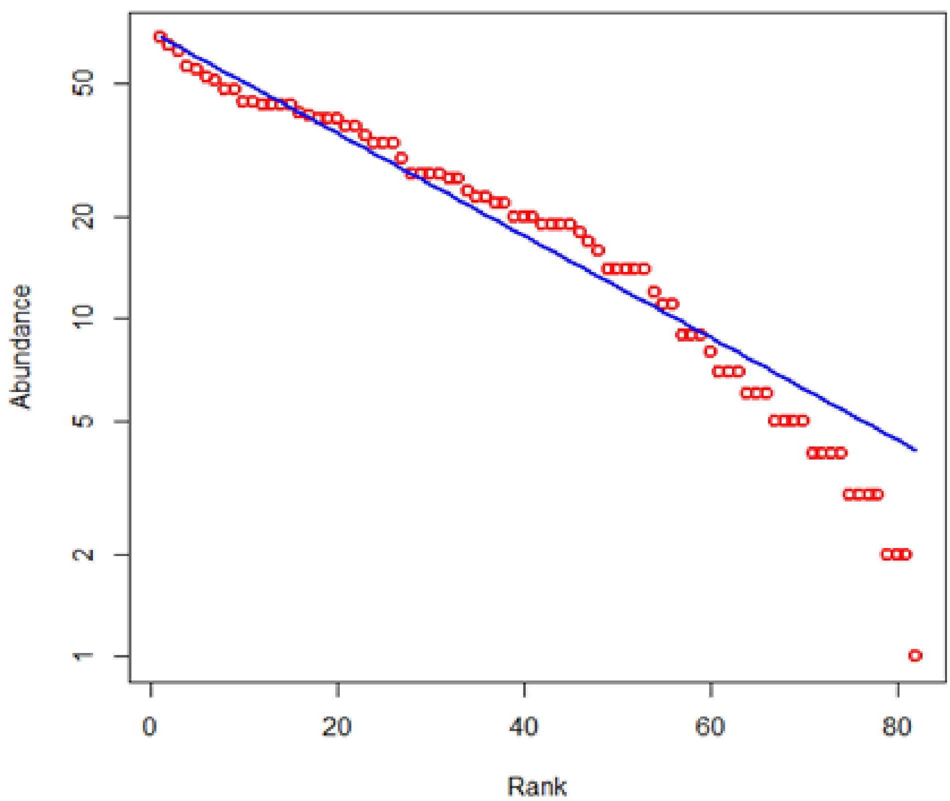


Figure 49. Rank abundance curve of MON

Table 25. Values of various models - POM

	par1	par2	par3	AIC	BIC
Null				1130.13	1130.13
Preemption	0.030			1473.77	1476.62
Lognormal	2.839	1.091		726.23	731.92
Zipf	0.111	-0.789		737.15	742.84
Mandelbrot	0.169	-0.897	0.936	714.23	722.77

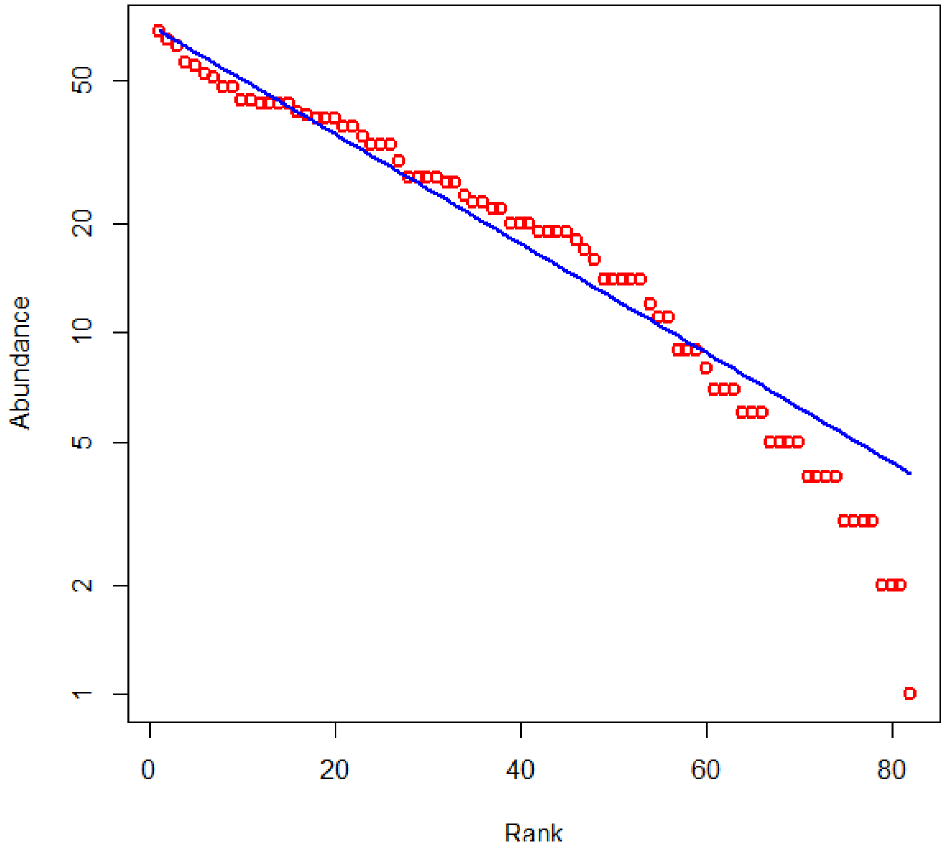


Figure 50. Rank abundance curve of POM

4.5.3. Rarefaction Curves

Rarefaction curves plot number of species as a function of number of specimens being sampled. They function as easy tools for estimating species richness together with comparison of diversity among different sites under consideration.

Over all richness, degree of completion of the sampling effort, and degree of heterogeneity in the samples etc. are the major information that could be elucidated from the analysis of rarefaction curves. Rarefaction curves can be effectively used to assess the adequacy of sampling by comparing S_{obs} to richness estimators like Chao2 or by systematic extrapolation of the curve (Colwell & Coddington, 1994).

Suddenly rising steep slope denotes the probability of many more species to be met with. A curve with shallow slope, on the contrary indicates a comparatively satisfactory situation and that the sample is saturated.

Crist & Veech (2006) adopted additive partitioning approach and demonstrated that observed partitions of species richness corresponds to sample-based rarefaction curves, while the expected partitions resulting from randomization tests approximately tallies with individual – based rarefaction curves. A homogenous community is represented as a flat or wavy curve while a highly irregular curve stands for a relatively heterogenous community. A quickly flattening curve points out inadequate sampling.

In this study, a composite rarefaction curve representing rarefied abundance of all five sites across three seasons was drawn as a single plot (Figure 51). Careful examination of individual curves could give valuable information regarding the dominance structure, attainment of asymptote and adequacy of sampling effort etc. The curve vividly displays that the one corresponding to the post monsoon season of MPZ has got the maximum richness. Suddenly increasing slope of the curve indicates the probability of recording a higher richness with augmented sampling efforts.

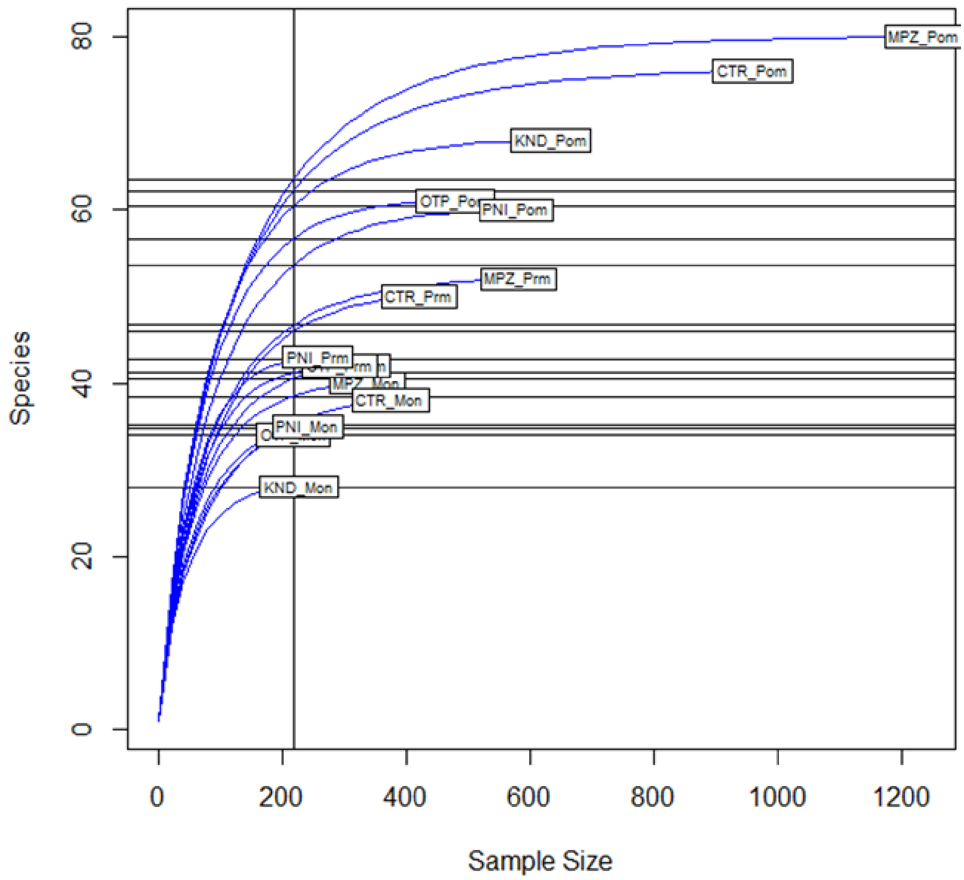


Figure 51. Rarefaction curves – pooled data

4.6. Guild structure analysis

In terms of ecology, a guild comprises a group of organisms assigned with similar ecological niche; resorting to similar functional roles. It is obvious that members of a guild try to exploit similar resources by adopting similar methods; thereby highlighting the increased chances of competition among them. Various parameters are being considered for guild classification; foraging behaviour, reproductive strategies etc., are the prominent ones. Foraging or feeding guilds are of paramount importance in spider taxonomy, as it explains a lot about the web making, prey capture and some more specialised features among spider groups.

The concept of guild dates to Balogh & Loksa (1948), who divided spiders into three groups (Syntrophia); web spinners, cursorial forms and saltatory forms. Later, Young & Edwards (1990) proposed five functional guilds of spiders, primarily based on prey capture mechanisms. Wandering – active, web- orb, web- sheet, web- matrix and wandering – ambush were the categories put forward by them. Uetz et al, (1999) made one of the noteworthy classifications of spider guilds. Major hunting strategies, predation habits and the mode of microhabitat utilisation formed the backbone of his classification. Eight guilds proposed by him were; ambushers, foliage runners, ground runners, orb- weavers, sheet – web builders, space web builders, stalkers and wandering sheet web builders.

Based on the dominant foraging behaviour, the spiders collected from five sampling sites were categorized to eight guilds (Cardoso et al., 2011); Ambush hunters, Ground hunters, Orb web weavers, Sensing web weavers, Sheet web weavers, Space web builders, Specialists, and Other hunters.

1. Ambush hunters: These group of spiders depend on stealth and camouflage to capture their prey. They wait for their prey to reach within an ensured ‘capture distance’. Members of the family Thomisidae constitute most remarkable examples for this guild. Many of them are endowed with a highly matching shade of colours of the flowers, thereby minimizing the chances of being detected by both the predators and prey species. This study recorded 366 individuals of this guild.
2. Ground hunters: Members of this group predominantly capture the prey moving on the ground. They prefer direct hunting strategy than constructing webs and waiting for the prey to get entangled in it. They are usually dull coloured, highly agile, and fast moving. They are distributed in a variety of

habitats including forest floor, river banks and deserts. Major contributing families of this guild are; Corinnidae, Gnaphosidae, Lycosidae, and Oonopidae. An aggregate of 535 individuals of this guild was recorded in this study. Family wise split up is as follows; Corinnidae (62), Gnaphosidae (24), Lycosidae (431) and Oonopidae (11). Spiders of this guild prove to be highly helpful in regulating soil borne pests.

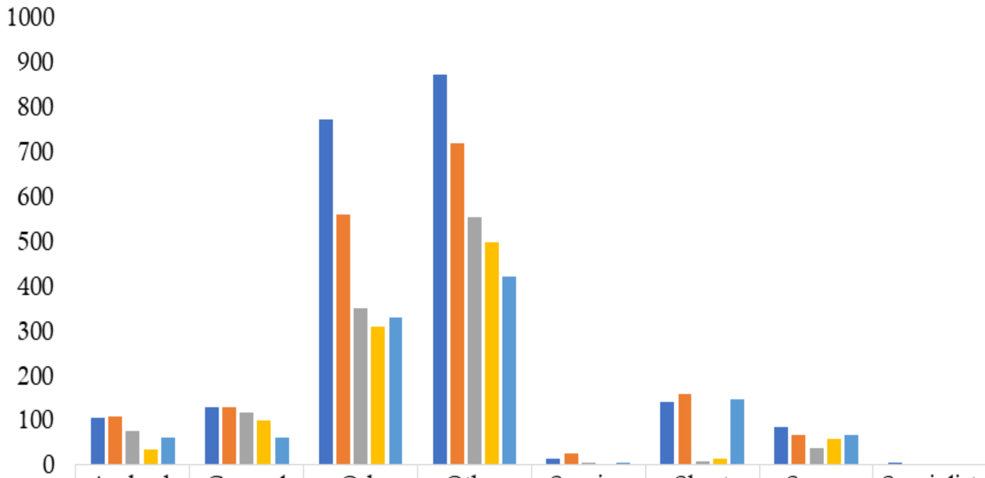
3. Orb – web weavers: They construct webs of perfect geometry, starting from a central focus, they construct radial spokes that act as the main supporting structure of the web. The centripetal spiral threads connecting the spokes are made of special sticky silk and are mainly helpful in trapping the prey. The spiders release non- sticky threads to move around the web. The size of the orb webs varies with family, genera and with age. Some members of the family Araneidae add an additional 'X' shaped structure called stabilimentum to their webs, thereby adding on to the complexity of web making. Total individuals recorded from this guild was 2361. Family wise contribution included Araneidae (1654), Tetragnathidae (652), Uloboridae (19) and Nephilidae (36).
4. Sensing web weavers: They utilise specially designed sense threads found on their web fir prey capture. This guild provided only negligible percentage of individuals recorded in this study. Family Hersiliidae– 48 members of a single species. Family Theraphosidae, the only mygalomorph family in this study had 2 members; two genus and two species each, contributing the unique species of this study.
5. Sheet web weavers: Comprise a total of 471 members distributed among five families; Amaurobiidae (4), Eresidae (16), Linyphiidae (25), Pisauridae and

Hahniidae. Here, the major share of this guild is being contributed by family Pisauridae, with 425 individuals of 2 species. Family Hahniidae deserves special mention as it contributed to a unique species reported only once from OTP.

6. Space web builders: A highly irregular, imperfect space webs are being employed for prey capture. 305 members coming under 2 families, Theridiidae (187) and Pholcidae (118).
7. Other hunters: Members included in this group are either commonly noticed on the leaf blades, where they can be seen moving around with agility and even quickly disappearing to the lower side of the leaves or leaf axils. The term 'foliage runners 'is sometimes used to specify this group. Still others are 'stalkers, found actively moving and searching for their prey, depend on visual or vibrational cues to find and hunt their prey. Jumping spiders tend to have better vision than their sedentary web- building counterparts. A highly abundant guild comprising 3065 individuals. Family wise distribution is; Cheiracanthiidae (117), Clubionidae (47), Ctenidae (7), Oxyopidae (981), Philodromidae (47), Salticidae (1670), Scytodidae (87) and Sparassidae (109).
8. Specialist hunters: Unlike the seven guilds mentioned earlier, this one is rather a loose cluster of species, characteristically specializing in one or very limited number of preys; thereby keeping themselves away from competition with larger groups. This category comprised only five individuals of *Mimetus* sp.1, family Mimetidae.

Detailed analysis of family – wise distribution of spiders revealed that six out of the eight foraging guilds were represented in all the five habitats under study;

i.e., sheet web, space web, orb web, other hunters, ground hunters and ambushers (Figure 52).



	Ambush hunters	Ground hunters	Orb weavers	Other hunters	Sensing web	Sheet web	Space web	Specialists
MPZ	106	128	773	873	15	142	86	5
CTR	108	128	560	720	25	158	67	0
KND	75	117	350	553	6	9	38	0
OTP	35	100	308	498	0	14	59	0
PNI	62	62	329	422	4	148	68	0

Figure 52. Guild wise distribution of abundance

4.6.1. Guild composition and abundance

Considering the site wise distribution of guild categories, in MPZ maximum number of individuals were included in the other hunters (873 individuals), that contributed to 41% of the collection from that site. Orb web weavers comprising 773 individuals (36%) were the immediate successors. Sheet web weavers (142;7%), Ground hunters (128;6%), Ambush hunters (106;5%), Space web (86;4%), Sensing web (15;1%) and Specialists (5;0.23%) were also represented in highly varying numbers (Figure 53).

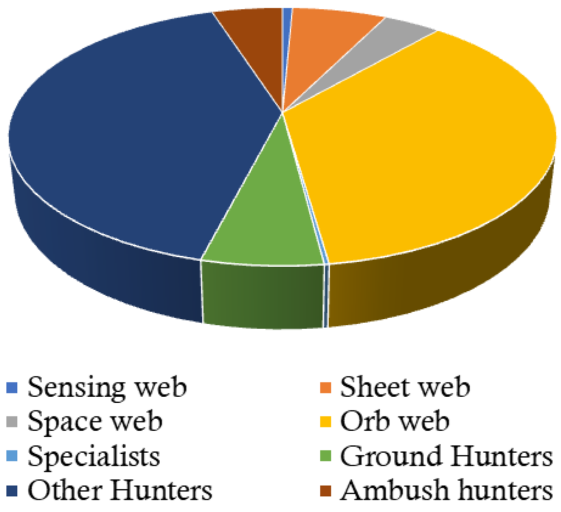


Figure 53. Guild structure in MPZ

In CTR, Other hunters with 720 individuals (41%) were the dominant guild followed by Orb weavers (560;32%), Sheet web (158;9%), Ground hunters (128;7%), Ambush hunters (108;6%), Space web builders (67;4%), and Sensing web (25;1%). There are no representatives from the guild ‘Specialists’ recorded from this site (Figure 54).

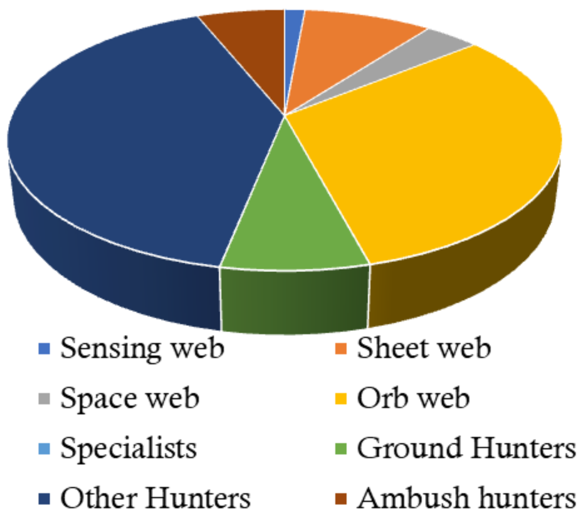


Figure 54. Guild structure in CTR

Site KND (Figure 55) had maximum representatives from Other hunters (553; 48 %), followed by Orb weavers (350; 30%). Other guilds were represented in comparatively negligible numbers; Ground hunters (117; 10%), Ambush hunters (75; 7%), Space web (38; 3%), Sheet web (9; 1%), and Sensing web (6; 0.52%).

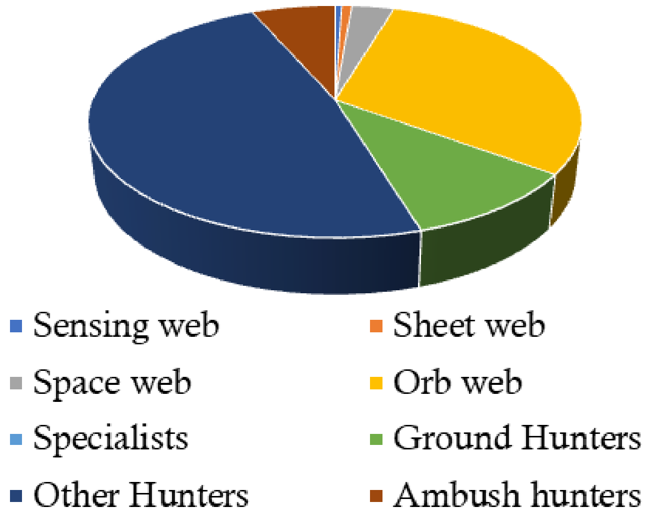


Figure 55. Guild structure in KND

Coming to OTP (Figure 56), Other hunters (498; 49%), and Orb weavers (308; 30%) were the truly dominating guilds. Very meagre representation of Ground hunters (100; 10%), Space web (59;6%), Ambush hunters (35; 3%), and Sheet web (14;1%) was noticed. No representatives of guilds Sensing web and Specialists were recorded from the site.

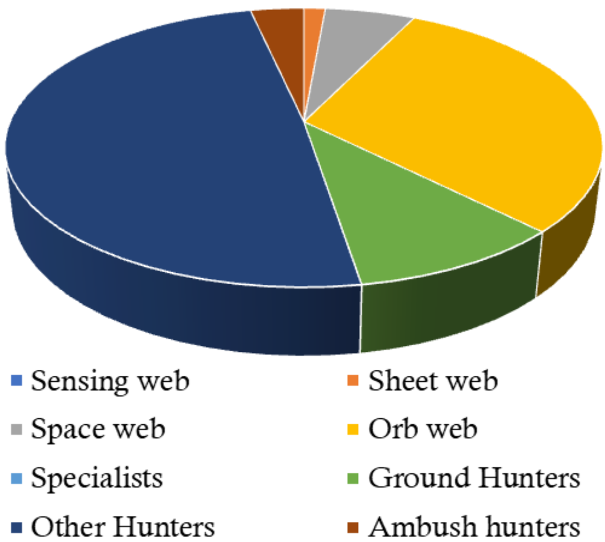


Figure 56. Guild structure in OTP

The guild wise distribution of site PNI (Figure 57) is as follows; as in the previous cases, Other hunters (422; 39%) and Orb web (329; 30%) claimed the lion's share of individuals. Remaining guilds were represented in very lower values; Sheet web (148; 14%), Space web (68; 6 %), Ambush hunters (62; 6%), Ground hunters (62; 6%) and Sensing web (4; 0.36%). Specialists were not recorded from this site.

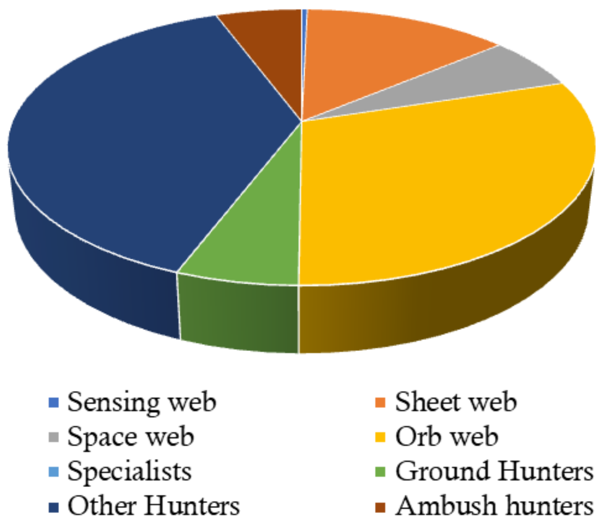


Figure 57. Guild structure in PNI

4.6.2. Percentage abundance of guilds (overall data)

Percentage-wise distribution of abundance in various guilds also indicates the dominance of other hunters and orb weavers. Other hunters occupied 45% of the total abundance while 35% was the share of Orb weavers. Other guilds were trailing far behind; Ground hunters (8%), Sheet web (7%), Ambushers (5%), Space web (4%), Sensing web (1%) and Specialists were represented for name's sake; their overall share was less than 1% (Figure 58).

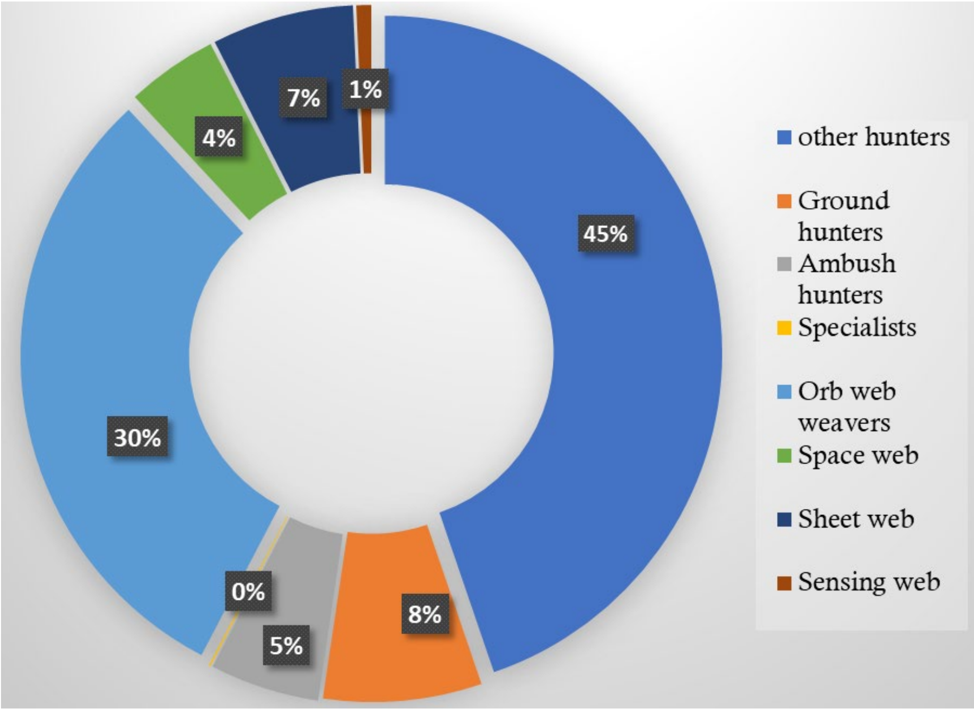


Figure 58. Percentage wise abundance of guilds

4.6.3. Guild composition and richness

Guild composition based on species richness varied widely. Other hunters reported maximum species richness value, contributing a total of 39%. Family Salticidae alone provided up to 20% of the above. On the second place, Orb weavers were having a species richness value 39, with a considerable 20% contribution by family Araneidae alone. Details of remaining guilds are; Space web (9%), Ground hunters (9%), Ambush hunters (5%), Sheet web (5%) and Sensing web (2%). The 'Specialists' guild had a richness percentage value less than one (Figure 59).

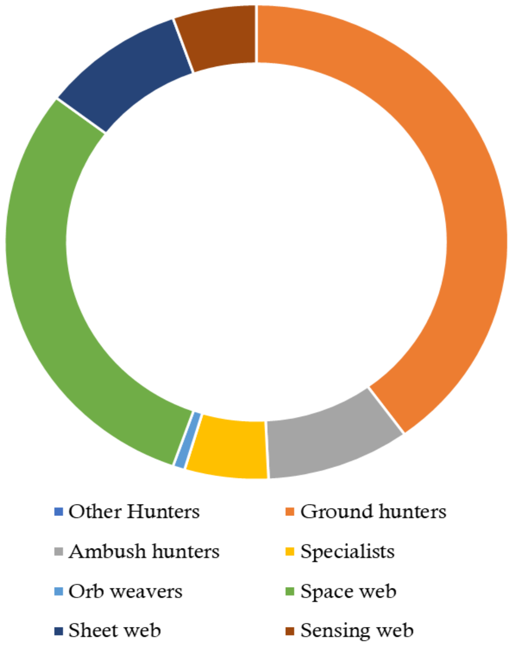


Figure 59. Percentage wise richness of guilds

Considering habitat-wise richness, in MPZ, a total of 114 species were recorded which amounts to 85.7% of the total species richness recorded during the study. Out of the eight guilds, Other hunters were represented in maximum (47 species), followed by Orb weavers (32 species). Other guilds were represented in lower values of less than 10 and the least represented was the Specialist hunters, with only one species (Figure 59).

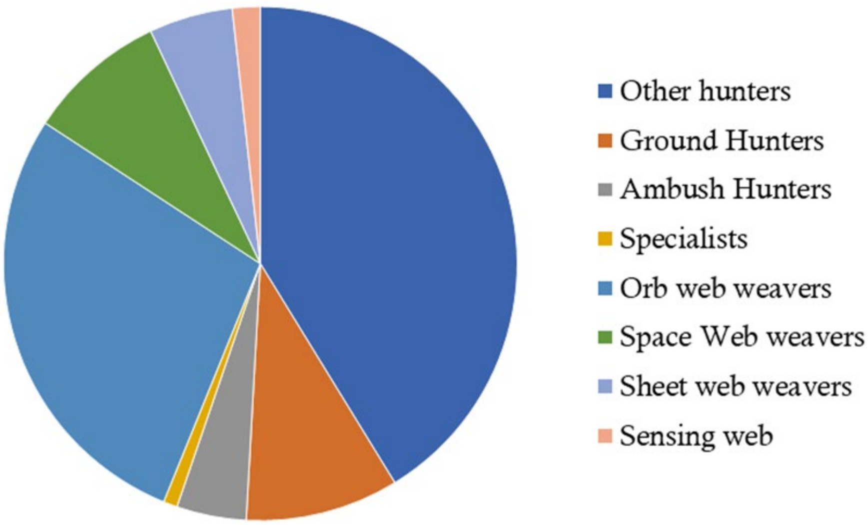


Figure 60. Species richness in MPZ

In CTR, 112 species were reported that reaches 84.2% of the total richness of the study. Here also, Other hunters and Orb weavers dominated the guilds; 42 species and 34 species respectively. Remaining guilds were represented in much lower values (Figure 61). Specialist hunters were not reported from this habitat.

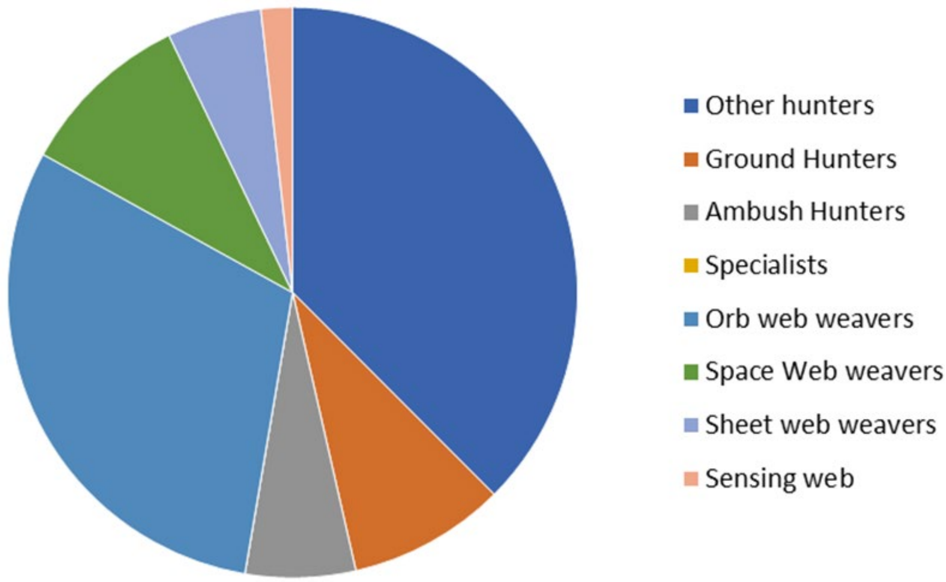


Figure 61. Species richness in CTR

Site OTP reported 99 species, 74.4% of the total species richness. Other hunters (43 species), Orb weavers (26 species), remaining guilds represented in far below numbers. No Specialists reported from this site (Figure 62).

In KND, a total of 101 species were recorded; 75.9% of the total richness. Orb weavers (30 species), Other hunters (41 species), other guilds were having only negligible representation. No Specialist hunters and Sensing web weavers were reported from this site (Figure 63).

In PNI, only 98 species were reported that amounts to 73.7 % of the total richness. As in other cases, Other hunters and Orb weavers were the dominant guilds, represented by 39 and 29 species respectively. Remaining guilds were represented in much lower numbers. No Specialist hunters and Sensing web weavers were reported from this site also (Figure 64).

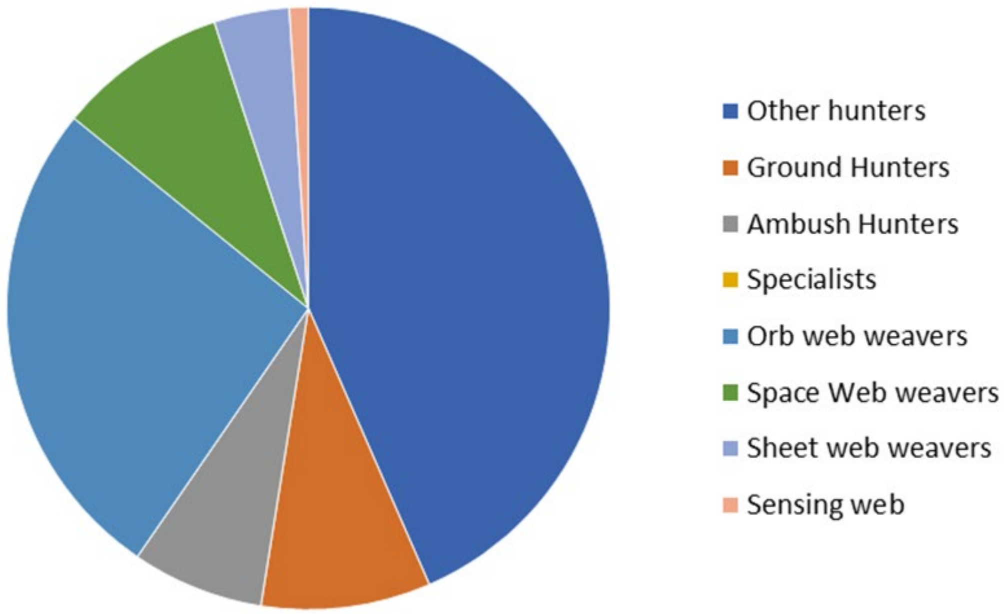


Figure 62. Species richness in OTP

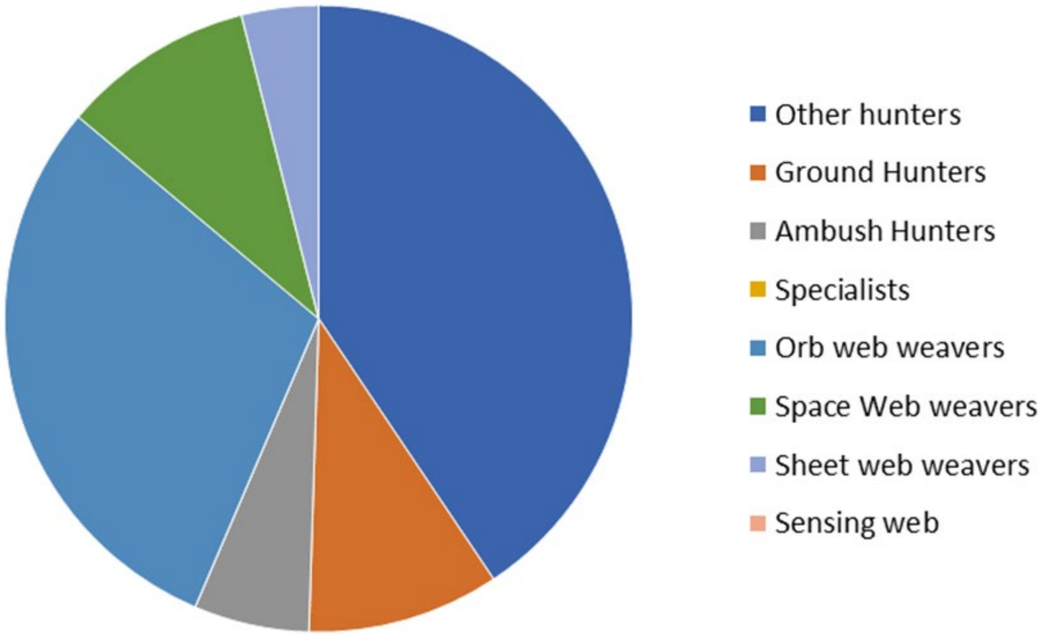


Figure 63. Species richness in KND

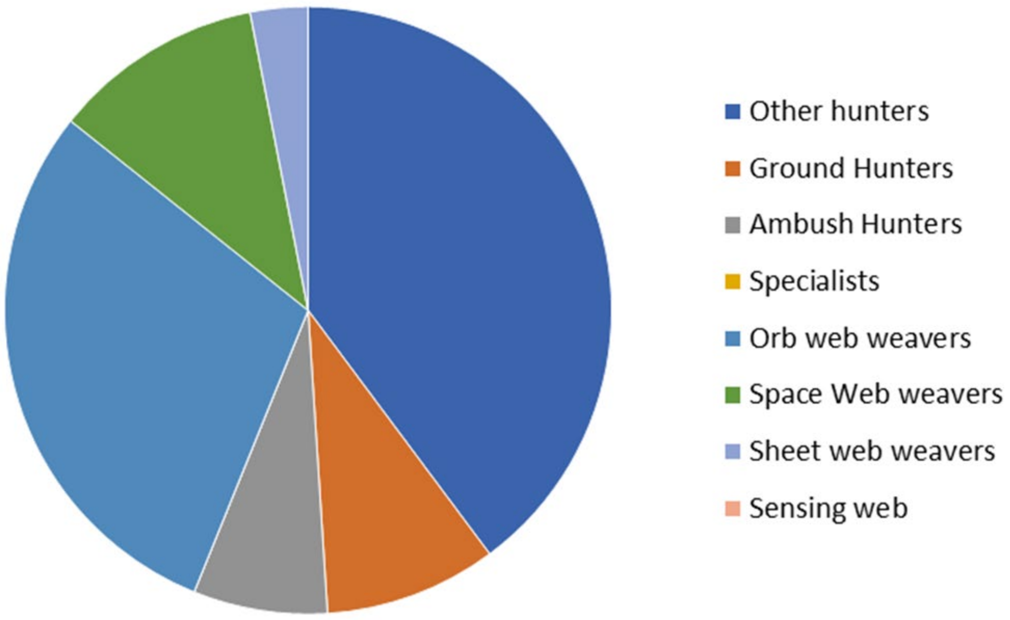
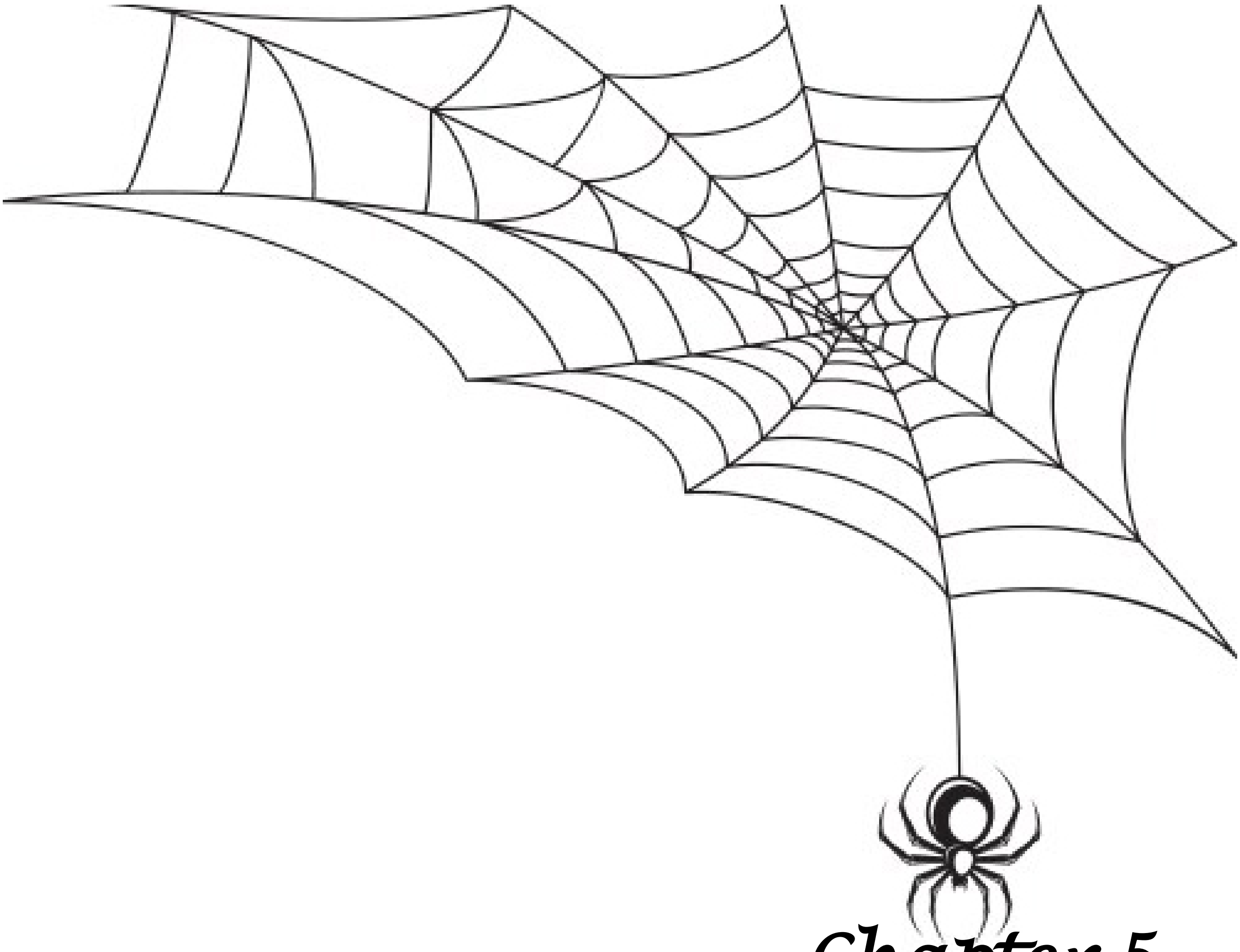


Figure 64. Species richness in PNI



Chapter 5. Discussion

DISCUSSION

Health and survival of a habitat is controlled by highly complex interactions of a variety of biotic and abiotic factors. Harmonious relationship among these factors along with conducive climatic and topographic factors decides the extent of biodiversity in a particular habitat. A balanced biotic world is predominantly maintained by ecological interactions. Predation emerges as the most helpful interaction in biological world, especially when dealt with prey of unparalleled fecundity rates. The ecological services rendered by smaller predators like insects and spiders are of paramount significance in any ecosystem.

Non – specific, predatory nature of spiders adds on to the well-being of habitats. Population of insect pests and vectors are being maintained below the damaging threshold by active interference of spiders. A lot of studies affirming the population dynamics of spiders are already available from various parts of the world; especially documenting the diversity, richness, equitability and seasonal variations in agro ecosystems. Recruiting spiders as biological control agents and integrating the services provided by spiders in harmony with other modes of pest control were some of the most recently discussed topics in this regard. Vivid information on the extent of diversity, distribution patterns and foraging behaviour of spiders is one among the compulsory prerequisites for successful implementation of integrated pest management (IPM). Agro ecosystems, hence farmers, owe a lot to the predation of spiders on pests. Present study focused on the diversity and seasonal fluctuations of spider populations in riparian habitats. One of the most important rivers of Kerala, Bharatapuzha was selected as the contributor of riparian habitats. The river with its extreme annual fluctuations in water content, basin coverage, associated vegetation, etc. proved to be potent enough to support a variety of microhabitats, where each one may have suitable niche for divergent forms of insects and spiders. Such a niche demarcated and microhabitat – wise allocation plays an important role in stabilizing ecosystems, by ensuring optimum resources' utilization and prevention of competition among members of related taxa.

5.1. Spider inventory

Study of spiders attained a sudden global recognition mainly from the revelation of their potential as biocontrol agents. According to Nyffeler & Birkhofer (2017), more than 400 million metric tons of preys per year are being consumed by spiders. Most note- worthy aspect is that majority of these preys are insect pests of agricultural or forest ecosystems. But it remains ironical that the various modern agricultural practices involving large inputs of agrochemicals pose the major threat for global spider population. Together with climate change, habitat degradation and pollution, the agricultural practices also contribute to a drastic reduction in spider populations (Branco & Cardosso, 2020).

The survey extending for a period of two years yielded 133 species of spiders belonging to 90 genera and 27 families. The study area spread over five randomly selected sites along the banks of Bharatapuzha, distributed in Palakkad and Malappuram districts of Kerala was found to be rich in spider fauna. The result does not comply with those of Kashmeera et al. (2020), where the riparian habitats were found to have poorer species richness.

Very few studies on riparian spiders were carried out from India. Sharma et al. (2010) could report 44 species of spiders assigned to 12 families from Barwani region of river Narmada. 112 species of spiders belonging to 21 families were reported by Jose et al. (2018) from Kavvayi river basin, Kannur, Kerala. Rajeevan et al. (2019) documented 28 species of spiders belonging to eight families, from riparian habitats connected to river Kabani, in Wayanad region of Western Ghats. Caleb (2020a) described 70 species of spiders included in 58 genera and 21 families from the riparian habitats of Araabath Lake, Chennai.

Capon et al. (2013) made interesting revelation regarding the significance of riparian ecosystems. According to him, they have the potential to play a deterministic role with respect to vulnerability of natural and anthropogenic systems to climate change. Griotti et al. (2017) assessed the relationship between vegetation structure and spider diversity in riparian habitats of Grande and Quinto river basins of Argentina.

In this study, Salticidae emerged as the most abundant family (24 genera and 27 species) followed by Araneidae (14 genera and 26 species). On a global basis, Salticidae itself is the most species rich family (6617 species), while Araneidae is the third dominant family (3040 species), preceded by Linyphiidae (4841 species) (WSC, 2024). In India also, Salticidae constitute the most species rich family; 309 species, followed by Araneidae (136 species). Abundance with respect to the families also tallies with the revised checklist of spiders of Kerala (Singh, 2023). He reported a total of 28 families, 116 genera and 218 species from Palakkad district, Kerala.The present study could report only single species representatives from the following families; Hersiliidae, Eresidae, Oonopidae, Amaurobiidae, Mimetidae, Nephilidae and Hahniidae. The study also tallies with that of Raiz et al.(2018) , describing spider diversity associated with Tungabhadra irrigation canal at Bellary, Karnataka. Salticidae and araneidae were the dominant families. A similar degree of consensus was also found with the results of Malhotra et al. (2019), studying the spider fauna of four different habitats of northern Rajasthan. Density of spiders was found to be highest (94.62% individuals per square metre) in riparian lands.

Salticidae is one of the extensively distributed families. This may be correlated with their highly adaptable nature, exemplary prey capturing skills and enhanced history of evolutionary diversification equipping them to invade varying climatic and topographic zones. On the other hand, the state-of-the-art orb webs of Araneids ensure that the suitable prey is not spared at any cost. Among Salticids, *Hyllus semicupreus* was represented in all samples and in all seasons. A total of 639 members were noticed during this study, comprising 8.9% of the total abundance. Similarly from Araneidae, *Anepsion maritatum* was recorded in all sites and seasons. 449 members of this species were reported, constituting 6.27% of the total abundance value. Other species reported in all seasons and sites in considerably higher numbers were *Oxyopes javanus* (420; 5.87 %), and *Tetragnatha javana* (303; 4.23%). Eventhough 348 members of *Dendrolycosa gitae* were recorded in this study, it was not reported from two sites; OTP and KND.

5.2. Population attributes of spiders

The study could record a considerable number of spiders distributed in eight diverse foraging guilds and still diverse families. Total abundance and site-wise and season wise split up of abundance were recorded. In a similar pattern, richness was also assessed. As evenness has a significant role in species distribution and species interactions, the equitability were also calculated for each site and seasons. Analysis of the equitability pointed out a moderately uneven distribution of the spiders. In totality, it was found out that the distribution pattern of spiders differed from each other, both site wise and season wise.

5.2.1. Habitat-wise abundance

Abundance from habitats demonstrated high degree of variability. With a total abundance of 7151 individuals, MPZ contributed 2156 individuals (30.15%). Percentage -wise contribution of other sites were; CTR – 24.55%, KND – 16.40%, PNI – 15.04% and OTP – 13.84%. Mean abundance ranged from 102.67 ± 26.54 (MPZ) to 78.20 ± 14.79 (OTP).

5.2.2. Habitat-wise richness

The total richness recorded was 133 species. Out of these, two were from Mygalomorphae and the remaining 131 were Araneomorphs. In contrary to the expectations, the sites could have a lesser contribution towards the abundance and richness. This is clearly indicated from the fact that the difference in richness between the site with maximum richness; MPZ (114) and that with minimum richness; PNI (98) is only 16 species. Furthermore, MPZ and CTR differed only by two species. Similarly, OTP and PNI had a difference of only one species.

Considering the extent up to which each habitat represented the total recorded richness, MPZ had the highest coverage of 89.76%, CTR followed closely with a richness of 88.18%. The remaining three sites had access to much lower richness; OTP – 79.52%, KND – 77.95%, and PNI – 77.16%. As already mentioned with respect to abundance, analysis of the richness recorded here directs us towards a dichotomous classification of the habitats; one group comprising MPZ and CTR and the other one comprising OTP, KND and PNI. Besides sharing richness and percentage wise contribution of richness, MPZ and CTR shared some specific ecological features; both sites are associated with perennial vegetation cover dominated by shrubs and trees, both habitats are shaded enough to prevent extreme diurnal variations of temperature. Also, the riverine body of Bharatapuzha associated with these habitats is comparatively perennial and bears considerable quantities of water. In site 1 MPZ, the Malampuzha dam mainly intended for irrigation and potable water ensures water availability in the sampling sites and consequently resulting in unbroken lush green vegetation cover contributing the basic requirements of richer spider population.

On the other hand, sites OTP, KND and PNI had very closely situated richness values. The riparian habitats associated with these experienced high degree of fluctuations; in ambient temperature, vegetation cover and water availability. In all of the habitats, the water body undergo such a drastic reduction that it becomes reduced to isolated stagnant patches.

5.2.3. Season-wise abundance

Strikingly different distribution of individuals was recorded during various seasons. The seasonal division of sampling was predominantly based on monsoon patterns experienced in Kerala. Apart from the availability of rainfall, a lot of other climatic and topographic factors tend to vary with these seasons, including ambient temperature, soil temperature, humidity, etc. All these factors together decide the existence or succession of plant communities and associated animals in that habitat. From the above discussion, it is quite evident that the seasonal fluctuation of abundance of spiders essentially reflects varying values of various environmental parameters; and hence the status of the habitat.

In the present study, the POM season was found to support the maximum individuals (3885) that amount to approximately 54% of the total abundance. This indicates the existence of optimal range of temperature, humidity, and prey availability; especially that of insects. Presence of uninterrupted vegetation cover with diverse patterns of plants bearing plenty of inflorescence provided the perfect venue for the co-existence of various types of spiders.

POM season has also recorded the highest mean abundance. *Hyllus semicupreus* was the species having maximum abundance during POM (371) affirming the high degree of adaptability and evolutionary diversification of family Salticidae as such.

Relative abundance indicated the contribution of individual species towards the total recorded abundance. These values are really helpful in categorizing the individual species as 'eudominants', 'dominants' , 'subdominants', etc. From the whole scenario, we concluded the non- existence of extremely odd species.

5.2.4. Season-wise richness

POM season was found to be ideal not only for highest recorded abundance, but also for the aggravated values of species richness. 127 out of the 133 species of spiders recorded during the study were met with in this season. This quantifies to approximately 95% of the species coverage of the study. Such a very high percentage of species availability correlates with the presence of diverse microhabitats and enormously diversified niche. High rate of proliferation of flora ensures sufficient food supply for insects, in turn ensuring the continuity of food chains operating in riparian habitats. Approximately 26% rare species were reported during POM.

5.2.5. Hill numbers and diversity indices

Analysis of Hill numbers, especially corresponding to 'q' values; q=0,1 and 2 provide valuable ideas with respect to the ambient species richness (q=0), Shannon diversity (q=1) and Simpson diversity (q=2). Hill number corresponding to q=0 reveals the degree of colonization of the habitat under consideration by various species. In the present study, the value was found to be higher in MPZ. A considerably high value was also recorded from CTR, while it was lowest in KND. High values recorded from sites MPZ and CTR are indicative of the structural complexity and variability of the habitats in these sites. Site 1 (MPZ) had a perennial and almost undisturbed niche; thereby tally the richness. Values corresponding to q=2 literally denotes the dominance of few species over the others. A higher value indicates highly uneven and skewed distribution of the richness , whereas lower values point out more or less equitable distribution of species and hence towards niche partitioning.

The three diversity indices considered in this study, Shannon diversity, Simpson diversity and Shannon equitability index had wide range of values with respect to sites and seasons. Both Shannon and Simpson indices had the highest value at MPZ (62.862 and 36.325 respectively). Some species of spiders like *Hyllus semicupreus* had clear cut dominance over others in all sites. Equitability values were restricted to a comparatively narrow range; 0.874 to 0.918.

Riparian habitats, being fluctuating in nature are frequently disturbed and subjected to rapid changes in environmental gradients and physiognomy. Any minute deviations pertaining to the characteristics of these habitats get expressed in a highly magnified way, especially because those changes tend to operate in both of the neighbouring ecosystems.

5.3. Beta diversity

Comparative account of the local diversity was performed using statistical testing tools including Kruskal Wallis, Mann – Whitney U and Wilcoxon. No statistically significant difference in abundance were reported among the following pairs; MPZ-CTR, KND-OTP, KND- PNI and OTP-PNI.

Hore & Uniyal (2008) demonstrated the existence of a direct correlation among complexity of vegetation and beta diversity in habitats. Pitta et al. (2019) reported how climatic changes play deterministic role in beta diversity. To find out the individual contribution of species to dissimilarity among habitats and seasons, SIMPER analysis was performed and in pair wise comparison, maximum overall average dissimilarity was found to exist between MPZ and OTP.

5.4. Study of curves

The species accumulation curves exhibited a general trend. In almost all cases, the exact, random, rarefaction and collector curves failed to reach the asymptotic region indicating the need of systematic and exhaustive sampling efforts. Most often, the curves were abruptly terminated in exponential phases.

To detect best fit model, both AIC and BIC values were being considered. In all cases, Zipf -Mandelbrot model was found to be the best fitting one. In addition to the usual parameters, complex species interactions inherent in a site are also taken in to account in this model. Rank abundance curves indicated moderately uneven distribution. Diversity profile curves also exhibited a general trend towards a negatively sloped curve showing moderately uneven distribution of the entities. Rarefaction curves were plotted as a multi – faceted curve with a single axis reference point. The variation in abundance across five sites and three seasons were also proportionately depicted in component curves.

5.5. Comparison of richness between habitats and seasons

Human interference and the resultant alteration in habitat could have a detrimental effect on biodiversity (Biswas & Mallik, 2010). The water bodies in various parts of the state are being threatened by anthropogenic disturbances like sand mining, discharging of untreated industrial effluents, dumping of non-bio degradable wastes including plastics, climate change and the resultant temperature fluctuations etc. All these entities will exert a direct influence on the riparian organisms, especially spiders. Considering the key role played by spiders as the living links between terrestrial and aquatic food chains, they form one of the badly affected groups. Ultimately it may force the organisms to invade newer habitats or to develop some physiological or behavioural adaptations equipping them to remain there itself.

As the present study explored the riparian habitats of Bharatapuzha and its tributaries with reference to spider diversity, both vegetation cover and climatic changes could be correlated with the results.

Markable difference in the composition, succession, and area of coverage of vegetation was observed in the study sites. Riparian habitats of site MPZ had a perennial vegetation coverage dominated by trees and shrubs. This in turn has deterministic role in the microclimate of the area; controlling the gradients of ambient temperature, moisture in the soil, humidity and most importantly the insects preferring to reside there. All these parameters directly or indirectly influence the spider fauna; perennial vegetation provides support for anchoring orb webs of large diameters, or elaborate sheet webs (Hatley & MacMahon, 1980). Corresponding abundance of weaver guilds of spiders were found in the site throughout the year. The litter content of the soil is also richer, both in quantity and in quality, expressed in terms of nutrients. A rich fauna of associated ground dwelling organisms including ground runner spiders was also supported.

Considering the riparian zone of site CTR, a mixed vegetation cover of perennial trees, shrubs and grasses was found. Litter content was also higher and the area was frequently interfered by grazing cattle, ensuring a periodic turnover of the shrubs and herbs, thereby exerting a regulatory role on associated fauna. A rich assemblage of Araneids with characteristic orb webs was noticed. The site was found to be productive in terms of spider diversity; both in richness and abundance.

Sites KND and OTP, even though located far from each other had striking similarities in terms of associated vegetation; dominance of grasses and shrubs with short life spans. Members of the family Poaceae were found in large numbers. Soil moisture and litter content was lower and spiders of the family Theridiidae and Tetragnathidae occurred in large numbers. The tributaries associated with these sites were also found to exhibit unparalleled annual fluctuations; flooding the banks and wiping out almost all vegetation during monsoon season, to remaining as lean channels and shallow puddles towards the fag end of pre monsoon season. The characteristic vegetation found was ideal for ground runners and small funnel web makers.

Site PNI was the only one among the five, situated in a different district; Malappuram. The riparian habitat was special in that the region of river in this locality is the ‘Bharatapuzha’ proper; formed by the confluence of all its tributaries and connected to Arabian sea, giving rise to a brackish water filled water body, comparable to that of an estuary. Even though a perennial water body was found to be associated with this habitat, the spider fauna was poor. High salinity and subsequent absence of aquatic insects, scanty vegetation cover dominated by coconut palms and *Casuarina* trees, marked diel variations in temperature of water, etc. are the most probable reasons behind the poor abundance and richness.

To sum up, our observations tallied the earlier ones of Balfour & Rypstra (1998) stating that structural variability and complexity of the habitat have a direct influence on species diversity. Physical structure and choices available with respect to environmental gradients was found to have a direct influence on the habitat preference (Jennings et al., 1988)

5.6. Guild structure

The most widely accepted definition of guild characterizes as an assemblage of species without any unified phylogeny, but rather united with respect to utilizing resources. This may range from direct competition to niche stratification, seasonal invasion and even kleptoparasitism. Determining guild status of groups are of prime interest in taxonomic studies, as it can tell a lot about their possible responses to disturbing factors; climate change, natural calamities, fragmentation of habitats, deforestation, monoculture, residual pesticides, introduction of exotic species, etc. Guilds also provide necessary inputs regarding environmental impact assessment, environmental management formulation of conservation strategies and fixing the extent of human interference in ecologically vulnerable habitats.

Quantifying diversity is one of the basic requirements of guild structure analysis. Various approaches have been developed from time to time for the same. Longino & Colwell (1997) developed a multi-dimensional matrix to study the dynamics and interactions related to guilds. A relatively simple method of comparing dendrogram branch lengths was developed by Petchy & Gaston (2006). Jaksic & Medel (1990) suggested existence of two different types of guilds (1) community guilds; true guilds - independent of trophic level and (2) assemblage guilds - taxon based.

Uetz et al. (1999) proposed the following guilds of spiders; stalkers, ambushers, foliage runners, ground runners, sheet web builders, wandering sheet web builders, orb weavers, space web builders and others.

Present study focused on classifying the riparian spiders especially based on their foraging behaviour. The scheme developed by Cardoso et al. (2011) was being followed throughout this. Accordingly, spiders collected from five sites among three seasons were sorted into eight foraging guilds; ambushers, ground hunters, orb webs, other hunters, sensing web, sheet web, space web and specialists.

The size, complexity and architecture of the web have a lot to do with the guild assignment of spiders. The characteristic webs along with the hunting strategies complete the guild-wise distribution of spiders. Study of webs and hunting strategies are of equal importance as different groups of spiders depend on the webs for prey capture in varying degrees. There are certain groups that do not weave webs at all. So, the key strategy of hunting the prey plays a pivotal role in guild classification.

Family Thomisidae alone represent the guild ambushers in the present study. Members of this group resort to a rather passive strategy of prey capturing. Unlike their counterparts in other guilds, they neither weave intricate webs, nor do they actively search their prey. Majority of them acquire brilliantly concealing colouration matching flowers or foliage and sit and wait over long periods for any unsuspecting prey. This makes approximately 5.12 % in total abundance. The brilliance underlying the 'blended' existence of these spiders in their substratum is so excellent that it could remain unnoticed even from a very closer observation. This could even be treated as a mechanism evolved to ensure increased rate of prey capture efficiency, coupled with minimum consumption of energy.

Families Corinnidae, Gnaphosidae, Lycosidae and Oonopidae together contributed the guild 'ground hunters,' comprising 7.38% of the total abundance. As the name indicates, members of this guild actively run along the ground chasing their prey. Majority of the species sampled were 'dusty' coloured, matching the soil substratum. Moreover, their highly agile nature permits them to overpower the prey.

Families Araneidae, Tetragnathidae and Uloboridae constituted the 'orb web weavers'. This is the second most abundant guild in the study, reaching 29.58%. They can be seen actively engaged in making perfect orb webs of variable sizes and waiting for their prey to get entangled in it. Some of the orb webs are provided with additional adornments like stabilimentum. Persistent, less disturbed and continuous patch of vegetation is required for supporting orb webs.

The most abundant guild of the present study is 'other hunters'; includes families Cheiracanthiidae, Clubionidae, Ctenidae, Oxyopidae, Philodromidae, Salticidae, Scytodidae and Sparassidae, taken together, these eight families contributed to 43.53% of the total abundance . From a closer view, it could be observed that families Oxyopidae and Salticidae, alone could contribute to major share of this guild's abundance.

Sensing web builders included two families; Theraphosidae and Hersiliidae. They constitute a meager 0.7% of the total abundance. The prey capture mechanism is unique in that the spiders literally spin a 'coccoon' of silk around the prey; by rotating around the prey at a very speedy manner.

Five families; Amaurobiidae, Eresidae, Hahniidae, Linyphiidae and Pisauridae together constitute the guild sheet web builders. Members of this guild occupy 6.61% of the total abundance. The webs constructed by them are either planar 'sheets' or funnel shaped or three dimensional in nature.

Space web builders include families Pholcidae and Theridiidae. Together they constitute to 4.27% of the total abundance. Members of this guild weave highly branched complex three dimensional non – sticky webs.

In this study, specialists are represented by a single family; Mimetidae. The members collected reach a negligible 0.07% of the total abundance. Unlike other guilds, members of this category are rather a cluster of species that capture their prey in multitude of ways.

Considering richness, other hunters themselves occupy the first position with a percentage richness of 39.09, followed by orb weavers (29.32 %). Richness of other guilds are; ground hunters (9.02 %), sensing web (2.25%), sheet web (5.26%), space web (9.02%), specialists (0.75%) and ambush hunters (5. 26%).

Considerable variation was found to exist in guild structure across the five sites under consideration. In MPZ, other hunters was the most abundant guild (12.21%), followed by orb weavers (10.81%), sensing web (0.21%), sheet web (1.99%), space web (1.02%), specialists (0.07%) and ambush hunters (1.48%).

Site 2 CTR had a slightly different profile of guilds. The most abundant guilds were other hunters (10.07%) and orb weavers (7.83%) themselves. In this site, the number of functional guilds got reduced to seven, as there were no representatives from 'specialists'. The remaining ones were; sensing web (0.35%), sheet web (2.21%), space web (0.94%), ground hunters (1.79%) and ambush hunters (1.51%).

In KND, other hunters were the most abundant (7.73%). Here also, there were no 'specialists'. Rest of the guilds were, orb web (4.89%), sensing web (0.08%), sheet web (0.13%), space web (0.53%), ground hunters (1.64%) and ambush hunters (0.49%).

Only seven foraging guilds could be identified from PNI; specialists were not recorded. Percentage wise abundance of various guilds was; other hunters (5.90%), orb weavers (4.60%), sensing web (0.06%), sheet web (2.07%), space web (0.95%), ground hunters (0.87%) and ambush hunters (0.87%).

To sum up, the guilds sheet web, space web, orb web, ground hunters, other hunters and ambush hunters were invariably found in all the five sites being studied. Structural variability and complexity of the habitat have a direct influence on species diversity (Balfour & Rypstra, 1998). Physical structure and choices available with respect to environmental gradients was found to have a direct influence on the habitat preference (Jennings et al., 1988)

Unless being operated by any major disruptive factors, the species richness at a locality tends to increase over time, primarily due to better sampling, replacement of existing communities by succession or operation of evolutionary changes like speciation (Preston, 1960).

The increased species diversity in MPZ may be due to the continuous availability of vegetation cover irrespective of the seasons. Presence of Malampuzha dam meant for irrigation purpose ensures perennial, water – filled river along with lush green vegetation on its banks,by the presence of large sized semi- ever green and ever green trees together with thorny shrubs. A strong positive correlation was found to exist between a structurally complex vegetation cover and corresponding diversity of spiders (Uetz, 1991). Thus the physically diverse and structurally complex environment inherent in MPZ and supported a highly diverse fauna of spiders. It is noteworthy that the genus to species ratio was of lower order, inferring the presence of multiple species per genera. This indirectly indicates a higher order habitat utilisation by closely related species (often from the same genera) co-existing, utilising a highly diverse and broader niche. In other words, all the possible niche spaces are being utilised by the members of such a community.

In OTP and KND, the richness was comparatively low. In these sites, by the middle of post- monsoon season itself, the river got almost dried up. The alluvial soil rich bed of the river gets exposed to strong uninterrupted sunlight, draining out the entire moisture from the river beds and literally charring the humus rich litter layer. Such a substratum remains unfit for succession or colonisation except for very hardy grass family members. They flourish there without any interventions from other plant species and establish themselves as the dominant vegetation of the riparian habitats. They are later on inhabited by some bugs and beetles adapted to withstand high diurnal temperature variations, later on followed by Theridiid and Tetragnathid spider groups.

The observed species diversity was greater during POM. The species richness estimators also predicted slightly higher values. A host of factors might be synergistically supporting an unexpectedly higher richness during POM. Elevated ambient temperature, moisture after intermittent but high intensity rains, moisture saturated atmosphere etc. are some among them.

There is no quantisation as such available regarding the degree of damage inflicted upon the riparian habitats in Kerala. Correlating the same with the results of species inventories of riparian organisms will provide highly meaningful inputs regarding the status of riparian habitats. The sudden and unprecedented changes in these habitats might be disrupting the trophic interactions of both of the neighbouring ecosystems. Degradation of the habitats extent a selection pressure on the neighbouring ecosystems to set a highly altered trend of species. Benitez – Malvido et al. (2020) formulated Riparian Condition Index (RCI) to assess the extent of alteration undergone by the habitat.

Out of the five sites selected, MPZ, OTP, KND and CTR come under Palakkad district of Kerala, whereas, the remaining one PNI is in Malappuram district. The four sites together comprise 6075 individuals, constituting 85% of the abundance. PNI had 1076 individuals (15% approx.).

Sumesh & Sudhikumar (2020) in connection with their works on sacred groves of northern Kerala, reported Araneidae as the dominant family. Quite contrary opinions do exist regarding the composition and abundance of spider communities and the nature of vegetation (Calixto et al., 2021). As the orb webs of araneids are of larger diametres, and supported by many points, there will be a requirement of taller shrubs or trees, rather than herbaceous vegetation.

As is seen in other animal groups, spiders generally try to avoid intraspecific and inter specific competition for resources. Foraging guilds provide a vivid clue regarding this.

The riparian habitats of Bharatapuzha being subjected to periodic inundation and total drying up, the soil fertility, soil moisture and other such related factors controlling plant growth undergo rapid revisions. Hence an overall shift in composition of plant communities could be reported in river bed region. This in turn will be reflected on the associated insect fauna and ultimately that of spiders. The thick layer of litter left behind after the flooding or inundation provides a highly productive microhabitat for so many insects and other organisms involved in humification. This in turn attracts many 'ground runner' spiders to that area. On the other hand, dominance of narrow, long – leaved grasses provides ideal habitats for Tetragnathid spiders. The major hurdle felt by diversity assessment studies is the time and effort inputs required. Coddington & Levi (1991) proposed a cluster of methods intended for rapid assessment of biodiversity. They described the effect of four variables; site, collecting method, collector and time of day as a function of observed species richness.

Chapter 5. Discussion

DISCUSSION

Health and survival of a habitat is controlled by highly complex interactions of a variety of biotic and abiotic factors. Harmonious relationship among these factors along with conducive climatic and topographic factors decides the extent of biodiversity in a particular habitat. A balanced biotic world is predominantly maintained by ecological interactions. Predation emerges as the most helpful interaction in biological world, especially when dealt with prey of unparalleled fecundity rates. The ecological services rendered by smaller predators like insects and spiders are of paramount significance in any ecosystem.

Non – specific, predatory nature of spiders adds on to the well-being of habitats. Population of insect pests and vectors are being maintained below the damaging threshold by active interference of spiders. A lot of studies affirming the population dynamics of spiders are already available from various parts of the world; especially documenting the diversity, richness, equitability and seasonal variations in agro ecosystems. Recruiting spiders as biological control agents and integrating the services provided by spiders in harmony with other modes of pest control were some of the most recently discussed topics in this regard. Vivid information on the extent of diversity, distribution patterns and foraging behaviour of spiders is one among the compulsory prerequisites for successful implementation of integrated pest management (IPM). Agro ecosystems, hence farmers, owe a lot to the predation of spiders on pests. Present study focused on the diversity and seasonal fluctuations of spider populations in riparian habitats. One of the most important rivers of Kerala, Bharatapuzha was selected as the contributor of riparian habitats. The river with its extreme annual fluctuations in water content, basin coverage, associated vegetation, etc. proved to be potent enough to support a variety of microhabitats, where each one may have suitable niche for divergent forms of insects and spiders. Such a niche demarcated and microhabitat – wise allocation plays an important role in stabilizing ecosystems, by ensuring optimum resources' utilization and prevention of competition among members of related taxa.

5.1. Spider inventory

Study of spiders attained a sudden global recognition mainly from the revelation of their potential as biocontrol agents. According to Nyffeler & Birkhofer (2017), more than 400 million metric tons of preys per year are being consumed by spiders. Most note- worthy aspect is that majority of these preys are insect pests of agricultural or forest ecosystems. But it remains ironical that the various modern agricultural practices involving large inputs of agrochemicals pose the major threat for global spider population. Together with climate change, habitat degradation and pollution, the agricultural practices also contribute to a drastic reduction in spider populations (Branco & Cardosso, 2020).

The survey extending for a period of two years yielded 133 species of spiders belonging to 90 genera and 27 families. The study area spread over five randomly selected sites along the banks of Bharatapuzha, distributed in Palakkad and Malappuram districts of Kerala was found to be rich in spider fauna. The result does not comply with those of Kashmeera et al. (2020), where the riparian habitats were found to have poorer species richness.

Very few studies on riparian spiders were carried out from India. Sharma et al. (2010) could report 44 species of spiders assigned to 12 families from Barwani region of river Narmada. 112 species of spiders belonging to 21 families were reported by Jose et al. (2018) from Kavvayi river basin, Kannur, Kerala. Rajeevan et al. (2019) documented 28 species of spiders belonging to eight families, from riparian habitats connected to river Kabani, in Wayanad region of Western Ghats. Caleb (2020a) described 70 species of spiders included in 58 genera and 21 families from the riparian habitats of Araabath Lake, Chennai.

Capon et al. (2013) made interesting revelation regarding the significance of riparian ecosystems. According to him, they have the potential to play a deterministic role with respect to vulnerability of natural and anthropogenic systems to climate change. Griotti et al. (2017) assessed the relationship between vegetation structure and spider diversity in riparian habitats of Grande and Quinto river basins of Argentina.

In this study, Salticidae emerged as the most abundant family (24 genera and 27 species) followed by Araneidae (14 genera and 26 species). On a global basis, Salticidae itself is the most species rich family (6617 species), while Araneidae is the third dominant family (3040 species), preceded by Linyphiidae (4841 species) (WSC, 2024). In India also, Salticidae constitute the most species rich family; 309 species, followed by Araneidae (136 species). Abundance with respect to the families also tallies with the revised checklist of spiders of Kerala (Singh, 2023). He reported a total of 28 families, 116 genera and 218 species from Palakkad district, Kerala.The present study could report only single species representatives from the following families; Hersiliidae, Eresidae, Oonopidae, Amaurobiidae, Mimetidae, Nephilidae and Hahniidae. The study also tallies with that of Raiz et al.(2018) , describing spider diversity associated with Tungabhadra irrigation canal at Bellary, Karnataka. Salticidae and araneidae were the dominant families. A similar degree of consensus was also found with the results of Malhotra et al. (2019), studying the spider fauna of four different habitats of northern Rajasthan. Density of spiders was found to be highest (94.62% individuals per square metre) in riparian lands.

Salticidae is one of the extensively distributed families. This may be correlated with their highly adaptable nature, exemplary prey capturing skills and enhanced history of evolutionary diversification equipping them to invade varying climatic and topographic zones. On the other hand, the state-of-the-art orb webs of Araneids ensure that the suitable prey is not spared at any cost. Among Salticids, *Hyllus semicupreus* was represented in all samples and in all seasons. A total of 639 members were noticed during this study, comprising 8.9% of the total abundance. Similarly from Araneidae, *Anepsion maritatum* was recorded in all sites and seasons. 449 members of this species were reported, constituting 6.27% of the total abundance value. Other species reported in all seasons and sites in considerably higher numbers were *Oxyopes javanus* (420; 5.87 %), and *Tetragnatha javana* (303; 4.23%). Eventhough 348 members of *Dendrolycosa gitae* were recorded in this study, it was not reported from two sites; OTP and KND.

5.2. Population attributes of spiders

The study could record a considerable number of spiders distributed in eight diverse foraging guilds and still diverse families. Total abundance and site-wise and season wise split up of abundance were recorded. In a similar pattern, richness was also assessed. As evenness has a significant role in species distribution and species interactions, the equitability were also calculated for each site and seasons. Analysis of the equitability pointed out a moderately uneven distribution of the spiders. In totality, it was found out that the distribution pattern of spiders differed from each other, both site wise and season wise.

5.2.1. Habitat-wise abundance

Abundance from habitats demonstrated high degree of variability. With a total abundance of 7151 individuals, MPZ contributed 2156 individuals (30.15%). Percentage -wise contribution of other sites were; CTR – 24.55%, KND – 16.40%, PNI – 15.04% and OTP – 13.84%. Mean abundance ranged from 102.67 ± 26.54 (MPZ) to 78.20 ± 14.79 (OTP).

5.2.2. Habitat-wise richness

The total richness recorded was 133 species. Out of these, two were from Mygalomorphae and the remaining 131 were Araneomorphs. In contrary to the expectations, the sites could have a lesser contribution towards the abundance and richness. This is clearly indicated from the fact that the difference in richness between the site with maximum richness; MPZ (114) and that with minimum richness; PNI (98) is only 16 species. Furthermore, MPZ and CTR differed only by two species. Similarly, OTP and PNI had a difference of only one species.

Considering the extent up to which each habitat represented the total recorded richness, MPZ had the highest coverage of 89.76%, CTR followed closely with a richness of 88.18%. The remaining three sites had access to much lower richness; OTP – 79.52%, KND – 77.95%, and PNI – 77.16%. As already mentioned with respect to abundance, analysis of the richness recorded here directs us towards a dichotomous classification of the habitats; one group comprising MPZ and CTR and the other one comprising OTP, KND and PNI. Besides sharing richness and percentage wise contribution of richness, MPZ and CTR shared some specific ecological features; both sites are associated with perennial vegetation cover dominated by shrubs and trees, both habitats are shaded enough to prevent extreme diurnal variations of temperature. Also, the riverine body of Bharatapuzha associated with these habitats is comparatively perennial and bears considerable quantities of water. In site 1 MPZ, the Malampuzha dam mainly intended for irrigation and potable water ensures water availability in the sampling sites and consequently resulting in unbroken lush green vegetation cover contributing the basic requirements of richer spider population.

On the other hand, sites OTP, KND and PNI had very closely situated richness values. The riparian habitats associated with these experienced high degree of fluctuations; in ambient temperature, vegetation cover and water availability. In all of the habitats, the water body undergo such a drastic reduction that it becomes reduced to isolated stagnant patches.

5.2.3. Season-wise abundance

Strikingly different distribution of individuals was recorded during various seasons. The seasonal division of sampling was predominantly based on monsoon patterns experienced in Kerala. Apart from the availability of rainfall, a lot of other climatic and topographic factors tend to vary with these seasons, including ambient temperature, soil temperature, humidity, etc. All these factors together decide the existence or succession of plant communities and associated animals in that habitat. From the above discussion, it is quite evident that the seasonal fluctuation of abundance of spiders essentially reflects varying values of various environmental parameters; and hence the status of the habitat.

In the present study, the POM season was found to support the maximum individuals (3885) that amount to approximately 54% of the total abundance. This indicates the existence of optimal range of temperature, humidity, and prey availability; especially that of insects. Presence of uninterrupted vegetation cover with diverse patterns of plants bearing plenty of inflorescence provided the perfect venue for the co-existence of various types of spiders.

POM season has also recorded the highest mean abundance. *Hyllus semicupreus* was the species having maximum abundance during POM (371) affirming the high degree of adaptability and evolutionary diversification of family Salticidae as such.

Relative abundance indicated the contribution of individual species towards the total recorded abundance. These values are really helpful in categorizing the individual species as 'eudominants', 'dominants' , 'subdominants', etc. From the whole scenario, we concluded the non- existence of extremely odd species.

5.2.4. Season-wise richness

POM season was found to be ideal not only for highest recorded abundance, but also for the aggravated values of species richness. 127 out of the 133 species of spiders recorded during the study were met with in this season. This quantifies to approximately 95% of the species coverage of the study. Such a very high percentage of species availability correlates with the presence of diverse microhabitats and enormously diversified niche. High rate of proliferation of flora ensures sufficient food supply for insects, in turn ensuring the continuity of food chains operating in riparian habitats. Approximately 26% rare species were reported during POM.

5.2.5. Hill numbers and diversity indices

Analysis of Hill numbers, especially corresponding to 'q' values; q=0,1 and 2 provide valuable ideas with respect to the ambient species richness (q=0), Shannon diversity (q=1) and Simpson diversity (q=2). Hill number corresponding to q=0 reveals the degree of colonization of the habitat under consideration by various species. In the present study, the value was found to be higher in MPZ. A considerably high value was also recorded from CTR, while it was lowest in KND. High values recorded from sites MPZ and CTR are indicative of the structural complexity and variability of the habitats in these sites. Site 1 (MPZ) had a perennial and almost undisturbed niche; thereby tally the richness. Values corresponding to q=2 literally denotes the dominance of few species over the others. A higher value indicates highly uneven and skewed distribution of the richness , whereas lower values point out more or less equitable distribution of species and hence towards niche partitioning.

The three diversity indices considered in this study, Shannon diversity, Simpson diversity and Shannon equitability index had wide range of values with respect to sites and seasons. Both Shannon and Simpson indices had the highest value at MPZ (62.862 and 36.325 respectively). Some species of spiders like *Hyllus semicupreus* had clear cut dominance over others in all sites. Equitability values were restricted to a comparatively narrow range; 0.874 to 0.918.

Riparian habitats, being fluctuating in nature are frequently disturbed and subjected to rapid changes in environmental gradients and physiognomy. Any minute deviations pertaining to the characteristics of these habitats get expressed in a highly magnified way, especially because those changes tend to operate in both of the neighbouring ecosystems.

5.3. Beta diversity

Comparative account of the local diversity was performed using statistical testing tools including Kruskal Wallis, Mann – Whitney U and Wilcoxon. No statistically significant difference in abundance were reported among the following pairs; MPZ-CTR, KND-OTP, KND- PNI and OTP-PNI.

Hore & Uniyal (2008) demonstrated the existence of a direct correlation among complexity of vegetation and beta diversity in habitats. Pitta et al. (2019) reported how climatic changes play deterministic role in beta diversity. To find out the individual contribution of species to dissimilarity among habitats and seasons, SIMPER analysis was performed and in pair wise comparison, maximum overall average dissimilarity was found to exist between MPZ and OTP.

5.4. Study of curves

The species accumulation curves exhibited a general trend. In almost all cases, the exact, random, rarefaction and collector curves failed to reach the asymptotic region indicating the need of systematic and exhaustive sampling efforts. Most often, the curves were abruptly terminated in exponential phases.

To detect best fit model, both AIC and BIC values were being considered. In all cases, Zipf -Mandelbrot model was found to be the best fitting one. In addition to the usual parameters, complex species interactions inherent in a site are also taken in to account in this model. Rank abundance curves indicated moderately uneven distribution. Diversity profile curves also exhibited a general trend towards a negatively sloped curve showing moderately uneven distribution of the entities. Rarefaction curves were plotted as a multi – faceted curve with a single axis reference point. The variation in abundance across five sites and three seasons were also proportionately depicted in component curves.

5.5. Comparison of richness between habitats and seasons

Human interference and the resultant alteration in habitat could have a detrimental effect on biodiversity (Biswas & Mallik, 2010). The water bodies in various parts of the state are being threatened by anthropogenic disturbances like sand mining, discharging of untreated industrial effluents, dumping of non-bio degradable wastes including plastics, climate change and the resultant temperature fluctuations etc. All these entities will exert a direct influence on the riparian organisms, especially spiders. Considering the key role played by spiders as the living links between terrestrial and aquatic food chains, they form one of the badly affected groups. Ultimately it may force the organisms to invade newer habitats or to develop some physiological or behavioural adaptations equipping them to remain there itself.

As the present study explored the riparian habitats of Bharatapuzha and its tributaries with reference to spider diversity, both vegetation cover and climatic changes could be correlated with the results.

Markable difference in the composition, succession, and area of coverage of vegetation was observed in the study sites. Riparian habitats of site MPZ had a perennial vegetation coverage dominated by trees and shrubs. This in turn has deterministic role in the microclimate of the area; controlling the gradients of ambient temperature, moisture in the soil, humidity and most importantly the insects preferring to reside there. All these parameters directly or indirectly influence the spider fauna; perennial vegetation provides support for anchoring orb webs of large diameters, or elaborate sheet webs (Hatley & MacMahon, 1980). Corresponding abundance of weaver guilds of spiders were found in the site throughout the year. The litter content of the soil is also richer, both in quantity and in quality, expressed in terms of nutrients. A rich fauna of associated ground dwelling organisms including ground runner spiders was also supported.

Considering the riparian zone of site CTR, a mixed vegetation cover of perennial trees, shrubs and grasses was found. Litter content was also higher and the area was frequently interfered by grazing cattle, ensuring a periodic turnover of the shrubs and herbs, thereby exerting a regulatory role on associated fauna. A rich assemblage of Araneids with characteristic orb webs was noticed. The site was found to be productive in terms of spider diversity; both in richness and abundance.

Sites KND and OTP, even though located far from each other had striking similarities in terms of associated vegetation; dominance of grasses and shrubs with short life spans. Members of the family Poaceae were found in large numbers. Soil moisture and litter content was lower and spiders of the family Theridiidae and Tetragnathidae occurred in large numbers. The tributaries associated with these sites were also found to exhibit unparalleled annual fluctuations; flooding the banks and wiping out almost all vegetation during monsoon season, to remaining as lean channels and shallow puddles towards the fag end of pre monsoon season. The characteristic vegetation found was ideal for ground runners and small funnel web makers.

Site PNI was the only one among the five, situated in a different district; Malappuram. The riparian habitat was special in that the region of river in this locality is the ‘Bharatapuzha’ proper; formed by the confluence of all its tributaries and connected to Arabian sea, giving rise to a brackish water filled water body, comparable to that of an estuary. Even though a perennial water body was found to be associated with this habitat, the spider fauna was poor. High salinity and subsequent absence of aquatic insects, scanty vegetation cover dominated by coconut palms and *Casuarina* trees, marked diel variations in temperature of water, etc. are the most probable reasons behind the poor abundance and richness.

To sum up, our observations tallied the earlier ones of Balfour & Rypstra (1998) stating that structural variability and complexity of the habitat have a direct influence on species diversity. Physical structure and choices available with respect to environmental gradients was found to have a direct influence on the habitat preference (Jennings et al., 1988)

5.6. Guild structure

The most widely accepted definition of guild characterizes as an assemblage of species without any unified phylogeny, but rather united with respect to utilizing resources. This may range from direct competition to niche stratification, seasonal invasion and even kleptoparasitism. Determining guild status of groups are of prime interest in taxonomic studies, as it can tell a lot about their possible responses to disturbing factors; climate change, natural calamities, fragmentation of habitats, deforestation, monoculture, residual pesticides, introduction of exotic species, etc. Guilds also provide necessary inputs regarding environmental impact assessment, environmental management formulation of conservation strategies and fixing the extent of human interference in ecologically vulnerable habitats.

Quantifying diversity is one of the basic requirements of guild structure analysis. Various approaches have been developed from time to time for the same. Longino & Colwell (1997) developed a multi-dimensional matrix to study the dynamics and interactions related to guilds. A relatively simple method of comparing dendrogram branch lengths was developed by Petchy & Gaston (2006). Jaksic & Medel (1990) suggested existence of two different types of guilds (1) community guilds; true guilds - independent of trophic level and (2) assemblage guilds - taxon based.

Uetz et al. (1999) proposed the following guilds of spiders; stalkers, ambushers, foliage runners, ground runners, sheet web builders, wandering sheet web builders, orb weavers, space web builders and others.

Present study focused on classifying the riparian spiders especially based on their foraging behaviour. The scheme developed by Cardoso et al. (2011) was being followed throughout this. Accordingly, spiders collected from five sites among three seasons were sorted into eight foraging guilds; ambushers, ground hunters, orb webs, other hunters, sensing web, sheet web, space web and specialists.

The size, complexity and architecture of the web have a lot to do with the guild assignment of spiders. The characteristic webs along with the hunting strategies complete the guild-wise distribution of spiders. Study of webs and hunting strategies are of equal importance as different groups of spiders depend on the webs for prey capture in varying degrees. There are certain groups that do not weave webs at all. So, the key strategy of hunting the prey plays a pivotal role in guild classification.

Family Thomisidae alone represent the guild ambushers in the present study. Members of this group resort to a rather passive strategy of prey capturing. Unlike their counterparts in other guilds, they neither weave intricate webs, nor do they actively search their prey. Majority of them acquire brilliantly concealing colouration matching flowers or foliage and sit and wait over long periods for any unsuspecting prey. This makes approximately 5.12 % in total abundance. The brilliance underlying the 'blended' existence of these spiders in their substratum is so excellent that it could remain unnoticed even from a very closer observation. This could even be treated as a mechanism evolved to ensure increased rate of prey capture efficiency, coupled with minimum consumption of energy.

Families Corinnidae, Gnaphosidae, Lycosidae and Oonopidae together contributed the guild 'ground hunters,' comprising 7.38% of the total abundance. As the name indicates, members of this guild actively run along the ground chasing their prey. Majority of the species sampled were 'dusty' coloured, matching the soil substratum. Moreover, their highly agile nature permits them to overpower the prey.

Families Araneidae, Tetragnathidae and Uloboridae constituted the 'orb web weavers'. This is the second most abundant guild in the study, reaching 29.58%. They can be seen actively engaged in making perfect orb webs of variable sizes and waiting for their prey to get entangled in it. Some of the orb webs are provided with additional adornments like stabilimentum. Persistent, less disturbed and continuous patch of vegetation is required for supporting orb webs.

The most abundant guild of the present study is 'other hunters'; includes families Cheiracanthiidae, Clubionidae, Ctenidae, Oxyopidae, Philodromidae, Salticidae, Scytodidae and Sparassidae, taken together, these eight families contributed to 43.53% of the total abundance . From a closer view, it could be observed that families Oxyopidae and Salticidae, alone could contribute to major share of this guild's abundance.

Sensing web builders included two families; Theraphosidae and Hersiliidae. They constitute a meager 0.7% of the total abundance. The prey capture mechanism is unique in that the spiders literally spin a 'coccoon' of silk around the prey; by rotating around the prey at a very speedy manner.

Five families; Amaurobiidae, Eresidae, Hahniidae, Linyphiidae and Pisauridae together constitute the guild sheet web builders. Members of this guild occupy 6.61% of the total abundance. The webs constructed by them are either planar 'sheets' or funnel shaped or three dimensional in nature.

Space web builders include families Pholcidae and Theridiidae. Together they constitute to 4.27% of the total abundance. Members of this guild weave highly branched complex three dimensional non – sticky webs.

In this study, specialists are represented by a single family; Mimetidae. The members collected reach a negligible 0.07% of the total abundance. Unlike other guilds, members of this category are rather a cluster of species that capture their prey in multitude of ways.

Considering richness, other hunters themselves occupy the first position with a percentage richness of 39.09, followed by orb weavers (29.32 %). Richness of other guilds are; ground hunters (9.02 %), sensing web (2.25%), sheet web (5.26%), space web (9.02%), specialists (0.75%) and ambush hunters (5. 26%).

Considerable variation was found to exist in guild structure across the five sites under consideration. In MPZ, other hunters was the most abundant guild (12.21%), followed by orb weavers (10.81%), sensing web (0.21%), sheet web (1.99%), space web (1.02%), specialists (0.07%) and ambush hunters (1.48%).

Site 2 CTR had a slightly different profile of guilds. The most abundant guilds were other hunters (10.07%) and orb weavers (7.83%) themselves. In this site, the number of functional guilds got reduced to seven, as there were no representatives from 'specialists'. The remaining ones were; sensing web (0.35%), sheet web (2.21%), space web (0.94%), ground hunters (1.79%) and ambush hunters (1.51%).

In KND, other hunters were the most abundant (7.73%). Here also, there were no 'specialists'. Rest of the guilds were, orb web (4.89%), sensing web (0.08%), sheet web (0.13%), space web (0.53%), ground hunters (1.64%) and ambush hunters (0.49%).

Only seven foraging guilds could be identified from PNI; specialists were not recorded. Percentage wise abundance of various guilds was; other hunters (5.90%), orb weavers (4.60%), sensing web (0.06%), sheet web (2.07%), space web (0.95%), ground hunters (0.87%) and ambush hunters (0.87%).

To sum up, the guilds sheet web, space web, orb web, ground hunters, other hunters and ambush hunters were invariably found in all the five sites being studied. Structural variability and complexity of the habitat have a direct influence on species diversity (Balfour & Rypstra, 1998). Physical structure and choices available with respect to environmental gradients was found to have a direct influence on the habitat preference (Jennings et al., 1988)

Unless being operated by any major disruptive factors, the species richness at a locality tends to increase over time, primarily due to better sampling, replacement of existing communities by succession or operation of evolutionary changes like speciation (Preston, 1960).

The increased species diversity in MPZ may be due to the continuous availability of vegetation cover irrespective of the seasons. Presence of Malampuzha dam meant for irrigation purpose ensures perennial, water – filled river along with lush green vegetation on its banks,by the presence of large sized semi- ever green and ever green trees together with thorny shrubs. A strong positive correlation was found to exist between a structurally complex vegetation cover and corresponding diversity of spiders (Uetz, 1991). Thus the physically diverse and structurally complex environment inherent in MPZ and supported a highly diverse fauna of spiders. It is noteworthy that the genus to species ratio was of lower order, inferring the presence of multiple species per genera. This indirectly indicates a higher order habitat utilisation by closely related species (often from the same genera) co-existing, utilising a highly diverse and broader niche. In other words, all the possible niche spaces are being utilised by the members of such a community.

In OTP and KND, the richness was comparatively low. In these sites, by the middle of post- monsoon season itself, the river got almost dried up. The alluvial soil rich bed of the river gets exposed to strong uninterrupted sunlight, draining out the entire moisture from the river beds and literally charring the humus rich litter layer. Such a substratum remains unfit for succession or colonisation except for very hardy grass family members. They flourish there without any interventions from other plant species and establish themselves as the dominant vegetation of the riparian habitats. They are later on inhabited by some bugs and beetles adapted to withstand high diurnal temperature variations, later on followed by Theridiid and Tetragnathid spider groups.

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Chapter 6.
Summary & Conclusion

SUMMARY AND CONCLUSION

6.1. Summary

This study focused on the diversity, abundance, and seasonality of spiders in riparian habitats near major tributaries of the Bharatapuzha River, Kerala. The study spanned from 2015 to 2020 and utilized systematic sampling, preservation, identification, and checklist preparation, with data analyzed using R software and MS Excel.

Five sites were chosen for sampling; MPZ (Malampuzha), CTR (Chittur), OTP (Ottappalam), KND (Kannadi) in Palakkad district and PNI (Ponnani) in Malappuram district .Sampling was conducted from 2016 to 2018.Taxonomic identification and statistical analysis were carried out from 2018 to 2020. Spiders were preserved in 70% ethanol, labelled, and catalogued. Identification relied on existing literature, including *Araneae of India* and *World Spider Catalogue*.

A total of 7151 adult spiders were identified, representing 27 families, 90 genera, and 133 species. The Salticidae family was the most diverse, with 24 genera and 27 species. MPZ exhibited the highest diversity and abundance (2156 individuals), while OTP showed the lowest (990 individuals). The study observed seasonal variations in spider abundance; Pre-monsoon (POM) = dominated by *Hyllus semicupreus* (220 individuals), Monsoon (MON) - dominated by *Tetragnatha javana* (226 individuals) and Post-monsoon (POM) - dominated by *Hyllus semicupreus* again (371 individuals).The post-monsoon season had the highest overall richness, especially at MPZ.

MPZ had the highest Shannon's Diversity Index (H = 62.862).MPZ also had the highest Simpson's Index (36.325), while OTP had the lowest (29.698). Equitability values ranged from 0.874 (MPZ, KND) to 0.918 (PNI).On the basis of relative abundance values, most abundant species included *Hyllus semicupreus* in

KND (12.42%), *Dendrolycosa gitae* in PNI (10.32%), and *Anepsion maritatum* in OTP (8.44%).

Kruskal-Wallis H Test revealed significant differences in abundance between several sites and seasons ($p < 0.001$).Post-hoc Wilcoxon tests indicated varying relationships between abundance values in different seasons. Species Accumulation Curves plateaued, indicating sufficient sampling efficiency. The Zipf-Mandelbrot model was the best fit for the data, providing the lowest AIC and BIC values. Guild structure analysis revealed 'Other Hunters' as the dominant foraging guild in all the sites.

6.2. Conclusion

Present study spread across two consecutive years could provide various insights regarding the diversity of spiders in selected riparian habitats of Bharatapuzha. It could also demonstrate the influence of various factors on the distribution, abundance, richness, and evenness of fauna of spiders in particular. A total of 7151 adult individuals classified under 133 species were recorded during this study.

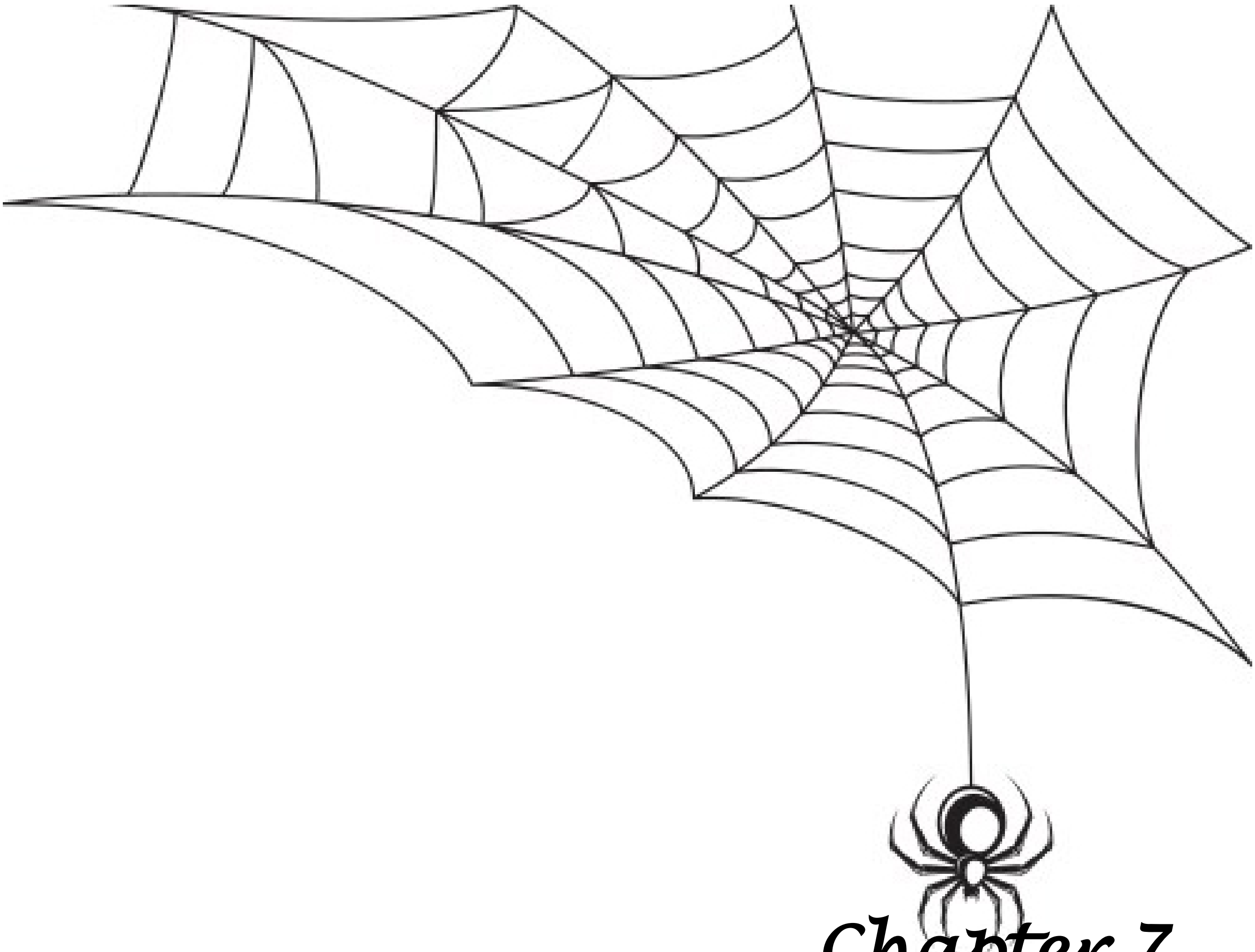
Riparian habitats could be employed as model ecosystems, especially as they reflect the human interventions to a larger scale. Drastically decreasing availability of indigenous fishes, for e.g., points out towards the alterations the riverine habitat had undergone during the recent periods. Sand mining, excessive input of detergents, unscrupulous dumping of domestic and industrial wastes, tourism – related pollution, etc. could be listed as the contributing factors.

Spiders resorting to versatile roles of both predators and prey are ideal candidates for studying the impact of anthropogenic disturbances in natural populations. Their patterns of distribution, presence, or absence in certain localities or during specific seasons etc. could be of ecological significance. Fluctuations in their population reflect the minute changes being undergone by both the neighbouring ecosystems. Even a casual, non -judicious interference from humans could leave a magnified and long-lasting effect on the riparian habitats, especially leaving behind highly disrupted food chains, and ultimately highly imbalanced biogeo chemical cycles.

Results of the study clearly indicated that the riparian habitats supported a highly diverse araneofauna. Both the richness and abundance were found to be higher in riparian habitats of Bharatapuzha. Families like Salticidae and Araneidae were found to have a clear – cut dominance, irrespective of the seasons and sites. This indicates the broad range of adaptability of the members of these families as well as the habitat preference strategies of individuals. Some species like *Hyllus semicupreus* was invariably distributed in all habitats, also in all seasons. It opens certain promising areas of investigation; like the morphological or behavioural mechanisms in operation that equips them to be successful in challenging environments. As a lot of discussions regarding the field trial of spiders as bio control agents are in vogue, the above-mentioned research would be of practical applications. Seasons were found to exert a major effect on both richness and abundance of spiders. Analyzing the data from five habitats across three seasons; PRM, MON and POM, a well demarcated range of values could be observed. Considering species richness, it was moderate during PRM, getting reduced by MON, and a sudden hike during POM. In climatic conditions of Kerala, monsoon season usually serves as the 'low phase' of many animals. A marked reduction in number of prey population exerts a similar effect in predatory spiders. Moreover, the incessant rain acts as impediment for many of the prey capture mechanisms like that of ground runners, ambushers, and some orb-weavers. Synchronized shift in the growth phases of plants available in the habitat also plays a considerable role. It is observed that many of the herbs and shrubs shift to a sudden vegetative growth phase during monsoon; to increase biomass and provision for storage in various parts. This phase serves as optimal for foliage feeding insects; hence corresponding groups of spiders dominate. This will be followed by the mobilization of these stored resources and profuse flowering during post monsoon season, thereby attracting many insects and in turn the predatory spiders.

Like many other natural ecosystems, riparian one is also badly affected by human exploitation, and is of immediate concern. It is obvious that the riparian fauna and flora also are of high degree concern. Strict and broad-spectrum laws that restrict the non-judicious use of river banks are need of the hour. Systematic and season-bound assessment of population richness and abundance of riparian spiders is potent enough to be considered in EIA, related with new projects. Interspecific interactions, sufficient availability of prey, suitable microclimatic conditions, and preferred combination of heterogeneity in habitats etc. are the major decisive factors behind the diversity in riparian habitats. Study of spider diversity of riparian habitats helps to assess ecological processes of higher strata including flow and transfer of energy and nutrients happening between terrestrial and aquatic ecosystems.

Awareness regarding the significance of riparian habitats is to be disseminated among laymen and learners. Local bodies should come up with real time strategic plans directed towards the maintenance and conservation of riparian habitats. Active, voluntary involvement of local people and self-help groups must be ensured in implementing the resolutions mentioned above. Annual surveys involving the active participation of students of various levels are to be carried out to maintain a composite biodiversity register on a local basis.



Chapter 7. Recommendations

RECOMMENDATIONS

As we could see, the riparian habitats of Bharatapuzha support a rich fauna of spiders. These spiders in turn form an irreplaceable part of the food chains; being capable of shifting their roles as predators and preys. Riparian ecosystems of Bharatapuzha are rapidly deteriorating due to various anthropogenic interventions. Climate change worsens the scenario with unpredictable floods and droughts. Many published articles describing the rich fauna of fish, planktons, etc. associated with the river are available. Also studies regarding the alterations happening in river beds and catchment areas of the river are already conducted. Various plans sponsored by local bodies, environmentalists, governmental and non-governmental organisations, were being implemented to 'save' Bharatapuzha in its totality. From the analyses of the results of this study, would like to recommend the conservation of Bharatapuzha and its tributaries from unscrupulous human interventions, paving way to the protection of associated flora and fauna. Both educated people and laymen should be made aware of the multitude of ways by which a river becomes a life line of a locality. Sustainability should be the focal point behind all programmes related with the utilisation of riverine resources.

Considering the fact that even the smallest organism contributes to the maintenance of biodiversity, a comprehensive approach comprising the other life forms as well resident in riparian habitats and the ecological interactions would be worthwhile in assessing the status of the ecosystems. A collaborative effort of experts in the fields of Zoology, Botany, Microbiology, Geology, Climate studies etc. working upon various dimensions of a single riparian habitat would provide a realistic and vivid situation of the alterations in ecosystems, its impacts in diversity and the most appropriate strategies to be implemented there in. This approach becomes more pertinent considering the drastic changes in monsoon patterns in Kerala. The river also is found to exhibit unexpected and unusual variations; hence posing a threat to the flourishing of many associated aquatic and riparian life forms.

As the 'disturbing elements' with respect to the local biodiversity are different in each ecosystem, 'area specific' programme of action is to be sorted out in deciding the conservation strategies. Categorizing the riparian zones as urban, semi urban or rural and then identifying , listing and ranking the threats to biodiversity in each category will be easier to study, plan and implement the activities that would address the area specific needs.

Many of the local people residing nearby the river utilize it for multitude of ways including fishing, bathing and washing, irrigation, short- term cultivation of crops, etc. All of these activities in one way or other alter both the aquatic and riparian ecosystems. As many sectors of people from lower socio- economic background depend on the Bharatapuzha for their livelihood, a total abolishment of human intervention is impossible. Chalking out the permissible extent of human interference on riparian habitats is highly required so that a vivid idea regarding the resource utilisation could be disseminated to the people.

Formulation of futuristic policies, timely revision of resource utilisation models and amendments of the existing nature conservation laws are the immediate actions to be implemented by the authorities. Awareness regarding the significance of riparian habitats and the inherent biodiversity, especially the noteworthy roles played by the spiders, is to be disseminated to all sectors of the society. Mass communication media can contribute a lot in this endeavour. Along with that the importance of biodiversity, the special attributes of riparian habitats, the ecosystem services rendered by them and the associated values are also to be communicated.

Protection of river banks along with the resident plants and animals including spiders matters a lot in restoring the dynamic equilibrium, a minimum requirement of all conservation strategies. In short, an in-situ conservation approach of the riparian habitats of Bharatapuzha will ultimately be beneficial in many ways; cyclizing the disintegrated biogeochemical cycles, increase in efficiency of resource sharing and equitable distribution of resources in the terrestrial , aquatic and, of course riparian zones.

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Publications

PUBLICATIONS

1. **Ambalath Veetil Saidu Mohamed Shihabudeen**, Naduvath Mana Krishnan Namboothiri Prasad & Ambalaparambil Vasu Sudhikumar 2022. Diversity of spiders in riparian habitats of Kalpathipuzha, Palakkad, Kerala, India. *Serket* ,vol. 18(3): 314-320.

2. Naduvath Mana Krishnan Namboothiri Prasad, **Ambalath Veettil Saidu Mohamed Shihabudeen** & Ambalaparambil Vasu Sudhikumar 2022. Araneofauna associated with the horticultural ecosystems of Thrissur District, Kerala, India. *Serket*, vol. 18(3): 305-313.

3. **Ambalath Veetil Saidu Mohamed Shihabudeen**, Naduvath Krishnan Namboodiri Prasad & Ambalaparambil Vasu Sudhikumar 2019. A comparative study of spider diversities associated with Chitturpuzha, Kerala, India, before and after the deluge of August 2018. Proceedings of International seminar organized by Department of Zoology, KKTM Government College, Pullut. ISBN: 978 81 7255130 8.

4. Naduvath Krishnan Namboodiri Prasad, **Ambalath Veetil Saidu Mohamed Shihabudeen** & Ambalaparambil Vasu Sudhikumar 2019. Assessment of biocontrol potential of selected spiders. Proceedings of International seminar organized by Department of Zoology, KKTM Government College, Pullut. ISBN: 978 81 7255130 8.

5. Naduvath Krishnan Namboodiri Prasad, **Ambalath Veetil Saidu Mohamed Shihabudeen** & Ambalaparambil Vasu Sudhikumar 2023.Impact of agricultural practices in selected horticultural ecosystems in Thrissur District, Kerala.

Proceedings of National seminar organized by Department of Zoology, SNGS College, Pattambi. ISBN: 978 81 7255173 5.

6.**Ambalath Veetil Saidu Mohamed Shihabudeen**, Naduvath Krishnan Namboodiri Prasad & Ambalaparambil Vasu Sudhikumar 2023. Study of seasonal variation in the occurrence of jumping spiders (Salticidae) in selected riparian habitats of Bharatpuzha. Proceedings of National seminar organized by Department of Zoology KKTM Government College, Pullut. ISBN: 978 81 7255172 8.

PRESENTATIONS

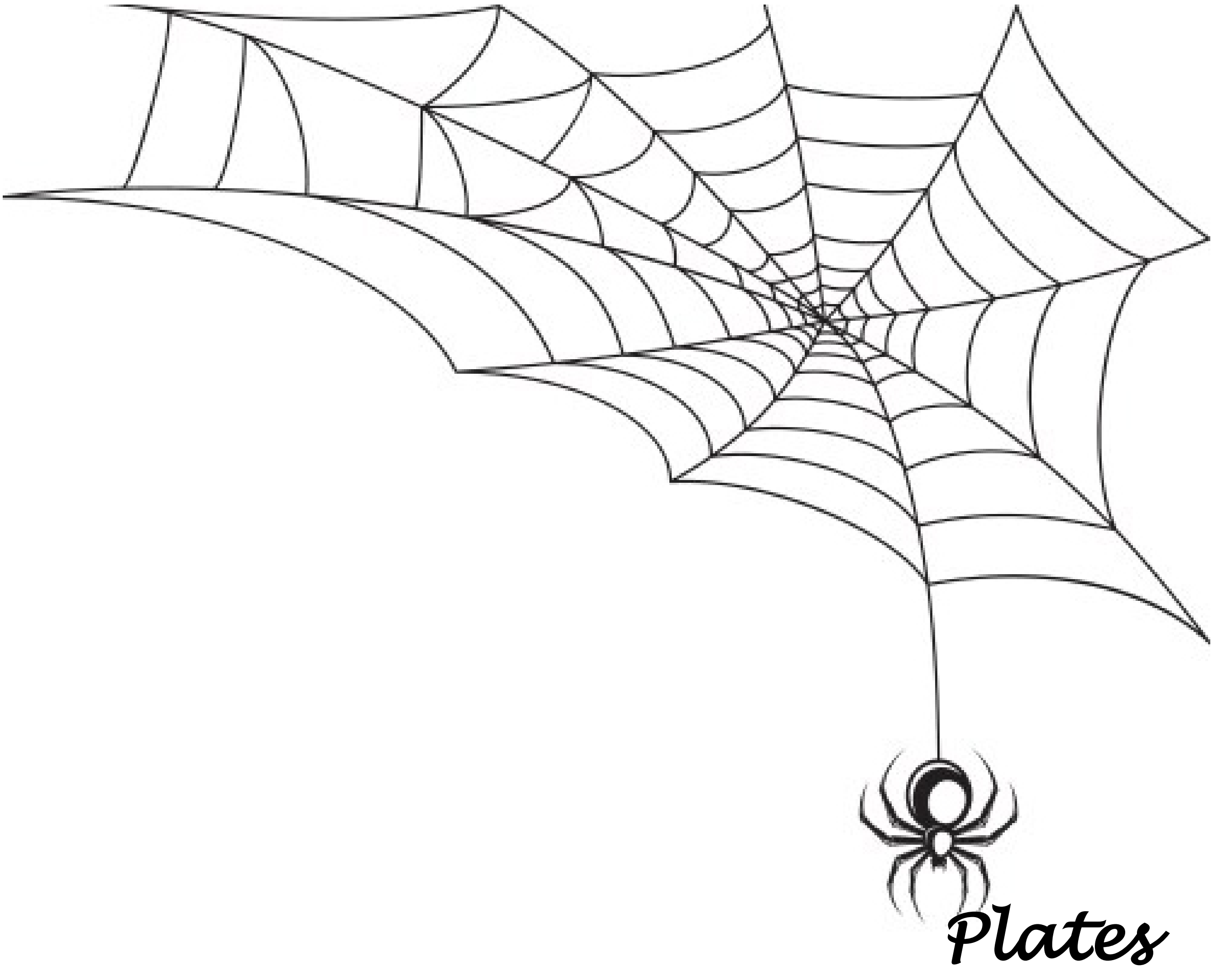
1. Presented a paper on "Diversity of spiders in Pullut mangrove, Kodungallur, Kerala". National workshop held on 16th and 17th October 2015, organized by Department of Zoology, St. Alolysius College, Elthuruth.

2. Presented a paper on "Diversity and seasonal fluctuation of spiders along the banks of Kalpathipuzha, Palakkad, Kerala". National seminar held on 25th and 26th November 2019, organized by department of Zoology, Maharajas College, Ernakulam.

3. Presented a paper on "A comparative study of spider diversities associated with Chitturpuzha, Kerala, India, before and after the deluge of August 2019". International seminar held on 30th October 2019, organized by Department of Zoology, KKTM Government College, Pullut.

4. Presented a paper on "Study of seasonal variation in the occurrence of jumping spiders (Salticidae) in selected riparian habitats of Bharatpuzha". International seminar held on 22nd and 23rd November 2023, organized by Department of Zoology, KKTM Government College, Pullut.

5. Presented a paper on "Study of the diversity and abundance of ground dwelling spiders along the banks of Gayathripuzha, Palakkad, Kerala, India". National seminar held on 15th October 2019, organized by Department of Zoology, University College Trivandrum.



Plates

PLATE 1

Collection methods

(1) (2) (3) (4)

1.Hand – picking, 2. Inverted umbrella method, 3. Sweep netting,
4. Litter sifting

PLATE 2

Study sites

(1)

(2)

1.Malampuzha – monsoon, 2. Malampuzha – pre monsoon

PLATE 3

Study sites

(3)

(4)

3. Chittur – monsoon, 4. Chittur – post monsoon.

PLATE 4

Study sites

(5)

(6)

5. Ottapalam – pre monsoon, 6. Ottapalam – post monsoon

PLATE 5

Study sites

(7)

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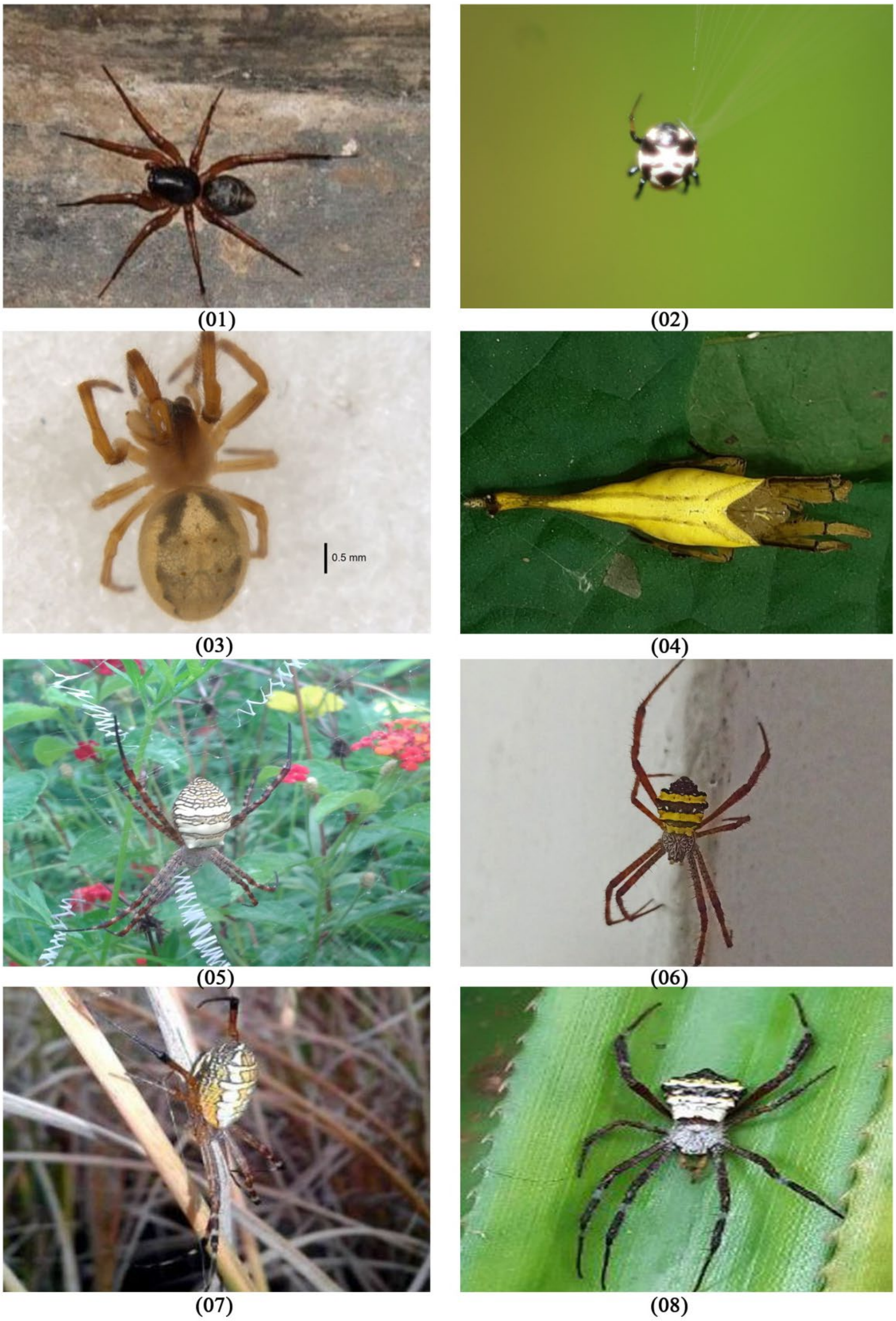
7. Kannadi – post monsoon, 8. Ponnani – monsoon

PLATE 6

Photographs of spiders collected



Family : Amaurobiidae – (1) *Amaurobius* sp.1, **Family :Araneidae** - (2) *Anepsion maritatum*, (3) *Araneus* sp.1, (4) *Arachnura angura*, (5) *Argiope aemula*, (6) *Argiope anasuja*, (7) *Argiope catenulata,* (8) *Argiope pulchella.*

PLATE 7

Photographs of spiders collected

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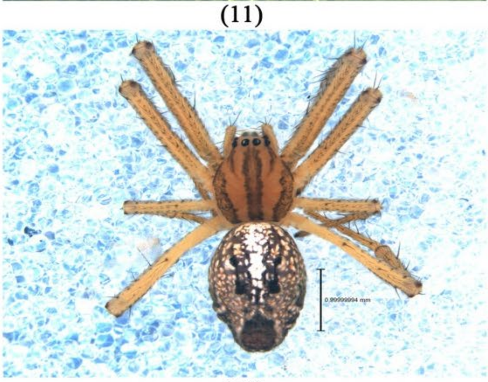

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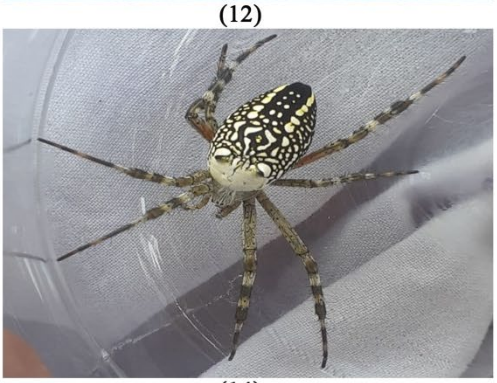

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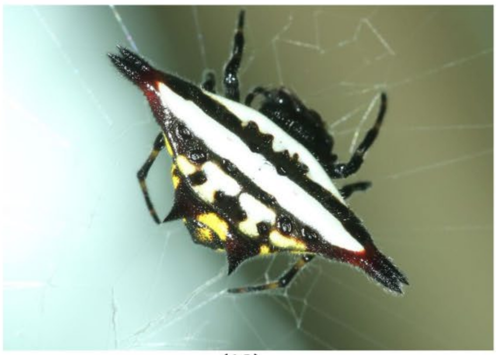
(9) *Argiope* sp.1, (10) *Chorizopes* sp.1., (11)*Cyclosa bifida*, (12) *Cyclosa* sp.1, (13) *Cyrtophora cicatrosa*, (14) *Cyrtophora moluccensis*, (15) *Eriovixia excelsa*, (16) *Eriovixia laglaizei*.

PLATE 8

Photographs of spiders collected


(17)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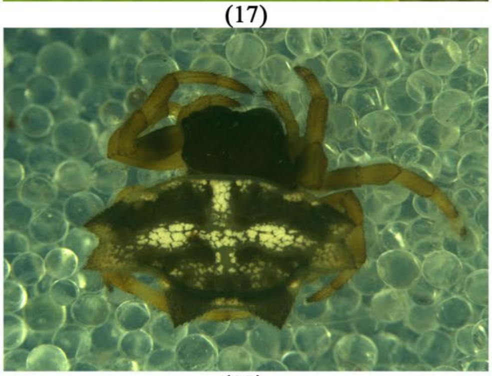
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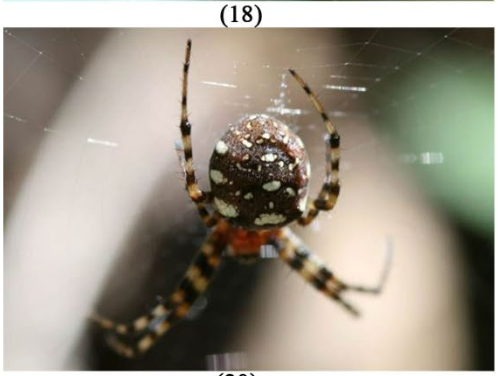
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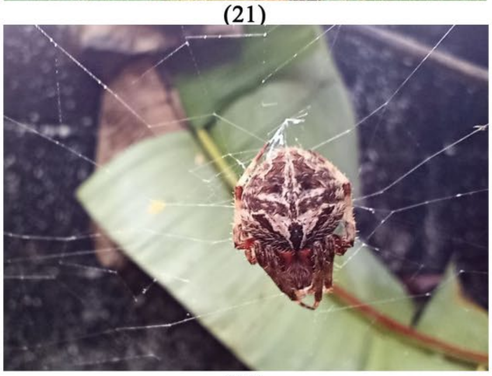
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(17) *Eriovixia* sp.1, (18) *Gasteracantha geminata* , (19) *Gasteracantha kuhlii*, (20) *Gea subarmata*, (21) *Neoscona bengalensis*, (22) *Neoscona mukerjei*, (23) *Neoscona vigilans*, (24) *Neoscona* sp.1

PLATE 9

Photographs of spiders collected

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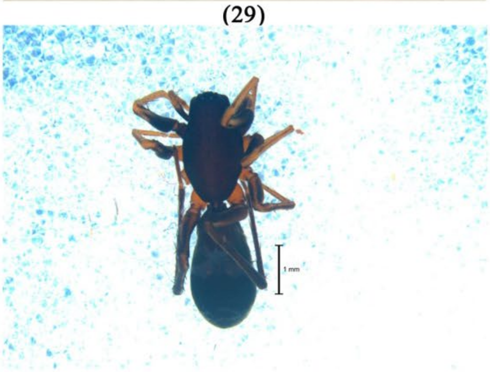

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(25*) Parawixia dehaani*, **Family : Cheiracanthiidae** – (26) *Cheiracanthium danieli*, (27) *Cheiracanthium melanostomum*, (28) *Cheiracanthium* sp.1, **Family : Clubionidae** – (29) *Clubiona drassodes*, **Family : Corinnidae** - (30) *Castianeira zetes*, (31) *Corinnoma* sp.1, **Family : Ctenidae** - (32) *Bowie cochinensis*.

PLATE 10
Photographs of spiders collected

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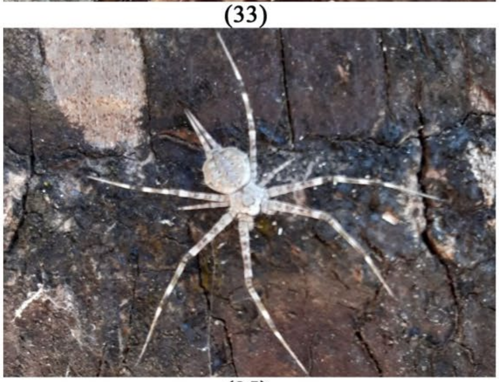

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Family : Eresidae – (33) *Stegodyphus sarasinorum*, **Family : Gnaphosidae** - (34) *Drassodes* sp.1, **Family : Hersiliidae** – (35) *Hersilia savignyi*, **Family : Lycosidae** – (36) *Hippasa agelenoides,* (37) *Pardosa pseudoannulata*, (38) *Pardosa sumatrana*, (39) *Pardosa* sp.1, **Family : Nephilidae** – (40) *Nephila pilipes.*

PLATE 11

Photographs of spiders collected


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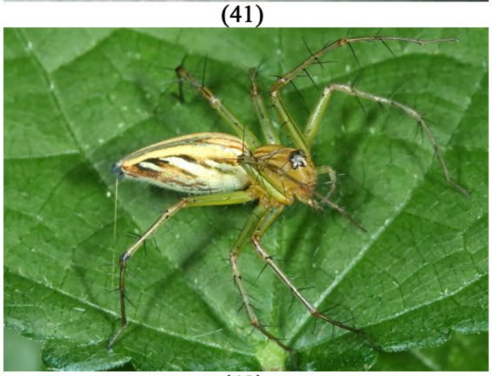
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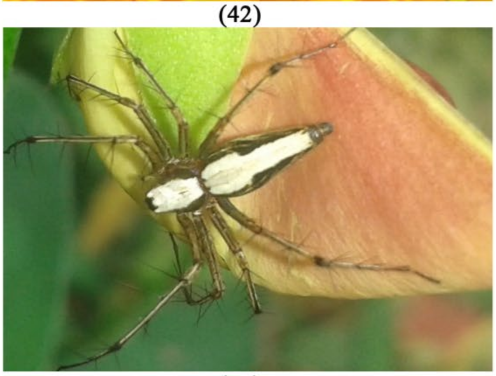
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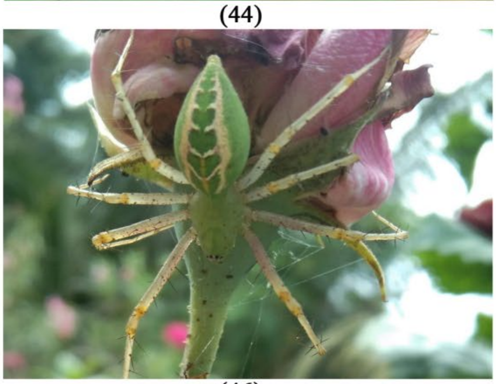
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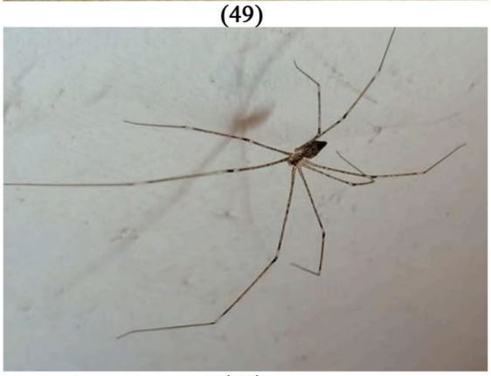
Family : Oxyopidae – (41) *Hamataliwa* sp.1, (42) *Oxyopes birmanicus*, (43) *Oxyopes javanus*, (44) *Oxyopes shweta,* (45) *Oxyopes sunandae*, (46) *Peucetia viridiana*, **Family : Philodromidae** – (47) *Philodromus* sp.1, (48) *Psellonus planus*.

PLATE 12
Photographs of spiders collected


(49) (50)




(51) (52)


(53) (54)


(55) (56)

Family : Pholcidae – (49) *Crossopriza* sp.1, (50) *Pholcus phalangioides* , (51) *Pholcus* sp.1, **Family : Dendrolycosidae**- (52) *Dendrolycosa gitae*, (53) *Dendrolycosa* sp.1, **Family : Salticidae** – (54) *Asemonea tenuipes*, (55) *Brettus cingulatus*, (56) *Carrhotus viduus.*

PLATE 13

Photographs of spiders collected

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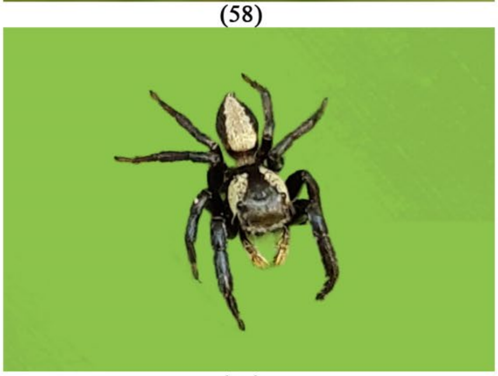

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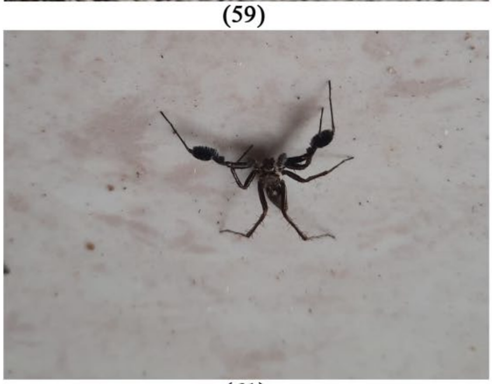

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(57) *Chrysilla volupe*, (58) *Epeus indicus*, (59) *Epocilla aurantiaca*, (60) Evarcha sp.1, (61) *Harmochirus brachiatus*, (62) *Hasarius adansoni*, (63) *Hyllus semicupreus*, (64) *Indopadilla insularis*.

PLATE 14

Photographs of spiders collected


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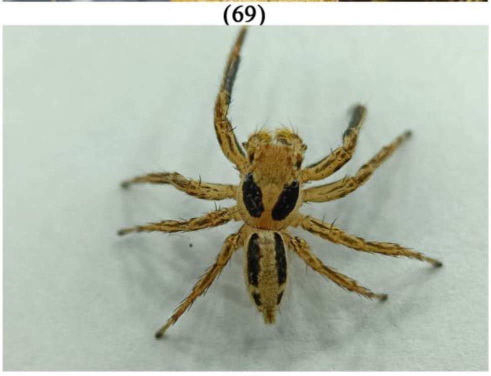
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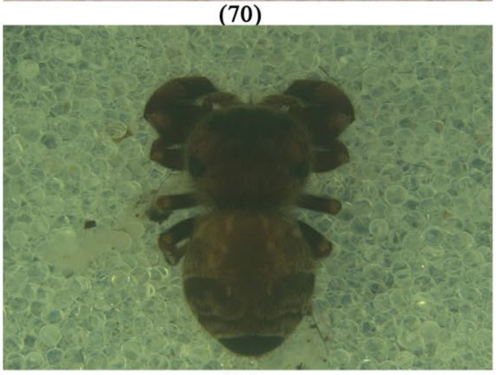
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(65) *Menemerus bivittatus*, (66) *Myrmaplata plataleoides*, (67) *Myrmarachne melanocephala*, (68) *Phidippus yasodharae*, (69) *Phintella vittata,* (70) *Plexippus paykulli*, (71) *Plexippus petersi*, (72) *Rhene flavigera*.

PLATE 15

Photographs of spiders collected


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(73) *Siler semiglaucus*, (74) *Telamonia dimidiata*, (75) *Thiania bhamoensis*, **Family : Scytodidae** – (76) *Scytodes fusca*, (77) *Scytodes pallida*, **Family: Sparassidae** – (78) *Heteropoda venatoria*, (79) *Thelcticopis* sp.1, (80) *Olios milleti*.

PLATE 16

Photographs of spiders collected

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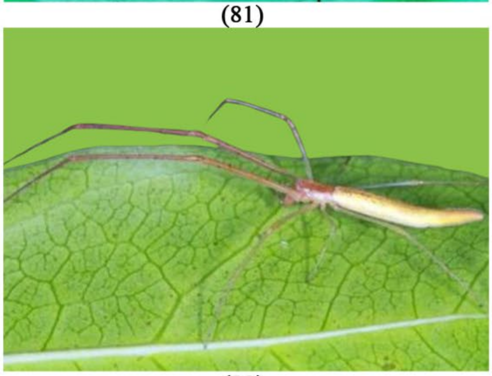

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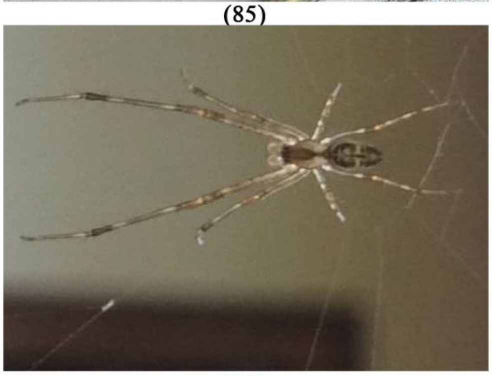

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Family : Tetragnathidae – (81) *Leucauge decorata*, (82) *Leucauge fastigata*, (83) *Tetragnatha javana*, (84) *Tetragnatha mandibulata*, (79) *Tetragnatha viridorufa*, (80) *Tylorida striata,* (81) *Tylorida ventralis*, **Family : Theraphosidae** – (82) *Annandaliella* sp.1.

PLATE 17

Photographs of spiders collected


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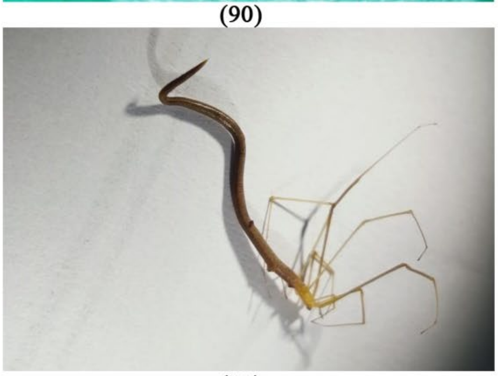
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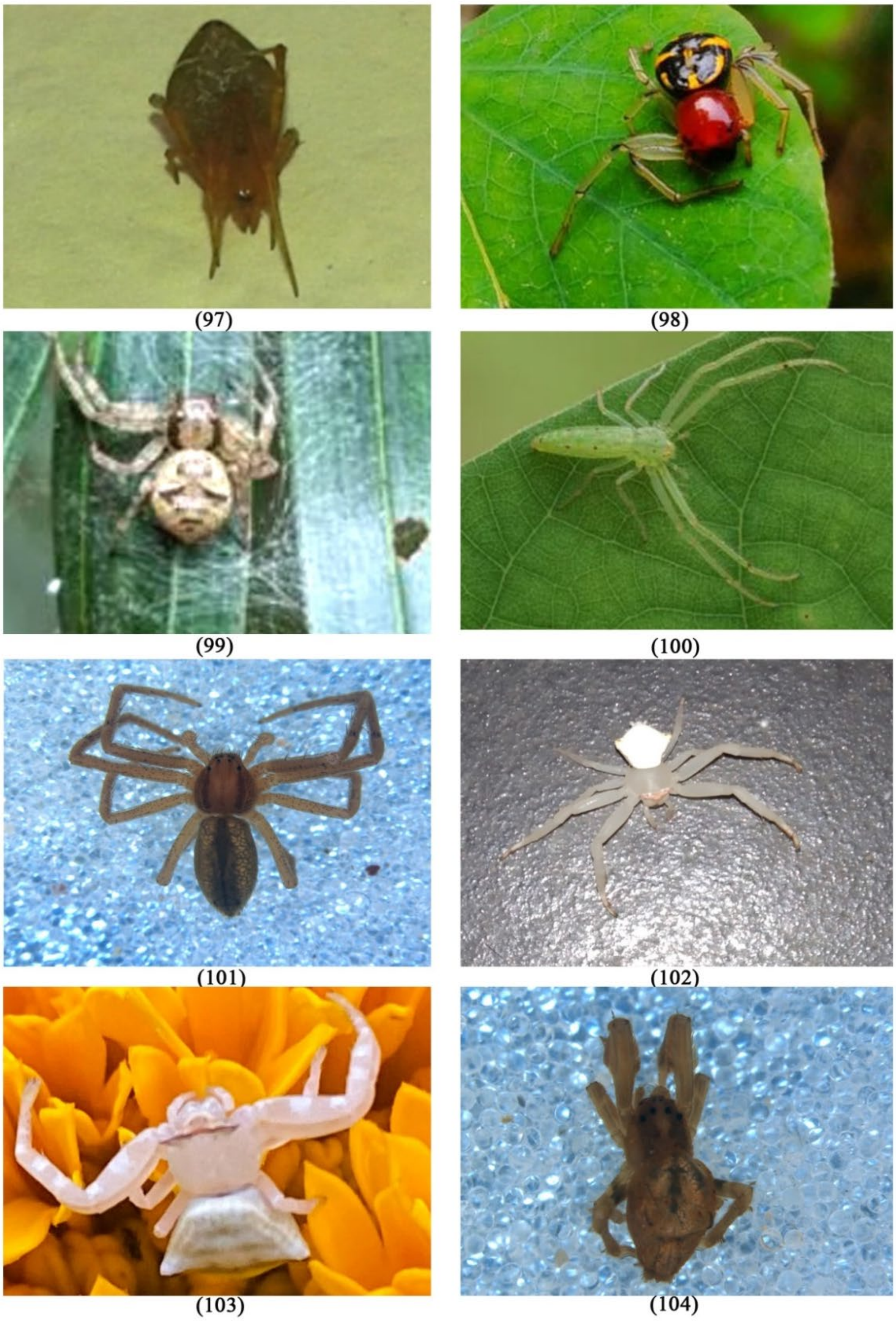
(95)


(96)

(89*) Chilobrachys* sp.1**, Family : Theridiidae** – (90) *Argyrodes flavescens* , (91) *Argyrodes sp.1,* (92) *Ariamnes flagellum*, (93) *Chikunia nigra*, (94) *Chrysso* sp.1, (95) *Meotipa* sp.1, (96) *Phoroncidia septemaculeata* .

PLATE 18

Photographs of spiders collected



(97) *Theridion* sp.1, **Family : Thomisidae-** (98) *Camaricus formosus*, (99) *Indoxysticus minutus*, (100) *Oxytate subvirens,* (101) *Runcinia insecta*, (102) *Thomisus lobosus*, (103) *Thomisus pugilis*, **Family : Uloboridae -** (104) *Uloborus krishnae.*