DIVERSITY AND ECOLOGY OF SPIDERS (ORDER: ARANEAE) IN MURIYAD KOL WETLANDS OF KERALA

Thesis submitted in fulfilment of the requirements for the degree of

DOCTOR OF PHILOSOPHY IN ZOOLOGY

Under the Faculty of Science
University of Calicut

by

NAFIN K.S.

Under the supervision of

Dr. SUDHIKUMAR A.V.
Assistant Professor
Department of Zoology
Christ College (Autonomous)
Irinjalakuda–680125, Kerala, India

JUNE, 2022

DECLARATION

I, NAFIN K. S., declare that the work embodied in the thesis titled, "Diversity and Ecology of Spiders (Order: Araneae) in Muriyad Kol Wetlands of Kerala" submitted to the University of Calicut in partial fulfilment of the requirements for the Degree of Doctor of Philosophy in Zoology is a bonafide record of the research work carried out by me under the supervision of Dr. Sudhikumar A.V, Assistant Professor, Department of Zoology, Christ College (Autonomous), Irinjalakuda. No part of the thesis has formed the basis for the award of any degree, diploma or other similar titles of any university.

NAFIN K. S.

Irinjalakuda
June 2022

Dr. SUDHIKUMAR A.V.
Assistant Professor

Centre for Animal Taxonomy & Ecology
Department of Zoology
Christ College (Autonomous)
Irinjalakuda, Kerala, INDIA - 680125
Mob: 0091-8547553174
Email: avsudhi@christcollegeijk.edu.in
https://sites.google.com/view/arachnology
http://www.christcollegeijk.edu.in

June 2022

CERTIFICATE

This is to certify that the thesis entitled **"DIVERSITY AND ECOLOGY OF SPIDER (ORDER: ARANEAE) IN MURIYAD KOL WETLANDS OF KERALA"** submitted to the University of Calicut in partial fulfilment of the requirements for the Degree of Doctor of Philosophy in Zoology is an authentic record of the work carried out by **Mr. NAFIN K. S.** under my supervision in Centre for Animal Taxonomy and Ecology, Department of Zoology, Christ College (Autonomous), Irinjalakuda, affiliated to the University of Calicut and no part of the thesis has formed the basis for the award of any degree, diploma or other similar titles of any University.

Dr. SUDHIKUMAR A.V.
(Guide)

Dr. SUDHIKUMAR A.V.
ASSISTANT PROFESSOR & RESEARCH SUPERVISOR
CENTRE FOR ANIMAL TAXONOMY & ECOLOGY
DEPARTMENT OF ZOOLOGY
CHRIST COLLEGE, IRINJALAKUDA, KERALA - 680 125

CHRIST COLLEGE
(AUTONOMOUS)
IRINJALAKUDA–680125, THRISSUR,
KERALA, INDIA

June 2022

CERTIFICATE

This is to certify that **Mr. NAFIN K. S.** has completed the research work for the full period prescribed under the Ph.D. ordinance of the University of Calicut. This thesis **"DIVERSITY AND ECOLOGY OF SPIDER (ORDER: ARANEAE) IN MURIYAD KOL WETLANDS OF KERALA"** embodies the results of his investigations conducted during the period at which he worked as a research scholar. I recommend the thesis to be submitted for the evaluation for the award of the degree of Doctor of Philosophy in Zoology of the University of Calicut.

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IRINJALAKUDA

UNIVERSITY OF CALICUT
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ASSISTANT PROFESSOR & RESEARCH SUPERVISOR
CENTRE FOR ANIMAL TAXONOMY & ECOLOGY
DEPARTMENT OF ZOOLOGY
CHRIST COLLEGE, IRINJALAKUDA, KERALA - 680 125

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To my parents,

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Diversity and Ecology of Spiders (Order: Araneae) in Muriyad Kol Wetlands of Kerala

Abstract

The Muriyad Kol wetlands, part of the Vembanad-Kol wetland complex, is one of the most valuable and threatened freshwater ecosystems of Thrissur district in Kerala. The landscape consists of low-lying, seasonally or perennial water logged area, plains, elevated, and crested areas that form a mosaic of diverse man-made and natural or semi-natural habitats, such as agricultural lands, fallow lands, riparian areas, home gardens, groves, streams, grasslands, and lakes. The primary objective of the present study was to make an inventory of the spiders inhabiting the different habitats of the wetland complex such as paddy fields, grasslands, banana plantations, mixed crops, uncultivated land and riparian habitats. The study also sought to understand diversity patterns and ecological processes at spatial and temporal scales. The sampling period was from September 2014 to December 2018, and methods such as hand searching, vegetation beating, sweep netting and litter sifting were used to collect the spiders. During the survey, 16,648 individuals belonging to 195 species, 135 genera and 34 families were collected. The majority of species are from the families Salticidae, Araneidae, Theridiidae and Tetragnathidae. Among them ten species are new to science. The results also include some redescriptions, first reports of five species and one genus from India, the first description of the male or female of three species and the revision of one genus. The results showed that habitat type, crops and management practices influence the abundance, diversity, and community structure of spiders. The most species-rich and diverse habitat in the study area was the uncultivated or semi-natural habitat, followed by riparian and mixed crops. Analysis of multiple site dissimilarity based on abundance and richness metrics showed that balanced variation and species replacement contributed more to overall dissimilarity. The study showed that the different habitats in the Muriyad Kol wetland supported distinct species assemblages. The sites belonging to paddy fields and grasslands showed significantly different species composition, although they share many of the species in their assemblages. The composition of spider guilds also showed significant differences in their proportions between habitats, both in terms of relative abundance and relative species richness. The study also provided a reduced list of indicator species for each habitat that will be useful for future ecosystem monitoring or can be tested with additional sampling. The studies on spider communities of paddy field showed that there was a general and consistent pattern in the community dynamics of spiders during the cropping seasons in paddy fields. There was also a significant influence of crop growth, cropping season and management practises on spider community abundance and richness. Species richness and diversity of spiders gradually increased with crop age and plant height in the paddy fields. Species turnover, on the other hand, showed a declining trend as most species appeared in the early stages of crop growth. The results showed that the vertical distribution of selected species such as *Oxyopes javanus, Pardosa pseudoannulata, Bianor angulosus, Tylorida striata, Tetragnatha javana* and *Araneus ellipticus* on the rice plants changed with the time of day. The study provided an insight into the diversity and dynamics of spiders in the wetland landscape. The discovery of new species during the study shows that our current knowledge of the spider fauna of the region is very limited and further sampling in the area could lead to the discovery of more species. Habitat-wise and seasonal differentiation of spider communities in the wetland landscape means that all biodiversity conservation efforts should focus on improving or mitigating the degradation of many habitats in the landscape. Similarly, maintaining and conserving natural or semi-natural habitats adjacent to crop fields may also serve as source habitat for various species that could ultimately improve natural pest control. They also have the potential to enhance biodiversity and prevent further degradation of existing rice fields. Environmentally friendly farming methods in paddy fields are a good way to increase the spider richness and abundance compared to conventional methods.

Key words: Araneofauna, Taxonomy, Rice agroecosystem, Ramsar site, Guild structure, Western Ghats region.

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Abbreviations

ADSH Division of Arachnology, Department of Zoology, Sacred Heart College, Thevara, Cochin, Kerala, India

AER Anterior Eye Row

ALE Anterior Lateral Eye

AME Anterior Median Eye

CATE Centre for Animal Taxonomy and Ecology, Christ College, Irinjalakuda, Kerala, India

DAT Days after transplantation

ENS Effective number of species

ETA Extra tegular apophysis

GLM Generalised linear model

GLMM Generalised linear mixed model

IPM Integrated Pest Management

MvGLM Multivariate generalised linear model

MEQ median eye quadrangle

MNHN Muséum national d'Histoire naturelle, Paris

MRS Mean rank shift

NCBS National center for Biological Sciences, Bangalore

OECM Other Effective area-based conservation measures

OUMNH Oxford University Museum of Natural History, London

PER Posterior Eye Row

PLE Posterior Lateral Eye

PLS Posterior lateral spinnerets

PME Posterior Median Eye

RAD Rank Abundance Distribution

TTA Theridioid tegular apophysis

1 | Introduction

> *"They are not brethren, they are not underlings; they are other nations, caught with ourselves in the net of life and time, fellow prisoners of the splendour and travail of the earth."*
>
> –Henry Beston

Biodiversity is all about the wealth and health of nature. Biodiversity has a major effect on the productivity and stability of natural ecosystems and the services they provide to humanity. How well ecosystems provide people with developmental and socioeconomic benefits depend on their condition and extent, and on the specific functions some species, groups of species or ecosystems perform (Roe, 2019). However, it is biodiversity that supports this extent, condition and abundance of these ecosystems and nature, and is essential to secure the flow of benefits that humans enjoy from nature. Ecosystem resilience depends on biodiversity and more diverse systems known to resist climate events (Cardinale et al., 2012; Isbell et al., 2015). Changing environmental conditions brought about by climate change, pollution, over-population and changes in land-use has put much pressure on diversity (Roe, 2019). Ecosystem's ability to function effectively and efficiently is undermined by the loss of diversity.

Biodiversity is currently declining at an unprecedented rate and the pressures faced continue to increase in a fast pace (Convention on Biological Diversity, 2020). Most of the earth's biodiversity is going to vanish without us ever knowing of its existence (Kolbert, 2014). Conservation efforts emphasising on protected areas and prioritisation of 'more important' species have prevented diversity loss to a large extent, including that of non-target species. Although, these efforts are recognised and supported worldwide as an effective way to curb diversity loss, there is growing consensus in the scientific community that it should not be limited to protected areas (Gray et al., 2016; Maxwell et al., 2020). Agriculture, together with grazing, forestry and other managed ecosystems cover around two thirds of the terrestrial surfaces of the planet, while only 5 percent of it is designated as protected areas (Patricia & Gilmour, 1995). Recently, new approaches in conservation such as the designation of 'other effective area-based conservation measures'(OECM) provides the opportunity to extend the range of protection beyond the protected areas (Donald et al., 2019; Dudley et al., 2018). These include some traditional agricultural practices, sacred natural sites (eg. Sacred groves), water catchments, hunting reserves, etc. (IUCN, 2019). Improved management of agriculture and forestry areas allow the possibility to safeguard more biodiversity than not doing so, but these areas will contain vastly different biodiversity than the original ecosystems they have replaced.

1.1 Wetlands–The Cradle of civilisations

Wetlands are the backbone of civilisations and play a vital role in human survival. The countless benefits or ecosystem services they provide ranges from freshwater supply, flood control, food production, tourism and recreation, building materials, biodiversity, groundwater recharge and climate change mitigation. Wetlands have an indispensable role in shaping the cultural heritage of humans; they influence our cosmological and religious beliefs, form the basis of many local traditions and source of aesthetic inspirations.

Wetlands are generally considered as transitional lands between terrestrial and aquatic ecosystems where the water table is at or near to the surface or land is covered by shallow water. The definition of wetlands, according to the Convention on Wetlands or Ramsar Convention (Ramsar, Iran, 1971), follows a broad approach and defines it as "Areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six meters"(Article 1.1) and "may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six metres at low tide lying within the wetlands"(Article 2.1). The inclusion of zones such as riparian and coastal zones with water bodies of both perennial and seasonal nature, was based on the understanding of how the abiotic and biotic factors are interconnected in these transitional biomes.

Wetlands make up a total area of 12.1 million km^2 and accounts for 40.6% of the total global ecosystem services value (Costanza et al., 2014; Ramsar Convention on Wetlands, 2018). It is apparent that our knowledge on many aspects of wetlands is limited amid the growing pressures that it faces. Costanza et al., 2014 estimated that we lost US$ 7.2 trillion per year in the value of ecosystem services due to changes in tidal marshes and mangroves, and US$ 2.7 trillion due to changes in swamps and floodplains.

Many wetland dependent species are in decline and many of them face the threat of extinction. Since 1970, we have lost 35% of the global wetlands due to unsustainable use and over-exploitation, but an almost commensurate increase of 44% in area under human-made wetlands (Ramsar Convention on Wetlands, 2018). In Asia, human-made wetlands mainly constitute paddy fields, but they also include uses such as fish and shrimp ponds, farm ponds, other irrigated agricultural land, salt pans, reservoirs, gravel pits, sewage farms and canals. It is important to note that the increase in its cover does not offset the loss in natural wetlands or consequent loss in ecosystem functions and services (Gardner et al., 2015). Inland wetlands including river systems faces a greater threat from habitat destruction, urbanisation, encroachment and diversion of water. Globally, the extent of inland wetlands declined by 69–75% during the 20th century and the decline of coastal wetlands was around 62–63% (Davidson, 2016). According to the Ramsar Convention on Wetlands 2018 report, 25% of inland wetland-dependent species out of 18,000 species surveyed are globally threatened and another 6% being Critically Endangered. In Kerala, vast expanses of wetlands were reclaimed for rice cultivation and this resulted in the substantial decline of natural wetlands. Over the decades, rice cultivation has shifted from local traditional environmental friendly practices to intensive management practices that involve massive quantities of fertilizers and pesticides. This has affected both terrestrial and aquatic biodiversity in the wetlands negatively (Chen et al., 2013; Ramasamy, 2016; Simpson et al., 1994; WISA, 2013).

1.2 Biodiversity in traditional agroecosystems

Freshwater wetlands are one of the most valuable and most threatened ecosystems on the planet (Costanza et al., 2014). Globally, freshwater wetlands continue to shrink at an alarming rate, mainly due of reclamation for agriculture. Large expanses of floodplains and wetlands are currently under large-scale cultivation of paddy, corn and other crops. The rapid pace of disappearance of natural wetlands causes substantial loss in biodiversity (Chen et al., 2013), and the need to conserve what is left of it has called for new strategies in conservation and management. With the loss of natural wetlands, farmed wetlands may be considered as surrogate for natural wetlands. Additionally, traditional agroecosystems have been identified as a complementary approach to protected areas (Patricia & Gilmour, 1995). Traditional farming methods which follow ecosystem-based approaches that are known to improve sustainability of the production systems and are resilient to climate fluctuations (Patel et al., 2020; Patricia & Gilmour, 1995). These organic agriculture practices are vividly different from conventional agriculture, that they support many more wild species than the latter (Veličković et al., 2016). It has become increasingly apparent that sustainable agriculture and forestry incorporating traditional practices, improved regulation and prevention of environmental risks and greater recognition of protected areas alongside agroecosystems in novel landscapes are key to ensuring the protection of biodiversity, especially arthropods (Batzer & Wu, 2020; Batzer, Sutter, et al., 2019; Culliney, 2013; Gabriela A. Cardona-Rivera et al., 2021; Mercer et al., 2017; Samways et al., 2020).

1.3 Terrestrial arthropods in Wetland ecosystems

Arthropods are the most diverse groups in wetlands(Costanza et al., 2014), and considered as an important influence on the ecology of these systems (Batzer, Cooper, et al., 2014). Yet, they are seldom studied and their role in wetland ecosystems are underappreciated. Myriapoda, Arachnida (mostly Araneae), Collembola, Carabidae, Hymenoptera, Lepidoptera, Coleoptera, Hemiptera, Staphylinidae and Diptera are the common groups of arthropods found in wetlands (Batzer & Wu, 2020). Terrestrial arthropods are more diverse than aquatic arthropods. The wide range of habitats provided by the wetlands presents opportunities for various unique faunas to associate with plant substrates, ground litter and soils, peatlands and swamps. They play important roles in food webs and as bioindicators of ecological health. Terrestrial arthropods unlike their aquatic cousins are typically highly mobile and are capable of avoiding flooding by running, flying, ballooning, climbing to higher grounds or emergent vegetation, using floating woods as rafts. Their success in wetland ecosystems does not necessarily mean that they have sophisticated adaptations to wetland conditions, in fact most of them possess rudimentary adaptations (Adis & Junk, 2002).

One of the many important roles arthropods play in the functioning of wetland ecosystems is the top-down effect on herbivorous arthropods exerted by predatory arthropods like spiders, beetles and parasitic wasps, keeps herbivory in check. This is brought about by the interactions between plants, herbivores and predators, and this remains stable in natural ecosystems (Aschehoug et al., 2015). Another important role is the breakdown of detritus by arthropods in the wetland ecosystems, which happens faster on the surface rather than the underground because of the lack of termites in inundated areas. Moreover, the changes in the soil structure, nutrient dynamics and soil properties brought about by arthropods, especially ants and termites, greatly influences the overall functioning of the ecosystem as a whole (Batzer, Wu, et al., 2016). It has many implications in the context of changing global climate as it changes spatial and temporal heterogeneity of soil gas emissions by altering the carbon and nitrogen cycles in the wetland soil (Wu, Batzer, et al., 2013; Wu, Lu, Jiang, et al., 2009; Wu, Lu, Wu, et al., 2013).

1.4 Spiders in wetland agroecosystems

Spiders (Araneae) are very abundant and diverse in wetlands, especially in the floodplain and riparian habitats, because of the emerging aquatic insects from water bodies. Like other terrestrial arthropods, many spiders species have a variety of unique strategies and adaptations to survive in wetland ecosystems. But some generalist species of spiders also cope well in many habitats of the ecosystems, especially in riparian habitats and in grasslands during dry seasons. Wetland specialists have adapted well to live close to water bodies, and their many adaptations allow some species to walk on the surface of water, dive under water, prey on aquatic creatures and migrate to emergent vegetations during floods. Other web-building wetland specialist spiders construct their webs close to water bodies like perennial streams, rivers, lakes and man-made wetlands. These abilities enable spiders to recolonise a flooded habitat rapidly (Ballinger et al., 2005).

Spiders in wetlands are typically associated with plants such as trees, shrubs, herbs and grasses. Therefore, spiders are generally affected by changes in vegetation structure, plant species composition, plant diversity and density (Holmquist et al., 2011; Hore & Uniyal, 2008; Lafage et al., 2015; Malumbres-Olarte et al., 2013; Popescu et al., 2021). Typically, the relationship is positive, ie. spider diversity and abundance increases with increase in habitat heterogeneity and density. Sometimes, species richness of spiders in wetlands exceed that in adjacent managed upland areas (Greenwood et al., 1995). The spider species assemblages also differ between natural swamps and managed plantations (Hore & Uniyal, 2008).

Spiders are major generalist predators in agricultural fields, but the majority of their prey consists of arthropods like Diptera, Hemiptera, Hymenoptera, Collembola, Coleoptera, Lepidoptera, Orthoptera and Araneae (Kajak et al., 1968;

Nyffeler, 1999; Robinson & Robinson, 1970; Robinson & Robinson, 1973; Robinson & Robinson, 1974). Agriculture provides alternative sources of prey, which in turn depend on decaying organic materials in the field. However, agricultural landscapes support only about half of the arthropods including spiders that is present in natural wetlands (Chen et al., 2013). Various management activities like mowing vegetation, reed cutting and grazing harm the spiders (Cattin Blandenier et al., 2003; Entling et al., 2005). Different families, genera or species use various foraging strategies and exhibit specialisations with respect to microhabitat, prey items and activity periods, which together with broad food spectrum enable them to coexist even during periods of low prey availability in agricultural fields.

Spiders and insects dominate the arthropod community of paddy fields and spiders are considered to be an important biological control agents in rice fields. Families such as Tetragnathidae, Lycosidae, Oxyopidae, Salticidae and Araneidae represents the majority of the spider fauna in paddy fields (Baba & Tanaka, 2016; Jung et al., 2008; Rodrigues & Mendonça, 2009). Centuries of rice cultivation around the world has allowed the predators like spiders and rice insect pests to establish a stable relationship (Ooi & Shepard, 1994). Tropical lowland irrigated paddy fields have been shown to support greater number of species of spiders (Sebastian, Mathew, et al., 2005; Way & Heong, 1994), and sometimes the abundance of spiders may be greater than those of the insect pest populations in the field (Settle et al., 1996). However, spiders together with other predators have beneficial effect in reducing population of hemipteran pests in rice or wheat growing areas with little or no pesticide usage (Kiritani et al., 1972; Nyffeler & Benz, 1987; Nyffeler & Benz, 1988; Sunderland et al., 1986). The landscape surrounding the fields influences the abundance and diversity of predators by providing alternative habitats for organisms, for both predators and prey, when the arable fields are unfavourable (Betz & Tscharntke, 2017; Katayama et al., 2015; Tscharntke et al., 2007; Tsutsui et al., 2016). The landscapes that surround the wetlands vary between regions of the world, and because of this the composition of spiders may completely differ among the paddy fields of different regions. Diverse natural or semi-natural habitats near crop fields as well as more complex landscape structure with comparatively undisturbed habitats such as fallow lands or hedgerows, can provide additional refuges and source habitats for recolonisation (Betz & Tscharntke, 2017; Bianchi et al., 2006). Encouraging high levels of natural biological control by reducing pesticide use and increasing heterogeneity is the best strategy to conserve the diversity of existing species in agroecosystems, which is important for biological pest control. Rice-paddy fields integrated in heterogeneous landscapes supports high populations of spiders between cropping seasons thereby improving biological control of pest species in rice paddies (Radermacher et al., 2020). Here, I attempt to explore the diversity of spider fauna of a coastal fresh water wetland ecosystem dominated by paddy fields and mixed crops in Kerala state, India.

1.5 Vembanad-Kol wetlands

Wetlands account for 4.6% of the geographical area of India with an area of 15.26 million hectares, and hosts 49 Ramsar sites covering a surface area of 1.09 million hectares (The Ramsar Convention Secretariat, 2022). Ashtamudi, Sasthamkotta and Vembanad Kol wetlands are the three Ramsar sites in Kerala. Vembanad Kol wetland, the largest of the three, is spread over an area of 151,250 hectares and spans along the coastline of Alappuzha, Ernakulam and Thrissur districts. It is the second largest Ramsar site in India after the Sunderbans in West Bengal . The total extent of the wetland complex is estimated at 1,780 km^2. The Vembanad Kol wetland complex is the largest brackish, humid tropical wetland ecosystem in the south-west coast of India, and composed of Vembanad estuary which is flanked by river floodplains of Kuttanad and Kol, in south and north respectively (Chandra et al., 2021). An intricate network of 10 rivers and many man-made channels feed the wetland, interspersed with river estuaries and mangrove swamps. Rivers Periyar, Chalakkudy, Achencoil, Pamba, Manimala, Meenachil, Muvattupuzha, Keecheri, Puzhakkal and Karuvannur are the major rivers that drain into the estuary, with a combined drainage basins spanning 15,554 km^2 area.

The wetland complex is vital for the survival of millions of residents of the region, supporting thickly populated coastal areas of the three districts and indirectly supporting the neighbouring districts. The major anthropogenic pressures on the wetlands started in the late 19th century with the establishment of the Cochin port, and the subsequent developments in the later century catalysed the economic development of the region. Large areas of natural floodplain marshes and swamps were replaced by agricultural lands, mostly paddy fields. By the mid-20th century, shallow regions and marshes in the Kuttanad and Kol wetlands were converted into polders or *padashekharams*, achieved by creating bunds gated with indigenously developed pumps called *petti and para.* This enabled the provision of cultivation by evacuating water out of the polders, but it requires intricate water management practices. In addition, many spillways, regulators and locks were constructed for regulating inflows and prevent salinity intrusions from the sea.

The later decades of the 20th century saw rapid industrial developments in the region, primarily on the banks of river Periyar, and many major industries were established in the Ernakulam district. Industrial pollution, municipal sewage discharge, over-use of pesticides and fertilizers, unsustainable tourism, uncontrolled urbanisation, habitat loss, reclamation, alteration of natural hydrological regimes and many others pose increasing threat to the wetlands (WISA, 2013). These changes have resulted in the fragmentation of once extensive regime of estuaries and network of river floodplains extending between Thrissur in the North and Arattupuzha on the South which existed till the beginning of the 19th century.

The Vembanad-Kol wetlands supports high habitat diversity that support a huge array of species. Many wetland-dependent organisms find refuge in its varied habitats, which includes tidal creeks, mangrove patches, riverine floodplains, lowland swamps and human-made wetlands. The salinity gradient formed as a result of the interaction between freshwater and coastal environments provides conductive conditions for many migratory species. Several species of economically important fishes, prawns, migratory birds and innumerable other groups of animals flourish in these ecosystems. Currently, biodiversity persists with minimal threat in tiny protected areas/refugias such as Pathiramanal Islands, Kumarokom bird sanctuary, Mangalavanam bird sanctuary and a few sacred groves spread around the wetland complex. But, our knowledge of the biodiversity of these unique wetland is still a long way from complete. Systematic inventories and assessment of diversity of many lower order fauna and flora are lacking. Our current understanding of the biodiversity of the wetlands is mostly based on information about groups such as waterbirds, mangroves, mangrove associates, planktons, crabs, clams, bivalves, mussels and fish (Cleetus, 2016; CMFRI, 2005; ICMAM, 2002; Jayan & Sathyanathan, 2010; Jayson & Easa, 2000; Jhon et al., 2009; KFRI, 2007; Kurup et al., 2004; Roy & Nandi, 2008).

Today, man-made wetlands in the form of Paddy fields or *padashekharams* makes up a sizeable portion of the Vembanad and Kol wetlands. Still, many habitats in the riverine floodplains and estuarine ecosystems harbour high diversity of terrestrial invertebrates, including many resilient to anthropogenic disturbances. Spiders are most abundant among them and several species are known to be wetland specialists. Yet, this group received no attention whatsoever until the dawn of 21st century, because of the dearth in taxonomical knowledge and professionals. Recent doctoral works by Sudhikumar, 2007 explored the diversity and studied the bionomics of certain spiders in the paddy fields of Kuttanad region. Whereas, Jobi, 2018 investigated the spider fauna of the estuarine islands of the Vembanad estuary, namely Pathiramanal and Perumbalam. They contributed significantly to the knowledge base on the spider fauna of the ecosystem and provides a benchmark data for future research. These studies limited their scope to the Vembanad region of the wetland complex.

1.6 Muriyad kol wetlands

Wetlands of the Kol or 'Kole'are similar in nature to the Vembanad wetlands. They are characterised by a network of natural and man-made channels interconnecting vast expanses of reclaimed floodplain marshes, brackish and freshwater lakes and man-made wetlands. Kol wetlands are originally floodplains of the Keecheri and Karuvannur rivers and cover an area of about 425 km^2. Muriyad kol, also called Muriyad kayal, is a fresh water wetland which forms a greater portion of the south Kol lands (Nayar & Nayar, 1997). It is composed of low-lying seasonal or perennial water logged area, plains, elevated and crested areas lands, and an elevation range of 0–20 m mean sea level (John Thomas et al., 2003). The highly fertile plains and some of the surrounding elevated areas of the Muriyad Kol are dominated by paddy fields, and grown as three crop (Mundakan, Virippu, Puncha), two crops (Mundakan and Puncha), and single crop cultivated area (Puncha) depending on the elevation of the landscape. Most of the wetland area has been reclaimed for mixed crops and other crops such as coconut, tapioca, areca nut and plantain. Currently, the wetland is a mosaic of various man-made and natural or semi-natural habitats such as agricultural plots, fallow, uncultivated elevated areas, riparian, home gardens, groves, streams, grasslands and lakes. The complex landscape structure of the wetlands may support a diverse spider fauna and a range of habitats for them that function as source habitats for recolonisation and refuges for survival during unfavourable conditions.

In this thesis, I aim to provide a faunistic inventory of the spiders inhabiting the Muriyad Kol wetlands and the landscape associated with it. It elucidates how various habitats in the landscape effects the diversity, community structure and composition of spider species assemblages, and seasonal changes happening in the community. Special emphasis was given to the spider fauna of paddy fields.

1.7 Research Objectives

The thesis addresses the following main research objectives:

1. To conduct a survey of spiders in the different habitats of Muriyad Kol wetlands.

2. To compare the diversity and composition of spider assemblages in the different habitats.

3. To study the habitat associations of spiders.

4. To elucidate the effect of cropping seasons on the community composition and abundance of spiders in the paddy fields of the wetlands.

5. To study the guild structure and vertical stratification of spiders.

1.8 Structure of thesis

The main objectives are discussed in the following chapters.

Chapter 2: Study area

This chapter presents a description of the study area, Muriyad Kol wetland. The delimitation of different habitats and details of collection sites are mentioned, with maps of the region.

Chapter 3: Survey of spiders

This chapter presents the results of exploratory survey of spider fauna in different habitats of the wetland landscape is presented. The chapter presents the taxonomic treatment of the collected spiders, including the description of new species, new records from India and redescriptions of some spiders. It also includes supporting illustrations, digital microphotographs and digital photographs of more than hundred live spiders collected during the survey. A checklist of spiders collected from the region is also provided.

Chapter 3: Diversity and community structure of spiders

The chapter elucidates the diversity and community structure of the spider communities in the different habitats of the Muriyad Kol wetland landscape. It details the results of studies into the effects of various habitats and seasons on the abundance, richness and diversity of spiders in the wetland. The chapter describes the β diversity among habitats in terms of variation and turnover, and also among different seasons, namely, pre-monsoon, monsoon and post monsoon. Additionally, the differences in community structure of spider assemblages between the habitats is also presented.

Chapter 4: Composition and habitat associations of spiders

Here the aim is to elucidate the associations of spider assemblages to different habitats, namely paddy, grasslands, banana plantations, mixed crops, uncultivated land and riparian areas in the Muriyad Kol wetland landscape. The variations in guild composition of spiders among different habitats is discussed. A list of potential indicator species of these habitats are also given.

Chapter 5: Paddy field spiders: Turnover, temporal dynamics and vertical stratification

Here, the attention is given to the spider communities of the paddy fields of the wetland. It details the diversity and seasonal variation of spiders collected from various cropping seasons of rice in the region. Variations in guild composition among the seasons is discussed. Additionally, results of vertical stratification of selected spiders is also detailed in this chapter.

1.9 Limitations

The results presented and analysed in chapters 3 to 5 are mostly based on semi-quantitative data, samples from pitfall traps were not considered in this study. The habitats considered in the study were not differentiated by microclimatic variables, but by vegetation or crops. In addition, the knowledge gap in spider taxonomy is large and some species mentioned in the study could therefore not be determined to species level.

2 | Study Area

2.1 Kol wetland

The Kol or Kole wetland is one of the most important freshwater wetlands of Kerala and forms an important rice growing area in the state. The Kol is a unique wetland geographically located in Mukundapuram, Chavakkad and Thrissur taluks of Thrissur district and Ponnani thaluk of Malappuram district. The wetland is flanked by laterite Its low-lying areas are 0.5 to 1 m below mean sea level, located between 10°20´and 10°40´N latitude and between 75°58´to 76°11´E longitude (Johnkutty & Venugopal, 1993). The Malayalam term 'Kol'refers to bumper yield or high returns from rice crop in the region. The wetland consists of the Thrissur Kol, which lies between Velukkara in the south on the banks of the Chalakudy River in the Mukundapuram taluk to Mullassery in the Chavakkad taluk and Tholur-Kaiparama in the Thrissur taluk, and the Ponnani Kol, comprising the area from Chavakkad and Choondal to Thavannur, covering the Chavakkad and Thalapally taluks of Thrissur district and the Ponnani taluk of Malappuram district (Johnkutty & Venugopal, 1993). The Kol is essentially a saucer-like landscape with elevated laterite lands on the east and west.

Most of the Kol wetland is seasonally flooded during the monsoon season for up to six months a year. The flood water is mainly brought into the wetland by the Karuvannur and Keecheri rivers and eventually drains into the sea. This floodwater brings enormous nutrient-rich alluvium, which is deposited in the wetland, increasing crop yields (John Thomas et al., 2003). The wetland has a network of interconnected canals for irrigation and drainage, which facilitate rice cultivation. The Karuvannur river divides the Thrissur Kol into North and South Kol. The Thrissur North Kol is a stretch of low lying lands extending from the Karuvannur River in the south to Keecheri river in the north, while the area extending from the south bank of Karuvannur River to Vellangallur region is called the 'South Kol'. The South Kol is further divided into Karalam fields, Chemmada Kayal and Muriyad Kayal. The Thuppanthodu and Nedumthodu canals connect these fields to the Karuvannur river and drain or irrigate these wetlands. The Panoli canal flows through the north and north-west of the Urban center Irinjalakuda and drains into the Chemmanda Kayal. The Muriyad Kol is connected to the Chemmanda Kayal by the Muriyad–Moorkanad canal (M. M. canal).

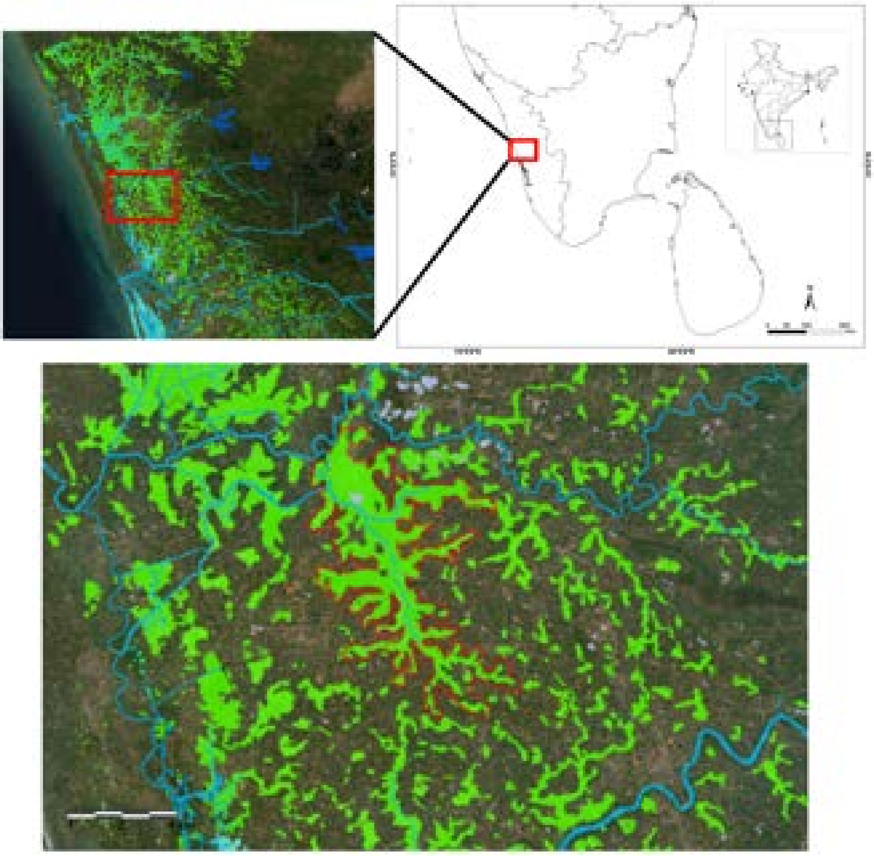

Figure 2.1: Muriyad Kol wetland in the Thrissur district of Kerala, India. The study area is highlighted in red. Blue—rivers/canals, green—wetlands/paddy fields (Adapted from Sebastian, Joseph, et al., 2019, http://arcg.is/1HmKGm).

2.2 Muriyad Wetland

Muriyad Wetland, locally known as Muriyad Kayal, is a freshwater wetland that extends from Thazhekad region in the south to Karuvannur to the north, with a total field area of 1,215 hectares (Fig. 2.1). It is situated in the villages of Muriyad, Porathissery, Velukkara, and Parappukkara Panchayaths, as well as the municipality of Irinjalakkuda (Fig. 2.3). The Nedumthode or Thamaravalayam canal runs through the centre of the wetland and functions for discharge of floodwater and letting irrigation water into the fields. The M. M. canal also functions as a outlet for the flood water. The relief of the region ranges from 5 to 22 meters above mean sea level.The floodplains of the Karuvannur River cover the northern half of the area. During the south-west monsoon, flood water levels can peak to 5.5 metres (John Thomas et al., 2003). The Muriyad Kol wetland has a general gradient towards the northwest and the surrounding landscapes contain elevated areas and mounts with mostly laterite soils such as Mulungu (15 metres above sea level), Anadapuram (20 metres), Alathoor, Thommana (20 metres) and areas in the southwest with elevations between 10 and 22 metres. Five micro-watersheds, Parappukkara (17 km^2), Anandapuram (11 km^2), Pullur (11.25 km^2), Avittathur (5.75 km^2) and Thazhekkad (12 km^2), form the wetland (John Thomas et al., 2003). The total water shed areas adds up to 57.75 km^2. The Parappukkara and Anandapuram watersheds contain most of the low lying areas including the deepest parts of the wetlands such as Kokrachal and Konthipulam.

An area of about 14.96 km^2 (25.9%) of the wetland is perennial and seasonal water bodies (John Thomas et al., 2003). Paddy cultivation has been carried out on 13.9% of the waterlogged area through dewatering and the construction of earthen embankments. However, the dominant land use of the region is mixed crop cultivation (56.33%), which was followed by paddy fields (21.48%). Some wetlands have been reclaimed for other land-use purposes including build up land (John Thomas et al., 2003). The Parappukkara region has several perineal water bodies as a result of commercial clay mining in the past, and the majority of terrain is not arable.

2.2.1 Climate

The Muriyad Kol wetland has mild climatic conditions. A minimum temperature of 21°C and a high temperature of 38°C were recorded in the area. During the study period of 2014 to 2018, the region received an average yearly rainfall of 2520 mm. The south west monsoon, which normally begins in early June, is responsible for the majority of rainfall. The wettest months in the region are July and June. Some rainfall is also brought by the north east monsoon. The humidity ranged from 80–90% during Monsoon and 65–85% during post monsoon and pre monsoon.

Table 2.1: Sampling sites and habitats of the Muriyad Kol wetland landscape.

No.	Site name	Coordinates	Description
Paddy fields			

Continued on next page

Table 2.1 – (continued) Sampling sites in the Muriyad Kol wetland landscape.

No.	Site name	Coordinates	Description
1	L-1	10°2257.2N 76°1356.7E	Konthipulam
2	L-2	10°2106.9N 76°1506.2E	Muriyad
3	L-3	10°2151.2N 76°1452.6E	Muriyad
4	L-4	10°1944.9N 76°1600.2E	Thazhekad, Edamana padam
5	L-5	10°2321.7N 76°1432.9E	Konthipulam
6	L-6	10°2422.2N 76°1510.8E	Rappal
7	L-7	10°1951.3N 76°1625.5E	Thazhekad
8	L-8	10°2024.8N 76°1457.3E	Avittathur, Punna padam
9	L-9	10°1948.9N 76°1657.8E	Thazhekadu chira,
10	L-10	10°1954.4N 76°1635.9E	Thazhekad, Peripadam
11	L-11	10°2321.3N 76°1419.2E	Konthipulam, Kadumgadu padam
12	L-12	10°2313.4N 76°1401E	Karingattipadam
13	L-13	10°2225.1N 76°1351.7E	Madayikonam
14	L-14	10°2237.6N 76°1422.6E	Valiya kol padam
15	L-15	10°1703.4N 76°1307.7E	Karattukulam padam
Grasslands			
16	Grs-A	10°19’41.9”N 76°16’03.6”E	Thazhekkad
17	Grs-B	10°23’32.1”N 76°13’46.1”E	Nedumbal
18	Grs-C	10°24’22.8”N 76°14’47.6”E	Parappukkara
Banana plantations			
19	Bn-A	10°23’19.3”N 76°14’33.1”E	Konthipulam thuruth
20	Bn-B	10°20’07.2”N 76°16’28.7”E	Thazhekkad
21	Bn-C	10°24’37.0”N 76°14’17.9”E	Mulangue
Mixed crop			
22	Mxd-A	10°24’00.7”N 76°14’22.1”E	Nedumbal
23	Mxd-B	10°25’25.9”N 76°14’13.3”E	Mulangue
24	Mxd-C	10°19’46.7”N 76°16’50.4”E	Thazhekad
Uncultivated			
25	Uc-A	10°20’26.1”N 76°16’12.3”E	Kalletumkara
26	Uc-B	10°19’39.2”N 76°15’21.9”E	Parappukara
27	Uc-C	10°21’9.41”N 76°15’32.96”E	Muriyad
Riparian			
28	R-A	10°24’55.3”N 76°14’31.5”E	Vadakkumury
29	R-B	10°23’19.4”N 76°13’47.0”E	Karuvannur riverside
30	R-C	10°24’10.1”N 76°13’32.5”E	Thamaravalayam canal

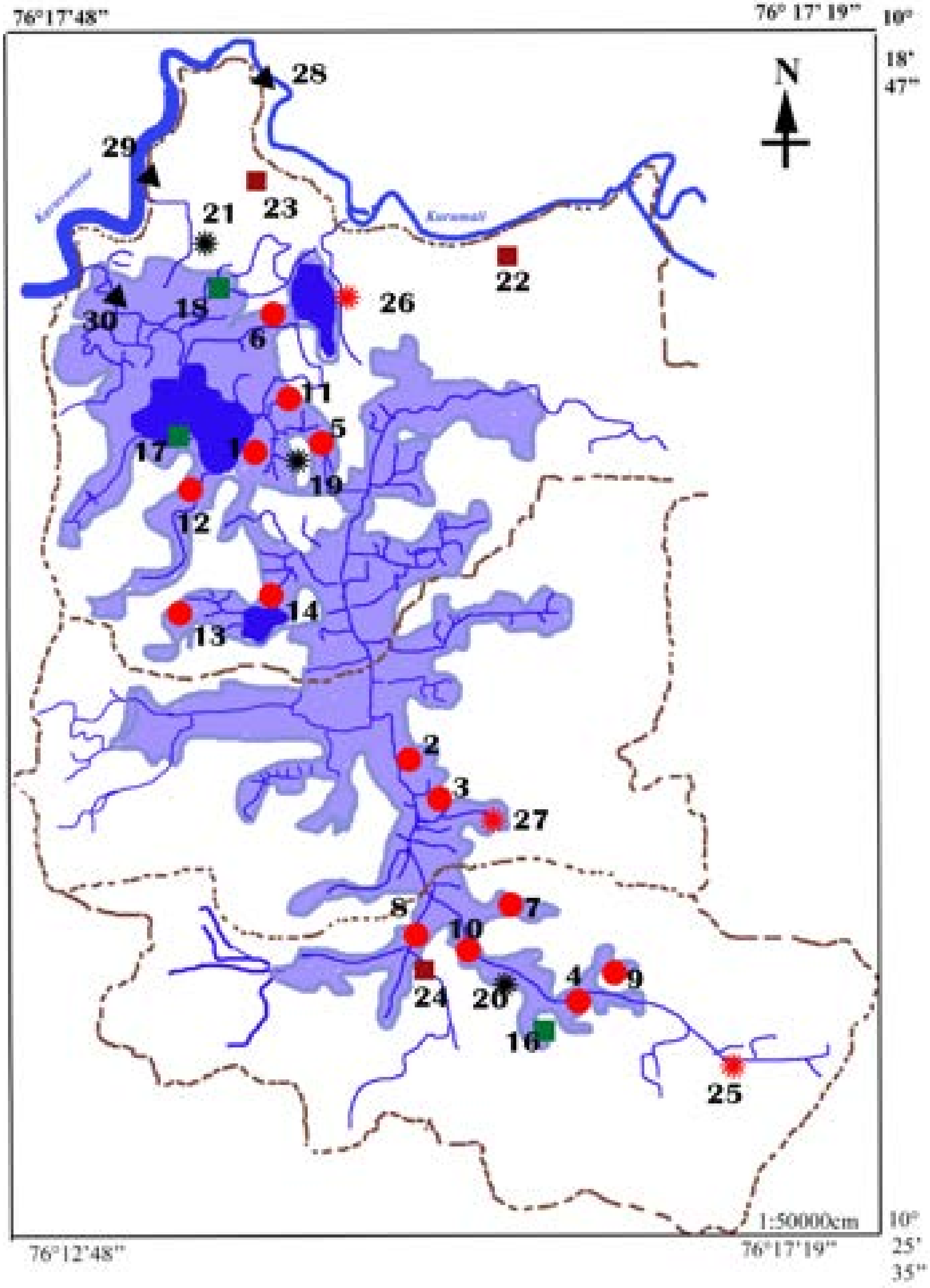

Figure 2.2: Map of Muriyad Kol wetland landscape with location of sampling sites. Blue indicates paddy fields/wetlands, Dark blue indicates perennial water bodies (Adapted from John Thomas et al., 2003). Legends: Red circle—Paddy fields, green square—grasslands, black star—banana plantations, brown square—Mixed crop, red star—uncultivated land, black triangle—riparian.

Figure 2.3: Arial view of Muriyad Kol wetland landscape showing the surrounding landscape (Source: google earth@2021 Maxar technologies).

2.2.2 Habitats studied

The wetland landscape of Muriyad Kol is a mosaic of different land uses. Besides paddy fields and mixed crops, some areas of the wetland have been reclaimed for bananas, coconut and areca nut cultivation. There are also areas of abandoned paddy fields, non-agricultural wasteland and perennial water bodies. Therefore, six types of habitats were selected for collecting spiders in this study. A list of the sampling sites of selected habitats is given in Table 2.1 and the location of different sites is given in Fig. 2.2. A brief description of the selected habitat types and their characteristics follows.

Paddy fields

Three crops of rice are grown in the region, Virippu, Mundakan and Puncha, depending on the duration of the floods and elevation of the land. Virippu is usually grown in comparatively higher areas than in the low-lying flooded areas. The flood water usually drains away within a few days after the rainy season. Here, the land is sown at the onset of the monsoon, so that the plants are up to 30–40 days old at the time of flooding. The cropping season usually runs from April–May to September–October. The Mundakan crop, also called Kadumkrishi, is done in medium elevated fields where the flood water reside by August. It is undertaken by dewatering the wetland when the water begins to reside by the end of the south-west monsoon, using indigenously made machinery called ‘petti and para’. Bunds made of laterite soil keep the water away from the fields and the water flows into the canals that eventually empty into the river Karuvannur. The duration of the season is from August–September to December–January. The harvest season for Puncha extends from December–January to April–May. The fields are irrigated by the river during the first period of crop growth, later water from dams is used. Jyothi, Uma and Jaya are the main varieties of rice cultivated in the region.However, some environmentally friendly or organic farmers prefer local varieties like Thavalakkannan for cultivation in the region. A total of 15 paddy fields were selected, fields in the low lying areas such as (L1, L–2, L3, L–11, L–6) were single cropped (Puncha), while Virippu was grown in the higher elevations (L–10, L–4), and Mundakan in the medium elevated areas (L9, L–13).

Grasslands

Abandoned paddy fields and fallows in the wetlands are considered as grasslands in the study. During the south-west monsoon, these become waterlogged on a seasonal basis. The Parappukkara microwatershed is overgrown with grasses and forbs near perennial water bodies and clay mined wastelands since they are not cultivated. In this study, these are also categorised as grasslands.

Banana plantations

Bananas are grown as plantations in many parts of the wetland. Usually single line row system where the distance between rows is wider than within the rows is used in the region. Homestead or home gardens also grow bananas in the region, but plantations are common in the reclaimed parts of the wetland.

Mixed crop

Mixed cropping occurs when two or more crops are grown on the same area of land at the same time. Multiple cropping improves soil fertility and, as a result, increases crop yield. When two crops are appropriately chosen, the products and refuse from one crop plant assist the other crop plant thrive, and vice versa. Bananas, for example, are typically grown with coconut and areca nuts, which give ground shade and additional money for farmers. Site Mxd–A was composed of nutmeg, coconut and bananas. While it was nutmeg and cococut in Mxd–B, and a mix of coconut, bananas and areca nut.

Uncultivated

Small patches of semi-natural wooded habitats can be found rarely in the wetland landscape. Abandoned arable land or neglected plots that have been left unused for different reasons, covered with a variety of plants including trees, climbers, and thick undergrowth, are examples. Farming operations outside the plots and grazing activities inside the habitats have a persistent impact on these ecosystems.

Riparian

Riparian zones or strips of vegetation along the interface between land and water have been selected as one of the habitat types in the region. The northern boundary of the wetland is formed by the Karuvannur river, whose banks are covered with vegetation in numerous places. The banks along the stretch are occasionally used for growing various crops or as home gardens. Coconuts, bananas, nutmeg, vegetables and tapioca are sometimes grown on the banks.

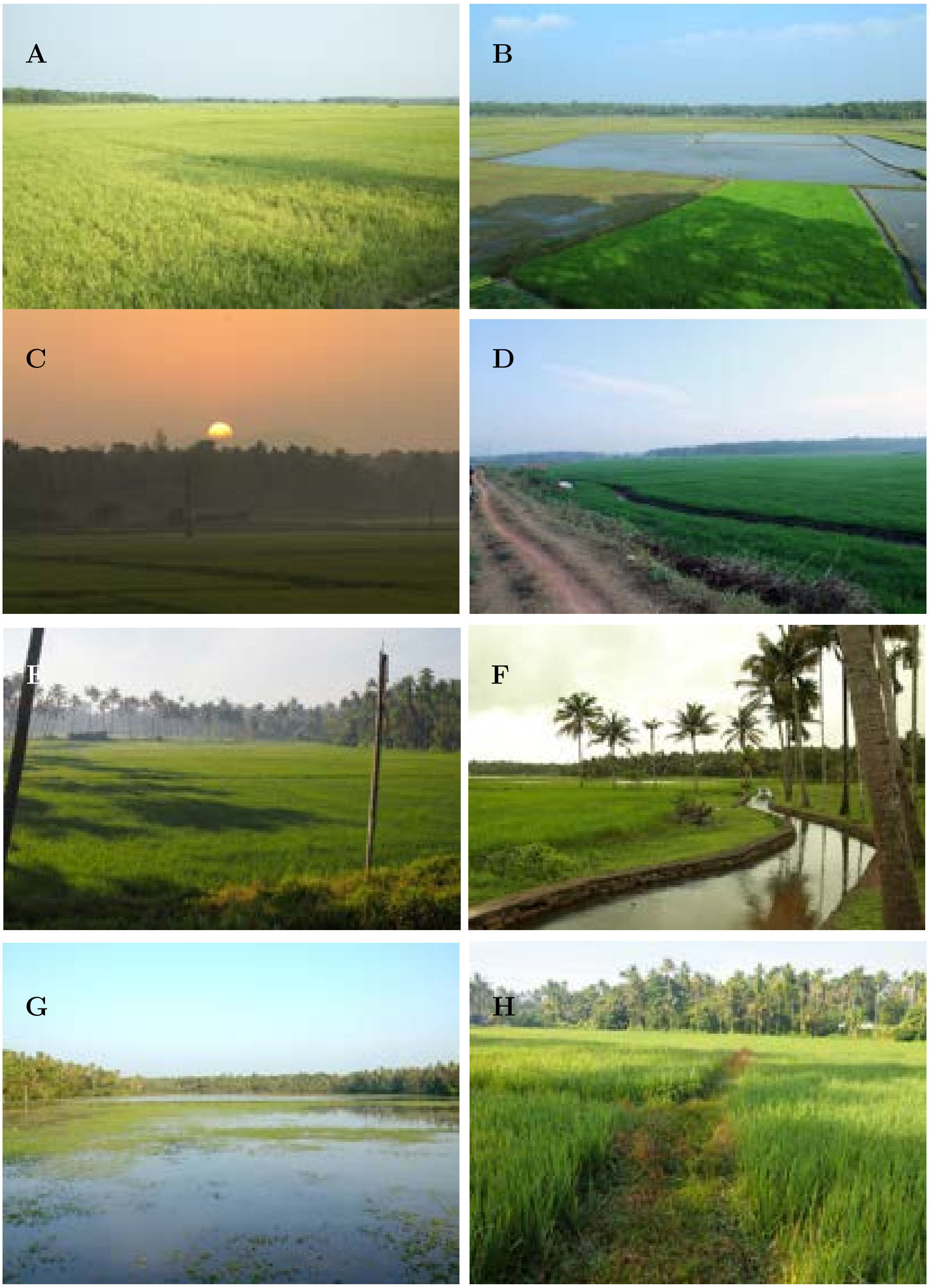

Figure 2.4: Sampling locations in the Muriyad Kol wetlands. A. Konthipulam puncha fields; B. Konthipulam fields, before transplantation; C–D Muriyad puncha fields; E. Edamana padam, virippu, Thazhekad; F. Peripadam, virippu, Thazhekad; G. Thazhekad chira, waterlogged during monsoon; H. Thazhekad mundakan fields.

Figure 2.5: Sampling locations in the Muriyad Kol wetlands. A. Puncha fields, Rappal; B. Puncha, punnapadam, Avittathur; C. Mundakan fields, Thazhekad; D. Kadumgadu puncha fields, Madaikonam; E. Harvest in puncha fields, Konthipulam; F. Puncha, Karingattipadam; G. Muriyad fields during monsoon season; H. Field margin overgrown with weeds, Karingattipadam.

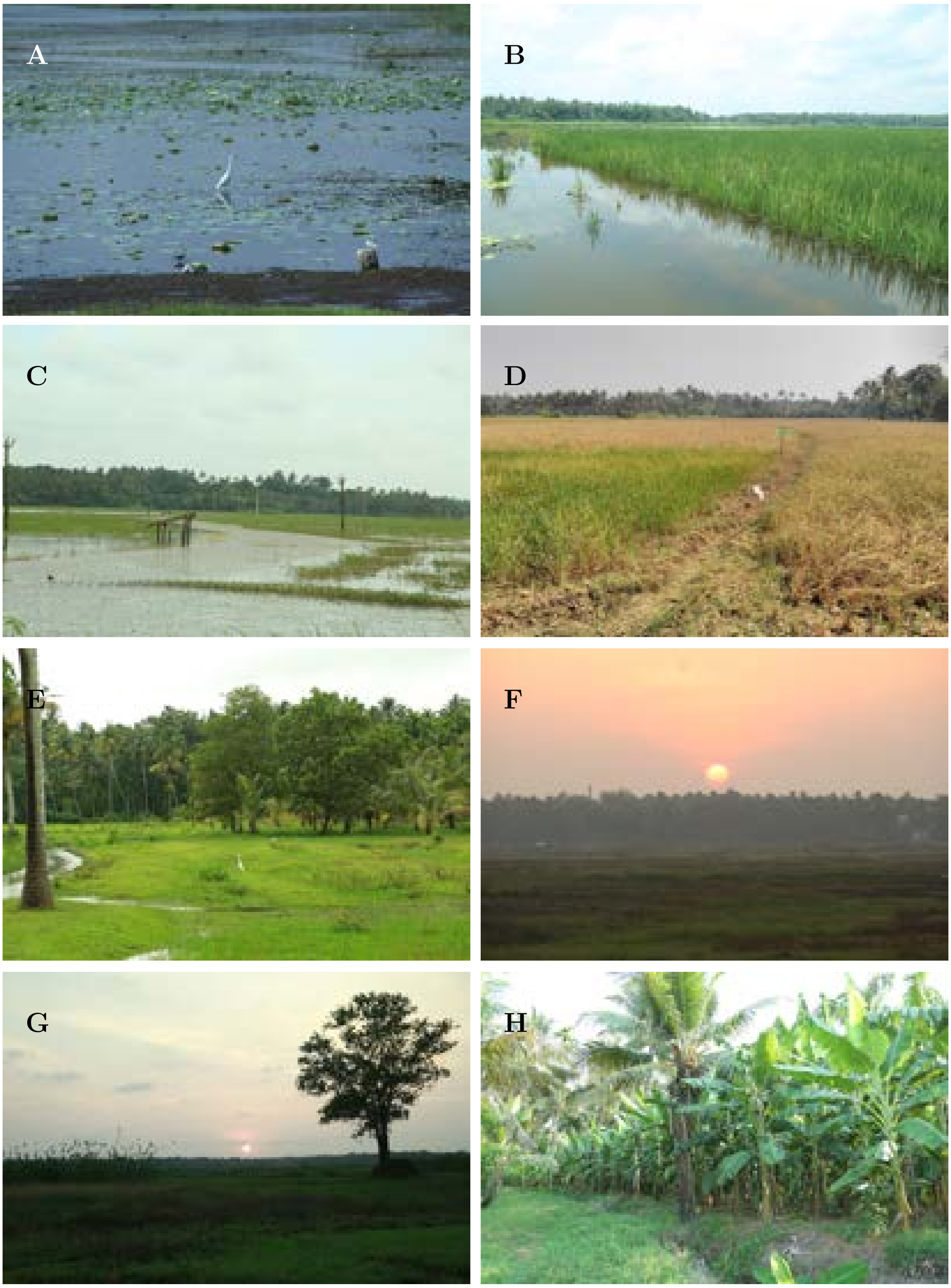

Figure 2.6: Sampling locations in the Muriyad Kol wetlands. A. Flooded field in the Muriyad region during monsoon; B. Valiya kol padam, puncha fields flooded due to water pump failure; C. Another flooded field during monsoon; D. Mundakan field, organic method; E. Grassland/long fallow adjacent to a paddy field in Thazhekad; F. Grassland, Parappukkara; G. Grassland, Nedumbal; H. Banana plantation, Mulangue.

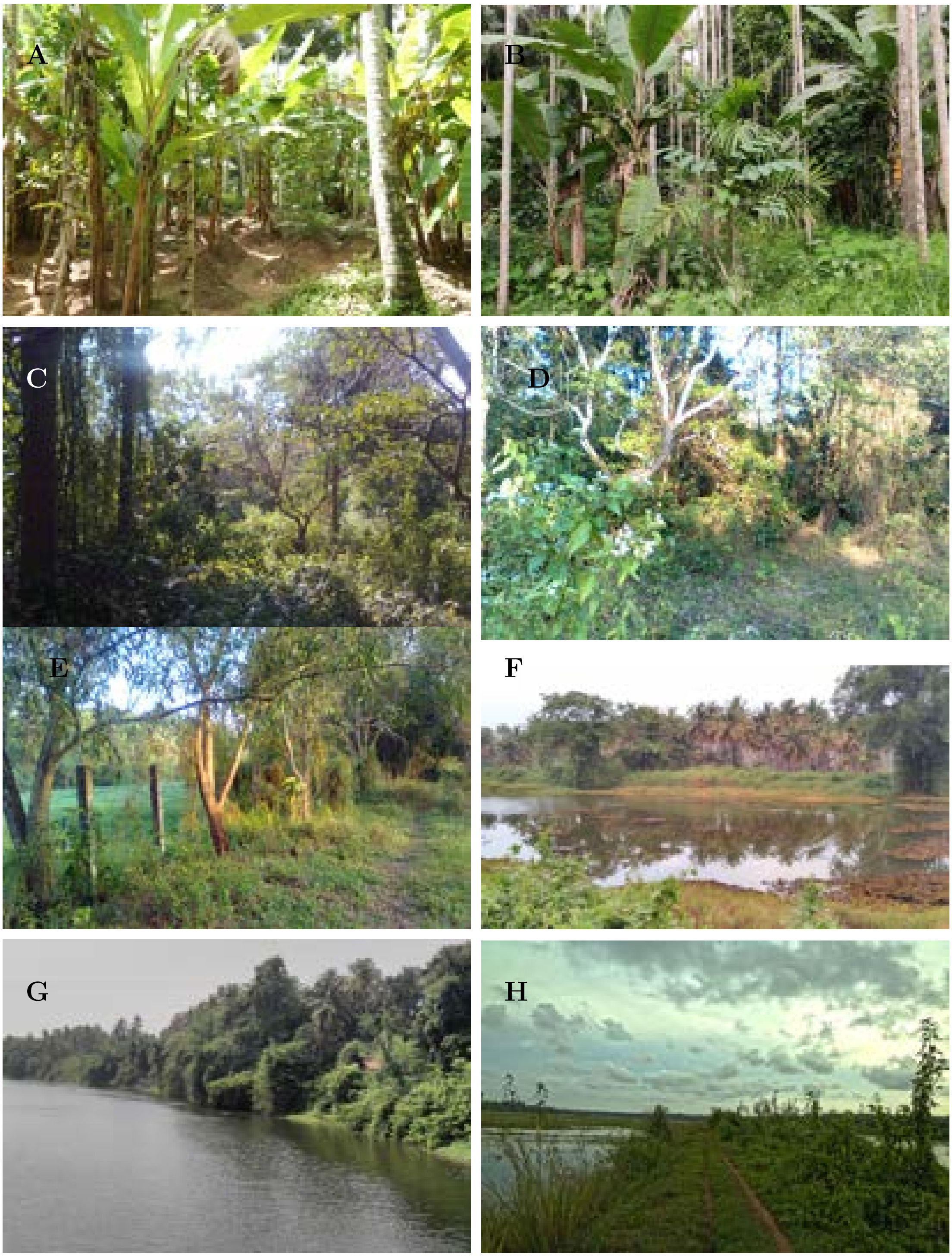

Figure 2.7: Sampling locations in the Muriyad Kol wetlands. A. Mixed crop, Nedumbal; B. mixed crop, Thazhekad; C. Uncultivated plot, Parappukkara; D. Uncultivated plot, Muriyad; E. Riparian, Vadakkumury; F. Riparian, Thamaravalayam canal; G. Riparian, Karuvannur river; H. Embankment with vegetation.

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3 | Survey of Spiders in the Muriyad Kol Wetlands

> *"Look closely at nature. Every species is a masterpiece, exquisitely adapted to the particular environment in which it has survived. Who are we to destroy or even diminish biodiversity?"*
>
> –E. O. Wilson

3.1 Introduction

Spiders are one of the most abundant and omnipresent organisms in most of the terrestrial ecosystems, and sometimes achieve peak densities of up to 1000 individuals per m^2 under favourable conditions (Ellenberg et al., 1986; Turnbull, 1973). They play a very important role in various ecosystems, both as a major predator and prey for a wide range of organisms (Nyffeler, 1999). They are nature's master spinners of silken webs and highly proficient predators for, in their absence, the insect pest world would run amok, creating havoc in the entire balance of their ecosystems posing serious threat to human health and food resources. Spiders have been successful in exploiting all niches of terrestrial ecosystems and have diversified to form many specialized functional groups (Blondel, 2003; Cardoso et al., 2011). Unfortunately, spiders are also the most feared and maligned of the nature's small creatures due to the infamy of a few infamous poisonous spiders like *Latrodectus mactans* Fabricius 1775, commonly called as Black widow spider, which is endemic to the North America. In addition, popular media have played their own share in promoting a more tainted image of this charismatic creatures.

The human curiosity about spiders began way back in the ages and continue to enthral the masses through many myths and even finds mentions in a number of Holy Scriptures. Around the globe, ancient civilizations in Europe, Africa, Asia, and the Americas have considered spiders in a high position and have associated them with gods in different forms. For instance, the ancient Egyptian mythology associates spider with the Goddess Neith in her aspect as spinner and weaver of destiny. The Greek mythology bears a story on the origin of the arachne (spider in Greek) from a tale connecting the Greek goddess Athena and princess Arachne over a weaving competition. So, it is no surprise that the name of the class Arachnida, to which the spiders belong was derived from the Greek word arachne. Many Holy Scriptures of the major religions of the world also have mentions of spiders. For example, The Hindu scriptures (Mundak Upanishad 1.1.7, Brihadaranyaka Upanishad 2.1.20), the Bible (Isaiah 59:5, Job 27:18, Job 8:14), The Quran [Surah Al ‘Ankaboot (The Spider) 29:41] have mentions, comparisons and expressions about spiders and their webs.

Spiders belong to the Phylum Arthropoda, which is the largest phylum in the animal kingdom. The principal classes belonging to this phylum are the insects, the crustaceans and the Arachnids- spiders and their allies. Class Arachnida is dominated by the order Araneae, to which the spiders belong. Araneae is one of the most numerous order in the animal kingdom in terms of the sheer number of species. It is ranked seventh in total species diversity of organisms with 49,825 described species currently known (World Spider Catalog, 2021). The Araneae is characterised by the presence of only two regions- a cephalothorax and abdomen. They are eight legged and have no compound eyes and no wings. Their kins comprises of subclass Acari (mites and ticks), Order Amblypygi (Tailless Whipscorpions), Order Araneae (spiders), Order Uropygi (whipscorpions), Order Opiliones (harvestmen), Order Palpigradi (microscropions), Order Pseudoscorpiones (pseudoscorpions), Order Schizomida (short-tailed whipscorpions), Order Scorpiones (scorpions) and Order Solifugae (windscorpions).

Spiders are generalist carnivore that primarily feed on insects, but they also eat other arthropods, including spiders (Birkhofer & Wolters, 2012; Nyffeler, 1999). But rarely they consume non arthropod prey and sometimes even plant materials to supplement their diet (Foelix, 2011; Nyffeler, Olson, et al., 2016; Symondson et al., 2002). Globally, spiders consume prey in the range of 400–800 million metric tons annually, with a majority of the captured prey composed of insects and collembolans (Nyffeler & Birkhofer, 2017). Spiders play a significant role in the terrestrial biomes not only as voracious predator, but also serve as an important food source for a diverse group of arthropod-eating carnivores. Additionally, the predatory pressures exerted by spiders have also led to the evolution of morphological and/or behavioural adaptations in numerous insects to avoid the risk of attack from them (Eisner et al., 1964; Wise, 1993). Spiders because of their enormous presence in most habitats exert some indirect effects on insects by intimidating them, thereby decreasing their feeding activity in the presence of spiders to avoid predation (Hlivko & Rypstra, 2003; Schmitz, 1998; Schmitz et al., 1997; Snyder & Wise, 2000).

Even though a consorted scientific interest in the arthropods started during the 18th century and heightened during the 20th century, the scientific community is yet to complete its inventory of the arthropods of the world. Such is the extent of diversity of arthropods including the spiders. To date, about 50195 species of spiders belonging to 4261 genera and 132 families have been known (World Spider Catalog, 2022), and further estimate of as many species remain to be discovered. Many new species, and sometimes previously unknown genera and even families, are discovered each year from different parts of the world. Even for the most common species, there is an enormous amount of data yet to be gathered before a better understanding of spiders and their roles in the environment are reached (Hawkeswood, 2003).

3.1.1 Spiders in Rice agroecosystems

Rice (*Oryza sativa*) is one of the major staple crops in the world, providing food to almost half of the world population. Rice consumption is the highest in Asia-pacific with more than 100 kg per capita in many countries and it accounts for almost 90 percent of its consumption. Rice production has more than doubled since the 1950s, driven by many factors such as population growth, income growth and other socio-economic variables, and its demand continues to rise mainly due to population and economic growth even though factors like income growth and changing dietary needs have reduced per capita consumption of rice products in some countries (OECD/FAO, 2021; Papademetriou, 2000). The global yields are expected to grow at around 12 percent by 2030, the highest projected yield among the major cereals in the world (OECD/FAO, 2021). However, irrigated paddy fields produces around 76 percent of the total rice yield, and with increased constraints on land conversion from forests, wetlands or pastures to arable land as well as urbanisation, land expansion of rice areas has become stagnant. As the area under rice cultivation in Asia has declined over the recent decades, pressure has mounted on the existing rice fields to increase yield by using more intensive farming techniques with more mineral fertilizers and pesticides (Wailes & Chavez, 2012). These intensive rice fields are prone to yield decline due to depletion of soil fertility and improper nutrient balance, which necessitates even more increased amounts of inputs. Increased use of high nitrogen fertilizers promotes sap-sucking herbivores, while insecticides may not only decrease the population of pest species but also many natural enemies of pests such as spiders, thereby reducing biological control of planthoppers and leafhoppers resulting in yield losses (Kiritani et al., 1972; Radermacher et al., 2020; Settle et al., 1996). To counter these effects, there is a need to develop or propagate region-wise practices in sustainable management, integrated pest management, traditional practices and Integrated Nutrient Management (Papademetriou, 2000).

Spiders are major generalist predators in rice agroecosystem and they have received considerable attention both taxonomically and ecologically (Tanaka, 2016); many studies on the species, diversity, distribution, ecology and biology, pest control and conservation have been reported from different parts of the world. Several studies explored the fauna and diversity of paddy field spiders around the world, mostly in the East and South-East Asia, especially China, South Korea and Philippines (Barrion, 1999; Barrion & Litsinger, 1995; Barrion, Villareal, et al., 2012; Heong et al., 1991; Jung et al., 2008; Kim, 1998; Li, Zhao, et al., 2001; Okuma, 1988a; Okuma, 1988c; Okuma, Lee, et al., 1978; Wen & Yan, 2004; Yan et al., 2002), and South Asia (Bambaradeniya, Edirisinghe, et al., 2004; Bambaradeniya, 2000; Bambaradeniya & Edirisinghe, 2001; Betz, 2016; Bhattacharyya, 2000; Dominik, 2019; Gupta, Rao, et al., 1986; Kumar, 1994; Liyanage, 2005; Nirmala, 1990; Okuma, Kamal, et al., 1993; Patel, Pate1, & Pandya, 2005; Pathak & Saha, 1999; Rajendran, 1987; Sankari, 2011; Sebastian, Mathew, et al., 2005; Sudhikumar, 2007). In the New World, rice land spiders of the subtropical and temperate regions of the United States of America were studied by Heiss and Meisch, 1985; Mercer et al., 2017; Oraze and Grigarick, 1989; Oraze, Grigarick, et al., 1988; Woods and Harrel, 1976; whereas, Bao et al., 2018; Bastidas and Pantoja, 1993; Rodrigues and Mendonça, 2009 documented spiders from the tropics.

Barrion and Litsinger, 1995 provided a comprehensive taxonomic account of spiders of the rice agroecosystems of South and South-East Asia, and recorded a total of 342 species, mostly from Philippines. Barrion, Villareal, et al., 2012 documented 167 species under 97 genera and 19 families of spiders from the rice agricultural landscapes of the Hainan island in China; 21 new species belonging to Araneidae, Clubionidae, Lycosidae, Salticidae, Theridiidae, Thomisidae and Zodariidae were described from the agroecosystem. Recent review of Chinese paddy field spiders by Yang et al., 2018 indicates the presence of no less than 375 species of spiders determined from various works between 1972–1999. Several studies from the Indian subcontinent are faunistic reports and diversity studies of spiders from different locations around the region (Anitha, Shanker, et al., 2019; Anitha & Vijay, 2016; Banerji et al., 1993; Patel, Pate1, & Desai, 2004; Sebastian, Mathew, et al., 2005; Zhimomi et al., 2001). Bambaradeniya and Edirisinghe, 2001 reported 60 species of spiders from irrigated paddy fields in the intermediate zone at Bathalagoda in Sri Lanka.

In Kerala state, Anis Joseph and Premila, 2016 reported 65 species of spiders from the paddy growing tracts of Thiruvananthapuram district in south Kerala. Spider fauna in selected rice fields of highlands in the Wayanad district of kerala was studied by Betz, 2016, and documented 86 species of spiders from the ecosystem. To date, two major studies have been conducted on the spider fauna of selected areas of the Vembanad wetland. Sudhikumar, 2007 reported 99 species of spiders from the paddy fields of Kuttanad region, which lies to the south of Vembanad lake. Recently, Jobi, 2018 studied the spiders in the Pathiramanal and Perumbalam estuarine islands and listed 147 species from the islands. In addition, Sudhikumar, 2015 provided a detailed account of the biology of some of the dominant spiders inhabiting the paddy fields of Kuttanad. Sebastian, Mathew, et al., 2005 explored the spiders of irrigated rice fields along an elevation gradient viz., highlands, midlands and lowland, during Kanni and Makara cropping seasons in central Kerala; they reported 92 species of spiders and found that the rice fields in the lowlands registered higher richness and diversity. Spiders of the rice fields in the Kumarakom region of Vembanad wetlands were briefly studied by John and Tom, 2018, they reported 17 species during the study period, and families Tetragnathidae and Salticidae as the dominant groups. Also, a preliminary study in the Kumarakom Bird Sanctuary, which is a mangrove habitat, situated in the same region reported 74 species of spiders, with Salticidae and Araneidae as the dominant families in terms of species richness (Jobi & Samson, 2014). A similar short-term study in the disturbed mangrove habitats of the Mangalavanam Bird Sanctuary along the Cochin Backwaters revealed 51 species of spiders (Sebastian, Murugesan, et al., 2005).

The aim of this study is to compile a faunistic inventory of spiders in the Muriyad Kol wetland landscape. Taxonomic details of new species discovered in the study area and new records of species from India are provided.

3.2 Methodology

3.2.1 Sampling

The sampling period extended from September 2014 to December 2018, covering the major terrestrial habitats in and around the Muriyad Kol wetlands. A major share of the landscape was under paddy cultivation. So, 15 plots of paddy fields were identified representing different areas of study area with a variety of geographical characteristics such as elevation, soil type and cropping cycle. The selection of sampling sites was done with the help of Google maps and local knowledge. Each plot was sampled at various growth stages of paddy plant (6 intervals) and during the three cropping seasons, viz. *Virippu*, *Mundakan* and *Puncha*. Additionally, 3 sites each from other habitats in the landscape, namely grasslands, banana plantations, mixed crops, uncultivated lands and riparian, were also identified. Each site was sampled 3 times per season, namely pre-monsoon, monsoon and post monsoon. Each site consisted of 4 randomly placed quadrats measuring 10 X 10 m. Each quadrat was sampled for 30 minutes using the methods mentioned in 3.2.1.1, thus giving an effective sampling time of 2 hours in a site. Subsequently, the collections from the 4 quadrats of a site were pooled to form one sample. It resulted in 261 samples of raw abundance data, including 126 exclusively from the paddy fields and 135 from other habitats (ie, 9 samples per site). Samples from random collections were also included in this study.

Figure 3.1: Collection and photography of spiders. A. Author collecting spiders. B. Field photography. C. Photographic setup in the lab.

3.2.1.1 Collection methods

The following semi-quantitative methods were used for the collection of spiders from various substrates:

Hand-searching. Spiders were collected from the ground level to one's arm length height directly by hand while moving about in the habitat (Coddington et al., 1991). A wide group composed of web-building and free-living spiders on leaves, branches, tree trunks and ground were collected by this method. The spiders encountered were captured in plastic containers with lid.

Beating. Spiders were collected by beating the branches of bushes, shrubs and small trees with a strong twig, thereby dislodging the spiders into the plastic white sheet or inverted umbrella which is conveniently placed below the branch shaken. The surface of the sheet or umbrella is thoroughly inspected for any fallen spiders, which will be collected into a plastic container.

Sweep net. Spiders were collected by sweeping the vegetation especially grass and paddy using a sweep net. The back and forth movement of the sweep net in a fast motion traps any spiders and invertebrates in vegetation to fall into the net, which is later transferred to a bottle.

Litter sifting. Spiders were picked out from ground litter samples collected from the plot through sifting it on a white tray. It is a time consuming method that requires sorting the litter contents while carefully looking for the spiders moving in the tray at the same time.

Each quadrat in a plot was sampled using all of the above mentioned methods, except in paddy fields where litter sifting and beating found little to no use. Each 30 minutes sampling involved almost equal periods of hand-searching and beating vegetation. Additionally, collections using other techniques were also added to the main sample—repeated sweeps (around 10 times) on lower vegetations and high grasses on a suitable location in each site, and litter samples collected from ground sorted at a later time.

3.2.2 Digital documentation of live spiders

Digital photographs of live spiders were taken in the field or in the lab under controlled setting. Equipment consisted of Canon EOS 5D Mark–III using Canon EF

100mm f/2.8 Macro USM Lens, Canon MP-E 65mm 1–5x Macro Lens, EF180mm f/3.5L Macro USM, Canon MT-24EX Macro Twin Lite Flash and other accessories (Fig. 3.1B,C). The pictures were processed in adobe Lightroom and adobe Photoshop.

3.2.3 Preservation and storage of spiders

Spiders were generally killed in the field and preserved in 70 percent ethyl alcohol or iso-propyl alcohol in well sealed and labelled plastic containers. All data on abundance were recorded in a field note book for later reference. Immature spiders, if numerous, were released after recording their identity up to species or genus level. Adults were also accounted for and released back into the open if many of them belonging to the same morphospecies are encountered while collecting. Spiders that need to be photographed in a controlled environment were brought to the lab alive and photographed (see Section 3.2.2).

Spiders were provisionally identified using a stereomicroscope at the lab and stored in a closed rack. These specimens were properly identified later at a convenient time and catalogued in a register kept in the museum of CATE. Eventually, collections were transferred to small vials and kept submerged in large glass jar filled with ethyl or iso-propyl alcohol for long term storage, in order to prevent drying up in hot and humid conditions. However, for large spiders 75–80 percent concentrations were used for long term storage.

3.2.4 Identification and Taxonomical studies

Majority of taxonomic literature used for identification of species were downloaded from World Spider Catalog, 2021, and the rest were collected from other sources and personal communication. Spiders were identified using a Leica M205 C and Magnus MSZ TR stereomicroscope. Micrographs of wet specimens were taken using Leica DMC4500 digital camera attached to Leica M205 C stereomicroscope, with the software package Leica Application Suite (LAS), version 4.3.0. All measurements of spiders are in millimetres (mm). Genitalia of females were cleared in 10 percent potassium hydroxide (KOH) solution. In some cases, methyl salicylate was used to clear the male palp. The specimens studied are deposited in the reference collections housed at Centre for Animal Taxonomy and Ecology (CATE), Department of Zoology, Christ College (Autonomous), Irinjalakuda, Kerala, India. Some species have not been identified to species level for various reasons such as lack of adult specimens, damaged genitalia, etc. These specimens could be used for subsequent studies on many taxonomic questions in the future.

3.3 Results

The survey of spiders in the Muriyad Kol wetlands resulted in the collection of 16,648 individuals belonging to 195 species, 135 genera and 34 families. Infraorder Mygalomorphae was represented by 4 species belonging to 3 genera and 3 families, whereas 191 species of 132 genera and 31 families belonged to Araneomorphae (Table 3.1). Majority of the species represented the families Salticidae, Araneidae, Theridiidae and Tetragnathidae.

The survey of the wetland landscape resulted in the documentation of ten new species of spiders, all of which belong to the Salticidae family except one (see Table 3.2). The other species is a wetland specialist which belongs to the family Tetragnathidae. The study also led to the redescription of six species of Salticidae, Tetragnathidae, Theridiidae, Philodromidae and Araneidae. The genus *Stertinius* is recorded for the first time in India. A new species and the first male of genus *Piranthus* (Salticidae) is described and illustrated. Additionally, four species belonging to Araneidae, Theridiidae and Tetragnathidae are new records to India.

The detailed taxonomic accounts of the spider fauna surveyed in the Muriyad Kol wetland and associated habitats in the surrounding landscapes is given in Section 3.3.2. Descriptions, illustrations and micrographs are provided for the new species and redescriptions. A concise species checklist of spiders documented from the study area is provided in Section 3.A.

3.3.1 Identification key to the families of spiders found in Muriyad Kol wetlands

MYGALOMORPHAE

1 Tarsi of leg with two claws, tarsi with clavate trichobothria (> 6); distal segments of posterior spinnerets long; clypeus wide ***THERAPHOSIDAE***

1: Tarsi of leg with three claws **2**

2 Legs short; sternum triangular; legs I and II with lateral bands of short curved thorn-like spines on distal segments; females lacking scopulae, present in males in some or all tarsi; posterior lateral spinnerets short, apical segments shortest, domed to triangulate .... ***HALONOPROCTIDAE***

2: Legs not as above, sternum different; Anterior paired tarsal claws with a medial row, single row or S-shaped in males; unusual excavation on prolateral palpal tibia of males, with a region of short thorn-like spines ***IDIOPIDAE***

ARANEOMORPHAE

1 Cribellate **2**

1: Ecribellate **6**

2 Large anal tubercles, two segmented fringed by long curved setae ***OECOBIIDAE (in part)***

2: Anal tubercle normal and single segmented **3**

3 Posterior median eyes enlarged, upto 4 times as large as anterior median eyes; anterior leg pairs very long and slender .... ***DEINOPIDAE***

3: Posterior median eyes not greatly enlarged; only the first pair of legs is greatly elongated or front legs not as long **4**

4 Long trichobothria on leg femora; metatarsi IV visibly compressed and curved with line of calamistrum, leg I longer than leg II ***ULOBORIDAE***

4: Rows of long trichobothria absent on femora; metatarsi IV not compressed and curved; leg I not longer; carapace rectangular; anterior lateral eyes and posterior lateral eyes widely apart .... ***ERESIDAE***

5 With less than 8 eyes **6**

5: With 8 eyes **11**

6 Anterior pair of legs stronger than others; strong prolateral scopulae on metatarsi and tibia I .... ***PALPIMANIDAE (in part)***

6: Not as above **7**

7 Eyes in triades, well seperated from eachother .... ***PHOLCIDAE***

7: Eye arrangement different **8**

8 Carapace domed, highest in the thoracic region; epigastric region with anchoring holes in females .... ***SCYTODIDAE***

8: Carapace shape different **9**

9 Palpal tarsi clawless in females; abdomen with scuta or uniformly soft .... ***OONOPIDAE***

9: Not as above **10**

10 Anterior median eyes clearly larger than others; cheliceral fangs short and thick; four spinnerets, anterior pair large and closer to each other ***ZODARIIDAE (in part)***

10: All eyes similar in size, in three diads; fangs long and slender; six spinnerets; two tarsal claws .... ***SICARIIDAE***

11 Two tarsal claws **12**

11: Three tarsal claws **22**

12 Anterior pairs of legs much stronger; strong prolateral scopulae on metatarsi and tibia I; carapace almost oval .... ***PALPIMANIDAE(in part)***

12: Legs different **13**

13 Eye formula (4:2:2) or rarely (2:2:2:2); anterior median eyes very large; jumping spiders .... ***SALTICIDAE***

13: Eye formula different **14**

14 Legs laterigrade, tarsi and metatarsi without scopulae; legs I and II longer than rest .... ***THOMISIDAE***

14: Tarsi and sometimes metatarsi with scopulae, legs length different ... **15**

15 Small to medium sized; chelicera without teeth or one teeth retromarginally; tarsi-metatarsi movement in one plane only .... ***PHILODROMIDAE***

15: Medium to large spiders; chelicerae with atleast two teeth on retromargin; free movement of tarsus facilitated by trilobate membrane ***SPARRASIDAE***

16 Posterior median eyes flat; anterior lateral spinnerets with enlarged gland spigots, anterior spinnerets cylindrical, widely seperated; eyes in two rows; endites obliquely depressed .... ***GNAPHOSIDAE***

16: Posterior median eyes with dome-shaped lens; endites usually not obliquely depressed **17**

17 Eyes in three rows (2:4:2), anterior lateral eyes just in front of posterior lateral eyes; numerous ventral spines on anterior legs; male palp with dorsally concave median apophysis; epigyne with lateral horns … ***CTENIDAE***

17: Eyes in two rows (4:4), male palp with median apophysis **18**

18 Posterior spinnerets two-segmented, distal segment conical ....***CHEIRACANTHIIDAE***

18: Posterior spinnerets one segmented, sometimes two-segmented with distal segment rounded **19**

19 Male palp pear-shaped, embolus short, distally situated; median apophysis absent; epigyne with spherical spermathecae, copulatory opening shiny through integument .... ***CORINNIDAE (Castianeirinae)***

19: Genitalia differently shaped **20**

20 Female median spinnerets with three and posterior spinnerets with two large cylindrical spigots; Legs with spines; clypeus concave; epigyne and booklung in single sclerotised plate .... ***CORINNIDAE (Corinninae)***

20: Spinnerets without such spigots **21**

21 Median spinnerets flattened laterally, with one row of large spigots

.... ***LIOCRANIDAE***

21: Median spinnerets not flattened, rows of large spigots absent ***CLUBIONIDAE***

22 Eyes in three rows (4:2:2); broad carapace, posterior raised ***PISAURIDAE***

22: Eyes in 3 or 4 rows (2:2:2:2; 4:2:2; 2:4:2); trochanters notched **23**

23 Very high clypeus; posterior eyes and anterior lateral eyes forms hexagonal group, anterior median eyes small; legs with numerous long spines ***OXYOPIDAE***

23: Clypeus not as high; eye grouping nad leg setation different **24**

24 Sessile eyes, not on tubercles; oval abdomen, posterior smoothly rounded; male palpal tibia without retrolateral apophysis; egg cocoon attached to spinnerets; anal tubercles single segmented ....***LYCOSIDAE***

24: Shallow tubercles for at least one pair of eyes; abdomen usually elongated, tapered posterior; retrolateral apophysis on male palpal tibia; egg cocoon carried below sternum .... ***PISAURIDAE (in part)***

25 Posterior spinnerets long or very long, distal segment at least three times longer than wide **26**

25: Posterior spinnerets no long **27**

26 Anal tubercle large, fringed with long setae; posterior spinnerets curved around it; carapace circular .... ***OECOBIIDAE(in part)***

26: Anal tubercle normal; carapace shape different; posterior spinnerets with a median row of spigots .... ***HERSILIIDAE***

27 Eyes in three groups; anterior median eyes apart, rest in two triads; legs long and thin, pseudo segmented tarsi .... ***PHOLCIDAE***

27: Eye pattern different; anterior tibiae and patellae with a row of alternating long and short curved spines prolaterally; peg-like teeth on chelicerae ***MIMETIDAE***

28 Paracymbium as a separate sclerite; chelicerae often with stridulating file; small spider (1.5–6 mm) .... ***LINYPHIIDAE***

28: Paracymbium fused to cymbium or rudimentary; no cheliceral stridulating file **29**

29 Ventral comb of serrated hairs on tarsi IV; eyes with brownish rings around them; paracymbium small hook at cymbial promargin distally; typical fan of setae on broadened extremity of male palpal tibia ***THERIDIIDAE***

29: Tarsi without ventral comb; eyes without brown rings; tiny spiders (< 2.6 mm); broadly truncate sternum with frontal pit organs; bunch of trichobothria on tibia III .... ***THERIDIOSOMATIDAE***

30 Male palp simple, median apophysis absent; embolus surrounded by conductor; elongated paracymbium; chelicerae usually swollen, long; chelicerae modified in males .... ***TETRAGNATHIDAE***

30: Complex male palp with median apophysis; embolus not surrounded by conductor; paracymbium often hook-shaped; often swollen chelicerae, not modified for courtship; epigyne often with scape .... ***ARANEIDAE***

Table 3.1: Number of species documented from Muriyad Kol wetlands and their families.

	Family	Number of species
	MYGALOMORPHAE	
1	Halonoproctidae	1
2	Idiopidae	2
3	Theraphosidae	1
	ARANEOMORPHAE	
4	Araneidae	34
5	Clubionidae	2
6	Corinnidae	2
7	Ctenidae	1
8	Deinopidae	1
9	Eresidae	1
10	Gnaphosidae	4
11	Hersiliidae	1
12	Linyphiidae	7
13	Liocranidae	1
14	Lycosidae	7
15	Mimetidae	1
16	Miturgidae	2
17	Oecobiidae	1
18	Oonopidae	2
19	Oxyopidae	6
20	Palpimanidae	1
21	Philodromidae	2
22	Pholcidae	6
23	Pisauridae	2
24	Salticidae	37
25	Scytodidae	2
26	Sicariidae	1
27	Sparassidae	5
28	Tetragnathidae	18
29	Theridiidae	25
30	Theridiosomatidae	1
31	Thomisidae	12
32	Trachelidae	1
33	Uloboridae	4
34	Zodariidae	1
	Total	**195**

Table 3.2: New species, new records, revision, description and redescription of spiders sampled from Muriyad Kol wetland.

	Species	Remarks
1	*Bianor kolensis* sp. nov.	New species
2	*Cocalus lacinia* Sudhin, Nafin, Sumesh & Sudhikumar, 2019	New species
3	*Epeus triangulopalpis* Malamel, Nafin, Sudhikumar & Sebastian, 2019	New species
4	*Hyllus kerala* sp. nov	New species
5	*Chinattus thamannae* sp. nov.	New species
6	*Piranthus planolancis* Malamel, Nafin, Sudhikumar & Sebastian, 2019	New species, First description of male of the genus
7	*Stertinius aluva* sp. nov	New species, first report of genus from India
8	*Tamigalesus noorae* sp. nov.	New species
9	*Tamigalesus malabaricus* sp. nov.	New species
10	*Tetragnatha concordia* sp. nov.	New species
11	*Phoroncidia septemaculeata* O. Pickard-Cambridge, 1873	Redescription, first record from India
12	*Argyrodes kumadai* Chida & Tanikawa, 1999	First record from India
13	*Meotipa multuma* Murthappa et al., 2017	First description of male
14	*Thwaitesia margaritifera* O. Pickard-Cambridge, 1881	Redescription
15	*Larinia tabida* (L. Koch, 1872)	First report from India
16	*Indopadilla insularis* (Malamel et al., 2015)	Redescription
17	*Chrysilla volupe* (Karsch, 1879)	Redescription
18	*Psellonus planus* Simon, 1897	Revision of the genus
19	*Tetragnatha squamata* Karsch, 1879	First record from India
20	*Tetragnatha serra* Doleschall, 1857	First record from India
21	*Tetragnatha cochinensis* Gravely 1921	Redescription, first description of female
22	*Guizygiella nadleri* (Heimer, 1984)	Redescription

3.3.2 Species inventory of spiders sampled from Muriyad Kol wetland

A. INFRAORDER MYGALOMORPHAE Pocock, 1892

3.3.3 FAMILY HALONOPROCTIDAE Pocock, 1901

TRAPDOOR SPIDERS

Family Halonoproctidae represents medium to large spiders, three-clawed, eight-eyed, with colour ranging from tan to black and lacking distinct markings. The family was earlier part of Ctenizidae, but recently split off to form a separate family following studies on its phylogeny (Godwin et al., 2018). They are burrowing spiders and uses either a wafer or cork-type trapdoor.

Diagnosis: Members of the family can be distinguished by the following characters: Eyes in two to three rows and either closely grouped on tubercle or with AME on tubercle (*Bothriocyrtum*, *Conothele, Hebestatis, Latouchia, Ummidia*), or lacking tubercle with eyes more widely separated (*Cyclocosmia*); females lacking scopulae but present on some to all tarsi of males; female legs I and II with uniquely curved thorn-like spines on the lateral sides of distal segments; posterior region of carapace sloping; fovea deep and strongly procurved; chelicerae strongly biserially dentate, with rastellum equiped with large teeth on a mound. Posterior lateral spinnerets relatively short with short apical segment, domed to triangulate (Godwin et al., 2018).

Type genus: *Cyclocosmia* Ausserer, 1871.

3.3.3.1 *CONOTHELE* Thorell, 1878

Genus *Conothele* is a less species-rich genus distributed in the Oriental, Australian, Polynesian and Palearctic regions, but mostly distributed in the Oriental region (World Spider Catalog, 2021). The genus is represented by 34 nominal species globally and 5 are currently known from India (World Spider Catalog, 2021).

Diagnosis: *Conothele* species can be distinguished from other genera by the following combination of characters: Trochanters I and II not notched ventrally; tibia III with saddle-shape depression dorsally (Siliwal et al., 2009).

Type species: *Conothele malayana* (Doleschall, 1859)

Species sampled from the Muriyad Kol Wetland.

***Conothele* sp.**

3.3.4 FAMILY IDIOPIDAE Simon,1889

ARMORED TRAPDOOR SPIDERS

Family Idiopidae represents medium to large spiders, three-clawed, eight-eyed with widespread distribution (Godwin et al., 2018). Currently, there are 437 species in 23 genera known globally (World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following combination of characters: males with a distal haematodocha extending down to the embolus; palpal tarsus bilobed with one blunt and one pointed lobe; domed apical segment of PLS; serrula absent (Raven, 1985).

Type genus: *Idiops* Perty, 1833.

3.3.4.1 *HELIGMOMERUS* Thorell, 1878

Genus *Heligmomerus* is a less species-rich genus distributed in the Oriental, Australian, Polynesian and Palearctic regions, but mostly ditributed in the Oriental region (World Spider Catalog, 2021). The genus is represented by 34 nominal species globally and 5 are currently known from India (World Spider Catalog, 2021).

Diagnosis: *Heligmomerus* species can be distinguished from other genera in the subfamily Idiopinae by the presence of a dorsal depression on tibia III (Raven, 1985).

Type species: *Heligmomerus taprobanicus* Simon, 1892.

Species sampled from the Muriyad Kol Wetland.

Heligmomerus maximus Sanap & Mirza, 2015
Fig. 3.2A

Heligmomerus maximus Sanap and Mirza, 2015: 243, Figs 1, 2A–B, 3A–F, 4A–B (♀).

Habitat: Collected from uncultivated plot with laterite soil.

Other species sampled:
***Heligmomerus* sp.**

3.3.5 FAMILY THERAPHOSIDAE Thorell, 1869

BABOON SPIDERS OR TARANTULAS

Family Theraphosidae represents group of medium-sized to large and often hairy spiders with a pantropical distribution. They are mostly ground dwellers living in burrows and leave their burrows at night to hunt prey. Some members have found their place as pets in international markets due to their attractive colouration and sometimes iridescent appearance. Some species are known to give painful bites and aggressively pursue humans when disturbed. Exposure to urticating hairs present on the body of some species of tarantulas can cause irritation to the skin. Currently, there are 1031 species in 153 genera known globally (World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following combination of characters: They have two or rarely three tarsal claws, eight eyes, four spinnerets and rastellum absent; well developed scopulae and iridescent claw tufts on legs tarsi and female palpal tarsi; tarsi with clavate trichobothria; labium and endites with numerous cuspules; distal segment of posterior spinnerets digitiform (Jocqué & Dippenaar-Schoeman, 2006).

Type genus: *Theraphosa* Thorell, 1870.

3.3.5.1 *ANNANDALIELLA* Hirst, 1909

Genus *Annandaliella* is a less species-rich genus endemic to India and is represented by three nominal species (World Spider Catalog, 2021). The current distribution of the genus is limited to South India, mostly from Kerala.

Diagnosis: *Annandaliella* species can be distinguished by the tibia I of male without apophyses, at most with a small one lobe-like process; stridulating organ on the inner chelicerae, made of an oblique row of five strong spines in front of many weak spines; legs relatively thin (Schmidt, 2003).

Type species: *Annandaliella travancorica* Hirst, 1909.

Species sampled from the Muriyad Kol Wetland.

Annandaliella pectinifera Gravely, 1935

Fig. 3.2C

Annandaliella pectinifera Schmidt, 2003: 115, Figs 60–61 (♂).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: Uncultivated, mixed crops and banana plantation.

Natural history: They are nocturnal and collected from laterite areas around the wetland.

Figure 3.2: Family Idiopidae: A. *Heligmomerus* sp., male; B. *Heligmomerus maximus*, female. **Family Theraphosidae:** C. *Annandaliella pectinifera*, male.

B. INFRAORDER ARANEOMORPHAE Smith, 1902

3.3.6 FAMILY ARANEIDAE Clerck, 1757

ORB WEB SPIDERS

Family Araneidae represents small to large araneomorph spiders, ecribellate, entelegyne, three-clawed, eight-eyed with cosmopolitan distribution (Jocqué & Dippenaar-Schoeman, 2006). They are commonly known as orb web spiders and most of them build highly specialised vertical orb webs in about all types of terrestrial niches (Barrion & Litsinger, 1995). The webs consists of many concentric rings and series of radii which characteristically hang down from the centre of the web (Barrion & Litsinger, 1995). Araneidae is the third largest family of spiders after Salticidae and Linyphidae (World Spider Catalog, 2021). The family currently has 3078 species in 176 genera globally (World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following characters: Carapace frequently flat, cephalic region usually separated from thoracic region by oblique depression, eight eyes in two rows, lateral eye groups widely separated from median eyes, labium rebordered, abdomen globose, overhanging the carapace; legs usually with numerous spines and sustentaculum on tarsi IV; male palp with mesal cymbium, median apophysis and radix in the embolic division; an orb web with a sticky spiral, or a modification of such a web, is constructed (Jocqué & Dippenaar-Schoeman, 2006).

Type genus: *Araneus* Clerck, 1757.

3.3.6.1 ***ARANEUS*** Latreille, 1804

Genus *Araneus* is a species-rich genus distributed worldwide (World Spider Catalog, 2021). The genus is represented by 594 nominal species globally, and 19 of them are currently known from India (World Spider Catalog, 2021). Some members of the genus are very common in wetland ecosystem. *Araneus* species have soft, round abdomen and they construct orb webs in low vegetation and rest in silken retreat constructed with leaves in the side of the web (Frances & Murphy, 2000).

Diagnosis: *Araneus* species can be distinguished from other Araneids by the following combination of characters: Moderately convex cephalothorax without horny outgrowth, fovea transverse in female and longitudinal in males; female abdomen sub-spherical to triangular, frequently with a pair of humps; Epigyne with annulate scape attached to a base, male palp with patellar setae, median apophysis with spines or hooks, conductor close behind on the rim of tegulum, and pressence of subterminal and terminal apophysis (Levi, 1991).

Type species: *Araneus angulatus* Clerck, 1757

Species sampled from the Muriyad Kol Wetland

Araneus ellipticus (Tikader & Bal, 1981)

Figs 3.A.1C to 3.A.1E

Neoscona elliptica Tikader and Bal, 1981: 24, Figs 45–49 (♂♀)

Araneus ellipticus Barrion and Litsinger, 1995: 639, Figs 406a–d (♀).

Neoscona elliptica Song et al., 1999: 299, Figs 175O–Q, 178Q–R, 180F (♂♀); Gajbe, 2007: 531, Figs 322–325 (♀); Yin, Peng, et al., 2012: 725, Figs 360a–k (♂♀); Biswas and Raychaudhuri, 2013: 171, Figs 7–13 (♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: Most commonly seen in wetland ecosystems, including paddy fields.

Natural history: *Araneus ellipticus* is one of the most abundant spiders in the wetland ecosystem. They spin vertical orb webs among the shrubs, grasses and paddy fields. Many of these nocturnal spiders occupy the upper strata of the paddy plants in the paddy fields and presumably play an important role as a pest control agent in the wetlands. The presence of tall weed grasses like *Echinochloa crus-galli* and sedges like *Cyperus iria* towering over the paddy plants provides additional substrate for web anchoring and retreat.

Araneus mitificus (Simon, 1886)

Fig. 3.A.1G

Epeira mitifica Simon, 1886: 150 (♀).

Aranea mitifica Bösenberg and Strand, 1906: 221, pl. 4, Figs 20, pl. 11, Fig. 207 (♀); Simon, 1909: 109.

Araneus mitificus Saitō, 1939: 19, Fig. 3(2) (♀).

Araneus mitifica Tikader, 1963: 43, Figs 4a–c (♂♀); Tikader and Bal, 1981: 53, Figs 115–120 (♂♀); Tikader, 1982a: 233, Figs 452–457 (♂♀).

Araneus mitificus Hu, 1984: 95, Figs 89.1–2 (♀); Barrion and Litsinger, 1995: 638, Figs 405a–h (♀); Song et al., 1999: 239, Figs 139A–B (♀); Tanikawa, 2007: 85, Figs 256, 699–701 (♂♀); Tanikawa, 2009: 457, Figs 275–277 (♂♀); Yin, Peng, et al., 2012: 609, Figs 294a–f (♂♀); Biswas and Raychaudhuri, 2013: 158, Figs 1–7 (♂♀); Sen, Dhali, et al., 2015: 122, Figs 771–776, pl. 23 (♀); Roy, Saha, et al., 2017: 26, Figs 161–165, 198 (♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: Lower branches of trees and low bushes surrounding wetland.

Natural history: *Araneus mitificus* is also known as Kidney garden spider or pale orb weaver. It builds orb webs that misses a section and rests in a silk-lined retreat in leaves at the margin of web. The leaf is bent at the edges and roof lined with silk (Koh, 1989). The spider detects the entangled prey via signal strand of silk positioned in the empty section of the web.

Araneus viridisomus Gravely, 1921

Araneus viridisoma Gravely, 1921a: 415, Fig. 3c (♂♀)

Araneus viridisomus Caleb, 2014c: 3, Figs 1–9 (♀); Patil and Uniyal, 2016: 172, Figs 1–11 (♂♀).

Habitat: Trees and bushes in the surroundings of the wetland.

Natural history: *Araneus viridisomus* has greenish cephalothorax and lateral abdomen. The dorsal abdomen is characteristically chalk white to pale yellow. It is a nocturnal spider and was observed resting inside silken retreat during daytime. The retreat is made by upwardly bending leaf edges and roofed with silk threads, and the spider sits inside the silkened roof showing off its green underside which blends in with the leaves.

3.3.6.2 *ANEPSION* Strand, 1929

Genus *Anepsion* is a less species-rich genus with a widespread distribution and is common in wetlands (Barrion & Litsinger, 1995; World Spider Catalog, 2021). The genus is represented by 16 nominal species globally, and only one is currently known from India (World Spider Catalog, 2021).

Diagnosis: *Anepsion* species can be distinguished from other Araneids by the following combination of characters: Small spiders; Carapace smooth and shiny; cephalic region high, with a pair of dorsal bulging; Thorax low, flat and overlaid by anterior part of abdomen. Abdomen oval, circular to rhomboidal and leathery, with dorsal and lateral sigillae. Male palp with large Median apophysis; embolus slender. Epigyne with short to very long, pointed or blunt ended scapus (Malamel, Sankaran, Joseph, et al., 2015).

Type species: *Anepsion rhomboides* (L. Koch, 1867)

Species sampled from the Muriyad Kol Wetland

Anepsion maritatum Gravely, 1921

Figs 3.A.1A and 3.A.1B

Paraplectana picta Thorell, 1877: 356 (♀).

Cyrtarachne keralensis Sunil Jose, 2011: 322, Figs 1a–g (♀).

Anepsion maritatum Malamel, Sankaran, Joseph, et al., 2015: 478, Figs 1A–O, 2A–I (♂♀); Tanikawa and Yamasaki, 2019: 11, Figs 1A–F (♂♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: Very common in the agricultural landscape surrounding the wetlands.

Natural history: Specimens of *Anepsion maritatum* were collected by hand directly from the web. They spin almost vertical orb web and sits in the centre of web.

3.3.6.3 *ARGIOPE* Audouin, 1826

Genus *Argiope* is moderately species-rich and distributed worldwide with a centre of its diversity in South East Asia (Jäger, 2012; World Spider Catalog, 2021). The genus is represented by 89 nominal species globally and 9 of them are currently known from India (World Spider Catalog, 2021). *Argiope* species are famous for their colourful opisthosomal pattern in females and the existence of strong sexual size and colour dimorphism (Levi, 1983).

Diagnosis: *Argiope* species can be distinguished from other Araneids by the following combination of characters: moderately large spider, carapace relatively flat and clothed with thick layer of white setae, wider in the thoracic area; eye arrangement with PMEs are closer to each other than to the laterals, head region bearing the PMEs is lower than in *Gea* and *Neogea*, Posterior Eye Row (PER) strongly procurved; epigyne bears a thin or thick medium septum. Webs provided with a zigzag stabilimentum (Levi, 1983).

Type species: *Argiope lobata* (Pallas, 1772)

Species sampled from the Muriyad Kol Wetland

Argiope catenulata (Doleschall, 1859)

Fig. 3.A.2B

Epeira catenulata Doleschall, 1859: 30, pl. 9, Fig. 1 (♀).

Argiope catenulata Kolosváry, 1931: 1071, pl. 30, Fig. 5 (♀); Tikader and Biswas, 1981: 35, Figs 56–58 (♀); Tikader, 1982a: 121, Figs 227–230 (♀); Levi, 1983: 274, fig. 36–41 (♂♀); Song et al., 1999: 261, Figs 151O–P, 152Q, 153K (♂♀); Jäger, 2012: 282, Figs 8–9 (♂♀); Brown and Henderson, 2019: 98, Figs 2–5 (♂♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Argiope catenulata* was abound in paddy fields and grasslands.

Natural history: Adults of *A. catenulata* were found in the flowering stages of the paddy growth. These large bodied orb weavers were observed to consume insect pests such as *Hieroglyphus banian, Oxya nitidula* and *Pelopidas mathias.* They occupy the middle section of the paddy plant and construct vertical orb webs spanning the empty space between adjacent plants.

Argiope pulchella Thorell, 1881

Fig. 3.A.2A

Argiope pulchella Tikader, 1970:27, Fig. 17a (♀); Tikader, 1982a: 129, Figs 243–246 (♀); Levi, 1983: 304, Figs 238–250 (♂♀); Jäger and Praxaysombath, 2009: 38, Figs 52–68, 74; Jäger, 2012: 304, Figs 115–118 (♂); Roy, Saha, et al., 2017: 8, Figs 23–27, 170 (♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: Low bushes and gardens.

Natural history: *Argiope pulchella* spins vertical orb webs with cross stabilimentum in the centre. This spider was collected by hand from its web on shrubs in the vicinity of wetlands.

3.3.6.4 *CYCLOSA* Menge, 1866

Genus *Cyclosa* is moderately species-rich with a worldwide distribution (World Spider Catalog, 2021). The genus is represented by 180 nominal species globally and 19 of them are currently known from India (World Spider Catalog, 2021). They are commonly called Trashline orbweavers, because their webs often contains linear web decorations comprising prey remains and other debris, and it serve to camouflage the spider.

Diagnosis: *Cyclosa* species can be distinguished from other Araneids by the following combination of characters: Cephalothorax with cephalic area markedly separated from thoracic area by an oblique groove forming a U-shape; AME usually larger than PME, PME very close, almost touching each other, with full canoe-shaped tapetum; abdomen usually longer than wide, extends posteriorly beyond spinnerets; spinnerets surrounded by black ring; male palp with paramedian apophysis (Barrion & Litsinger, 1995; Levi, 1999).

Type species: *Cyclosa conica* (Pallas, 1772)

Species sampled from the Muriyad Kol Wetland

Cyclosa bifida (Doleschall, 1859)

Fig. 3.A.2D

Epeira bifida Doleschall, 1859: 38, pl. 2, Fig. 8 (♀)

Epeira bifida Workman, 1896: 33, pl. 33 (♂♀). *Cyclosa bifida* Simon, 1895: 779, Fig. 852; Tikader, 1966a: 152, fig. 31-34 (♀); Barrion and Litsinger, 1995: 608, Figs 381a–g (♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: Grass and shrubs in the wetland.

Natural history: *Cyclosa bifida* were collected by hand directly from the web.

Cyclosa confraga (Thorell, 1892)

Epeira confraga Thorell, 1892: 239 (♀)

Cyclosa confraga Simon, 1909: 104; Tikader, 1982a: 193, Figs 372–376 (♀); Sen, Dhali, et al., 2015: 116, Figs 709–714, pl. 22 (♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: Grasses and shrubs in the wetlands and associated landscape.

Natural history: *Cyclosa confraga* were collection by hand from the web.

Cyclosa hexatuberculata Tikader, 1982

Fig. 3.A.2C

Cyclosa hexatuberculata Tikader, 1982a: 197, Figs 382–387 (♂♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: Shrubs and lower branches of trees.

Natural history: *Cyclosa hexatuberculata* were collected by hand directly from the web.

3.3.6.5 *CYRTOPHORA* Latreille, 1804

Genus *Cyrtophora* is moderately species-rich with a widespread distribution in the Oriental, Ethiopian, Australian regions and introduced in the Neotropical region

(World Spider Catalog, 2021). The genus is represented by 49 nominal species globally and 10 of them are currently known from India (World Spider Catalog, 2021). *Cyrtophora* is also called tent-web spiders, because they do not spin orb webs. Instead, their webs are non-sticky, tent-like and highly complex, and it may be considered as a precursor to simplified orb webs.

Diagnosis: *Cyrtophora* species can be distinguished from other Araneids by the following characters: Cephalothorax almost flat dorsally and a long cephalic area; Median ocular quadrangle slightly longer than wide, lateral eyes equal sized and slightly separated from each other; abdomen with paired tubercles along the very high anterior end (Barrion & Litsinger, 1995).

Type species: *Cyrtophora citricola* (Forsskål, 1775)

Species sampled from the Muriyad Kol Wetland

Cyrtophora cicatrosa (Stoliczka, 1869)

Fig. 3.A.2E

Epeira cicatrosa Stoliczka, 1869: 242, pl. 20, Fig. 5 (♀)

Cyrtophora cicatrosa Chrysanthus, 1960: 28, Figs 19–23 (♂♀); Tikader and Biswas, 1981: 32, Figs 45–46 (♀); Tikader, 1982a: 179, fig. 341–345 (♀); Song et al., 1999: 279, Figs 163P–Q, 164O–P, 165A (♂♀); Roy, Saha, et al., 2017: 14, fig. 58–62, 178 (♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Cyrtophora cicatrosa* was common in bushes and lower branches of trees in the surrounding landscape of the wetland.

Natural history: *Cyrtophora cicatrosa* were observed to be common among human habitations and their characteristic tent webs were seen on the outer walls of buildings. In colonies of *C. cicatrosa*, the adults occupy the highest strata, whereas the juveniles occupy the lower strata.

Cyrtophora unicolor (Doleschall, 1857)

Fig. 3.A.2H

Epeira unicolor Doleschall, 1857: 419.

Epeira unicolor Workman and Workman, 1894: 20, pl. 20 (♀); Barrion and Litsinger, 1995: 587, Figs 366a–i (♀); Malamel, 2018: 112, Figs 2A–B. 3A–I (♀♂).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: Shrubs and lower branches of trees.

Natural history: Specimens of *Cyrtophora unicolor* were collected from its retreat, which consisted of a dry leaf placed on top of the horizontal tent web. The spider appears reddish to brown which is similar in colouration to its retreat.

3.3.6.6 *ERIOVIXIA* Archer, 1951

Genus *Eriovixia* is a less species-rich genus distributed in the Oriental and Ethiopian regions (World Spider Catalog, 2021). The genus is represented by 25 nominal species globally and 8 of them are currently known from India (World Spider Catalog, 2021).

Diagnosis: *Eriovixia* species can be distinguished from other Araneids by the following combination of characters: Carapace pilose especially in the cephalic area; AER straighter than PER, PME slightly larger than AME; abdomen subtriangular, with or without a caudal appendage; epigyne with a stout scape with recurved tip, flatter than those in *Neoscona*; male palpal tibia with two long setae and median apophysis projected apically (Barrion & Litsinger, 1995).

Type species: *Eriovixia rhinura* (Pocock, 1900)

Species sampled from the Muriyad Kol Wetland

Eriovixia laglaizei (Simon, 1877)

Fig. 3.A.3A

Epeira thomisoides Doleschall, 1857: 422 (♀)

Araneus laglaizei Chrysanthus, 1960: 39, Figs 50, 56, 75 (♀); Chrysanthus, 1971: 28, Figs 45–47 (♂).

Eriovixia laglaizei Barrion and Litsinger, 1995: 641, Figs 408a–j (♀); Sen, Dhali, et al., 2015: 120, Figs 748–753, pl. 23 (♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: Grasses, bushes and trees around the wetland.

Natural history: *Eriovixia laglaizei* was common in the areas surrounding the wetlands. They are nocturnal and are usually found resting on dried leaf retreat during daytime. Its cryptic colouration and stubborn behaviour of not moving even if disturbed or agitated helps it blend in with its habitat during diurnal period.

Eriovixia excelsa (Simon, 1889)

Glyptogona excelsa Simon, 1889: 337 (♀)

Araneus excelsus Simon, 1906: 283.

Araneus excelsus Tikader and Biswas, 1981: 20, Figs 16–18 (♀)

Eriovixia excelsa Grasshoff, 1986: 118; Barrion and Litsinger, 1995: 643, Figs 409a–f (♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: Grasses, bushes and trees around the wetland.

Natural history: *Eriovixia excelsa* are nocturnal and create vertical orb webs.

3.3.6.7 *GASTERACANTHA* Sundevall, 1833

Gasteracantha is a moderately species-rich genus with a worldwide distribution (Barrion & Litsinger, 1995; World Spider Catalog, 2021). The genus is represented by 88 nominal species globally and 11 of them are currently known from India (World Spider Catalog, 2021). Members of the genus are beautiful, ornate with spines and sigilla on their abdomen (Barrion & Litsinger, 1995).

Diagnosis: *Gasteracantha* species can be distinguished from other Araneids by the following combination of characters: Cephalic region much elevated in the middle and sloping anteriorly and posteriorly; median ocular quadrangle wider posteriorly, median eyes subequal in size; abdomen large, transversely oblong, laterally narrowed and horny, dorsally impressed with prominant sigilla, marginal spines are large, situated anteriorly, medially and posteriorly, median ones often the longest; spinnerets forms a circular space ringed by a thick flange (Barrion & Litsinger, 1995).

Type species: *Gasteracantha cancriformis* (Linnaeus, 1758)

Species sampled from the Muriyad Kol Wetland

Gasteracantha dalyi Pocock, 1900

Fig. 3.A.3B

Pocock, 1900 Pocock, 1900: 232 (♀); Tikader, 1982a: 67, Figs 135–138 (♀).

Habitat: Collected from bushes and shrubs.

Natural history: *Gasteracantha dalyi* were collected from its vertical orb web among the foliage not too far from a water body.

Gasteracantha geminata Gravely, 1921

Fig. 3.A.3C

Aranea geminata Fabricius, 1798: 292 (♀).

Gasteracantha geminata C. L. Koch, 1837a: 16, Fig. 260 (♀); Simon, 1895: 836, Figs 883–887 (♂♀); Pocock, 1900: 233, Fig. 79 (♀); Dahl, 1914: 267, Fig. 11 (♀); Tikader, 1982b: 53, Figs 107–110 (♀); Kim and Lee, 2013: 175, Figs 1–8 (♀); Sankaran, Jobi, et al., 2015: 147, Figs 1A–F, 2A–F (♂♀); Caleb, 2020: 15717, Figs 3D, 24N (♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Gasteracantha geminata* was found on shrubs and lower branches of trees in the landscape.

Natural history: *Gasteracantha geminata* is commonly called oriental spiny orb-weaver, and they exhibit sexual dimorphism. Male and female have black and white transverse bands on the abdomen, which is strongly sclerotised. Males are comparatively smaller than females, with lesser colouration and abdominal spines.

3.3.6.8 *LARINIA* Simon, 1874

Larinia is a less species-rich genus with a worldwide distribution and is common in wetland habitats (Barrion & Litsinger, 1995; World Spider Catalog, 2021). The genus is represented by 58 nominal species globally and only 9 species are currently known from India (World Spider Catalog, 2021). The members of genus are nocturnal, and errect webs at night and remove them at first light in the morning. The species observed in the study area construct orb webs in the upper strata of tall grases and paddy plants.

Diagnosis: *Larinia* species can be distinguished from other Araneids by the following combination of characters: Cephalothorax longer than wide, vertical median fovea, median ocular quadrangle twice as wide than front, AME larger than others; abdomen longer than wide, rounded to slightly tapering posterior.

Type species: *Larinia lineata* (Lucas, 1846)

Species sampled from the Muriyad Kol Wetland

Larinia phthisica (L. Koch, 1871)
(Figs 3.A.3E and 3.3)

Epeira phthisica Keyserling, 1887: 171, pl. 14, Fig. 6 (♂)

Larinia phthisica Tikader and Biswas, 1981: 44, Figs 72–73 (♀); Tikader, 1982a: 208, Figs 408–410 (♀); Barrion and Litsinger, 1995: 614, Figs 386a–e, 387a–l (♂♀); Tanikawa, 2009: 447, Figs 193–196 (♂♀); Biswas and Raychaudhuri', 2012: 58, Figs 14–19 (♀); Sen, Dhali, et al., 2015: 118, Figs 737–742, pl. 23 (♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Larinia phthisica* was found numerously in the paddy fields and on tall grasses in the wetland.

Natural history: *Larinia phthisica* and *L. tabida* generally share the same niche, and often collected together from the Kol wetland.

Larinia tabida (L. Koch, 1871)
(Fig. 3.4)

Epeira tabida Koch, 1872: 105, pl. 8, Fig. 6 (♀)

Meta soror Thorell, 1877: 433 (♀)

Larinia tabida Thorell, 1890a:25 ; Chrysanthus, 1961: 205, Figs 46–49 (♀); Chrysanthus, 1971: 26, Fig. 42 (♂); Framenau and Scharff, 2008:242, Figs 36–46.

(For complete list of references, see World Spider Catalog, 2021)

Remarks: First report from India.

Habitat: *Larinia tabida* was numerously found in the paddy fields and on tall grasses in the wetland.

Natural history: *Larinia tabida* and *L. phthisica* dominated samples collected from embankments of canals in the wetland during the night.

Distribution: India (New record), Indonesia (Sulawesi) to Australia and New Caledonia (World Spider Catalog, 2021).

3.3.6.9 *NEOSCONA* Simon, 1864

Genus *Neoscona* is a moderately species-rich genus with a widespread distribution and is common in wetlands (World Spider Catalog, 2021). The genus is represented by 126 nominal species globally and 25 of them are currently known from India (World Spider Catalog, 2021).

Diagnosis: *Neoscona* species can be distinguished from other Araneids by

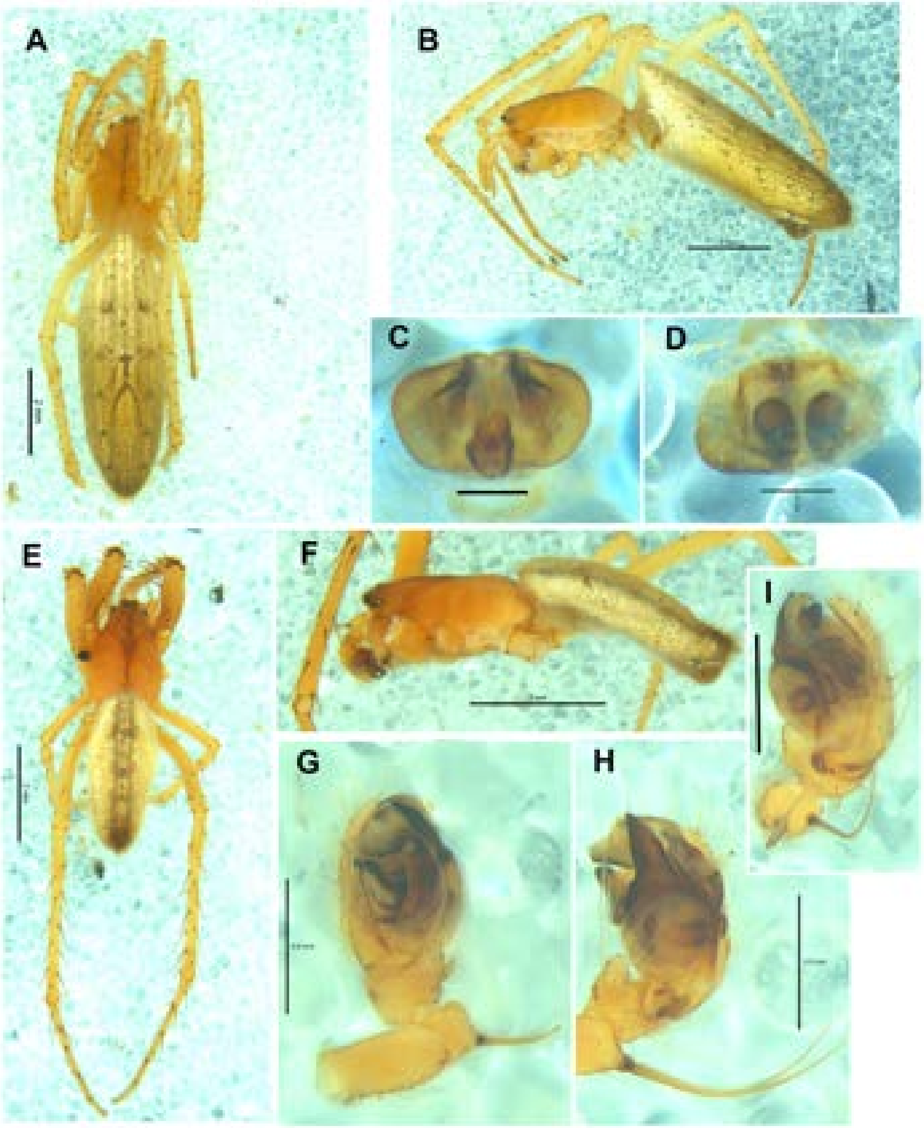

Figure 3.3: Male and female of *Larinia phthisica*. Female (**A–D**) and male (**E–I**). **A**, general appearance, dorsal view. **B**, same, lateral view. **C**, epigyne, ventral view. **D**, vulva, dorsal view. Scale bars. **A, B, E, F**, 2 mm. **C, D**, 0.2 mm. **G–I**, 0.5 mm

the following combination of characters: Cephalothorax with characteristic longitudinal thoracic groove, distinct in male; epigyne with smooth scape, without flexibility; male palpal cymbium situated ventrally, conformation of palpal sclerite is also characteristic (Barrion-Dupo, 2008; Tanikawa, 1998).

Type species: *Neoscona arabesca* (Walckenaer, 1841)

Species sampled from the Muriyad Kol Wetland

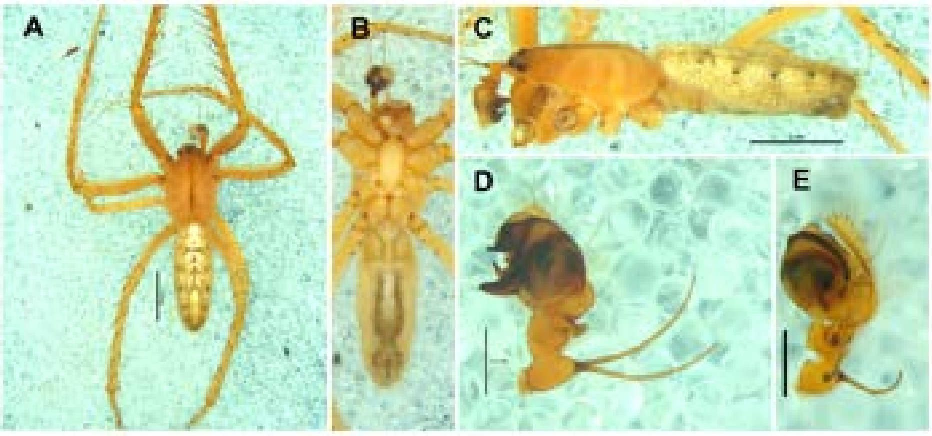

Figure 3.4: Male of *Larinia tabida*. **A**, general appearance, dorsal view. **B**, same, ventral view. **C**, same, lateral view. **D**, left palp, ventral view. **E**, same, retrolateral view. Scale bars. **A–C**, 2 mm. **D, E**, 0.5 mm.

Neoscona bengalensis Gravely, 1921

Neoscona bengalensis Tikader and Bal, 1981: 15, Figs 22–25 (♀); Biswas and Raychaudhuri, 2013: 171, Figs 1–6 (♀); Roy, Saha, et al., 2017: 23, Figs 132–137, 191 (♀); Basu, Roy, et al., 2017: 66, Figs xii–xvii, 12–17 (♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: Paddy fields, bushes and grasses on embankments, trees in the surrounding landscapes of the wetlands.

Natural history: *Neoscona bengalensis* is a nocturnal orb weaver, producing vertical webs at dawn and sits in the center of web in an upside down position. It is one of the most common *Neoscona* species encountered in the region.

Neoscona molemensis Gravely, 1921

Fig. 3.A.3F

Neoscona molemensis Tikader and Bal, 1981: 22, Figs 40–44 (♂♀); Tikader, 1982a: 257, Figs 510–514 (♂♀); Barrion and Litsinger, 1995: 627, Figs 396a–e (♀); Biswas and Raychaudhuri, 2013: 173, Figs 30–36 (♂♀).

Habitat: *Neoscona molemensis* was found in the grass and shrubs around the paddy fields.

Neoscona mukerjei Gravely, 1921

Fig. 3.A.3G

Neoscona mukerjei Tikader, 1980a: 247, Figs 1–23 (♂♀); Tikader, 1982a: 17, Figs 11–12, 26–30 (♂♀); Tikader, 1982a: 248, Figs 60–61, 478–500 (♂♀); Biswas and Raychaudhuri, 2013: 173, Figs 37–44 (♂♀); Sen, Dhali, et al., 2015: 125, Figs 805–810, pl. 24 (♀).
(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Neoscona mukerjei* is common in all habitats of wetland, including the fringes of paddy fields.

Natural history: *Neoscona mukerjei* exhibits a high degree of colour variatons in the abdomen (Tikader & Bal, 1981). It is nocturnal as other *Neoscona* species and is one of the most common spiders of paddy lands.

Neoscona theisi (Walckenaer, 1841)
Fig. 3.A.3H

Epeira theis Walckenaer, 1841: 53, pl. 18, Fig. 4.(♀)
Neoscona theisi Barrion and Litsinger, 1995: 625, Figs 394a–e, 305a–d (♂♀); Zamani, Marusik, and Šestáková, 2020: 36, Figs 11A–B, 12C–D, 13A–B, 14A,D, 17A–C. (For complete list of references, see World Spider Catalog, 2021)

Habitat: Most habitats of the wetland.

Natural history: *Neoscona theisi* was mostly collected from the panicle of grasses like *Echinochloa crus-galli* and shrubs in the vicinity of paddy fields during the day.

3.3.6.10 *PARAWIXIA* O. Pickard-Cambridge, 1904

Parawixia is a less species-rich genus, with 29 nominal species distributed mainly in the New World, and a few from the South, South-east Asia and Australia (World Spider Catalog, 2021). Only a single species is known from India (Caleb and Sankaran, 2020).

Diagnosis: *Parawixia* species can be distinguished from other Araneids by the following combination of characters: Epigynal scape as long as or longer than the width of the base, originating from posterior margin of base; palpal patella with one macrosetae, paramedian apophyis shaped like a disk with a finger distally Levi, 1992.

Type species: *Parawixia destricta* (O. Pickard-Cambridge, 1889)

Species sampled from the Muriyad Kol Wetland.

Parawixia dehaani (Doleschall, 1859)
Fig. 3.A.4A

Epeira dehaanii Doleschall, 1859: 33, pl. 2, Fig. 7 (♀).

Araneus dehaani Simon, 1899: 90; Feng, 1990: 55, Figs 30.1–4 (♀); Chen and Gao, 1990: 44, Fig. 46 (♀); Yin, Wang, Zhu, et al., 1997: 133, Figs 48a–i (♂♀); Yin, Peng, et al., 2012: 602, Figs 290a–h (♂♀).

Parawixia dehaanii Tikader, 1982a:212, Figs 414–418.

Parawixia dehaani Barrion and Litsinger, 1995: 582, Figs 362a–e (♀); Song et al., 1999: 302, Figs 182E–I (♂♀); Sen, Dhali, et al., 2015: 119, Figs 743–747, pl. 23 (♀); Roy, Saha, et al., 2017: 22, Figs 127–131, 190 (♀); Biswas and Raychaudhuri', 2017: 115, Figs 1a–g (♂♀); Nentwig et al., 2019: 34; Caleb, 2020: 15718, Figs 3J–L, 25D (♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Parawixia dehaani* has a wide distribution in the study area. They were common in the terrestrial habitats, although in low numbers, but were not collected from the paddy habitats.

Natural history: *Parawixia dehaani* also known as abandoned-web orb-weaving spider, construct large vertical orb webs with open hub among the openings in the undergrowth which looks partly damaged and abandoned. They are nocturnal and rests under a leaf next to its web during diurnal period, whilst falling down and playing dead when disturbed. They are large spiders, with triangular abdomen having sharp spikes in the corners, dark-brown in colour with varying patterns dorsally.

3.3.6.11 *POLTYS* C. L. Koch, 1843

Poltys is a moderately species-rich genus, distributed in the Oriental, Australasian and Ethiopian regions (World Spider Catalog, 2021). The genus is represented by 43 nominal species globally, with 7 of them currently known from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021). Most of the species are cryptic, exceptionally resembles leaves and twigs. The abdomen of spiders often takes bizarre shapes giving impressions of broken twigs or branches.

Diagnosis: *Poltys* species can be distinguished from other Araneids by the following combination of characters: Medium to large spiders, with distinct eye tubercles, carapace pear-shaped, median eyes form an anterior quadrangle on the tubercle; epigyne with bulbous base, thin extended scape; eye tubercle in males is not differentiated. Abdomen large, elevated anteriorly, with irregular tubercles

(Barrion & Litsinger, 1995; Smith, 2006).

Type species: *Poltys illepidus* C. L. Koch, 1843

Species sampled from the Muriyad Kol Wetland.

Poltys columnaris Thorell, 1890
Fig. 3.A.4B

Poltys columnaris Thorell, 1890a: 87 (♀); Smith, 2006: 88, Figs 223–225 (♀); Tanikawa, 2007: 91, Figs 289–294, 754–756 (♂♀); Tanikawa, 2009: 461, Figs 325–327 (♂♀); Kulkarni and Smith, 2013: 4524, Figs 1–3 (♀).

Habitat: Uncultivated plots.

Natural history: *Poltys columnaris* is a nocturnal spider, and it rests on thin branches of shrubs during the daytime. They are found in very low numbers in the study area due to its cryptic behaviour. The spider resembles a twig branching from the tree or shrub with its end broken off.

Poltys nagpurensis Tikader, 1982
Figs 3.A.4C and 3.A.4D

Poltys nagpurensis Tikader, 1982a: 169, Figs 321–325 (♀); Zamani, Marusik, Soofi, et al., 2019: 4, Figs 1a–f, 2a–g, 3a–h (♀); Caleb, 2020: 15719, Figs 3M–Q, 25E (♀).
Poltys illepidus Keswani, 2015: 8, Figs 1–4 (♀); Rajoria, 2015: 6, Figs 1–7 (♂♀).

Habitat: Uncultivated plots.

Natural history: *Poltys nagpurensis* is a nocturnal spider, and was collected from dried out branches of shrubs during daytime.

3.3.7 FAMILY CLUBIONIDAE Wagner, 1887

SAC SPIDERS

Family Clubionidae represents small to medium sized araneomorph spiders, ecribellate, entelegyne, two-clawed, eight-eyed with cosmopolitan distribution (Jocqué & Dippenaar-Schoeman, 2006). They are commonly known as Sac spiders, mostly encountered on foliage or on the ground. They make flat tubular retreats and nests in rolled-up leaves or under stones, litter or moss (Barrion & Litsinger, 1995). Ground forms of Clubionids are more diverse in their appearance, colouration and size than arboreal forms (Barrion & Litsinger, 1995). The family currently has 638 species in 15 genera globally and 28 of them are currently known from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following characters: Carapace oval-shaped, fovea shallow or absent altogether, eight eyes in two rows, eyes uniform size, small, PER slightly wider than AER; chelicerae long and slender, promargin with 2–7 teeth, 2–4 in retromargin, in some species with long fangs; abdomen oval, with small dorsal scutum in some species; epigynal plate convex, sclerotised sometimes, male palpal retrolateral tibial apophysis variable in shape, cymbium sometimes with basal apophysis; anterior spinnerets closer together, median spinnerets cylindrical (Barrion & Litsinger, 1995; Jocqué & Dippenaar-Schoeman, 2006).

Type genus: *Clubiona* Latreille, 1804

3.3.7.1 *CLUBIONA* Latreille, 1804

Genus *Clubiona* is a species-rich genus distributed worldwide (World Spider Catalog, 2021). The genus is represented by 505 nominal species globally, and 23 of them are currently known from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021). Small or medium-sized spiders, generally white, cream or pale, cephalic region and chelicerae dark brown.

Diagnosis: *Clubiona* species can be distinguished by the following characters: Carapace wider in front, mostly in females, thoracic groove present, PER wider than AER, eyes equidistant or medians are farther from each other than from laterals; all tarsi with long claws; abdomen truncate anteriorly, tapering posteriorly, with silky surface, most species are without markings (Barrion & Litsinger, 1995).

Type species: *Clubiona pallidula* (Clerck, 1757)

Species sampled from the Muriyad Kol Wetland

Clubiona sp. 1

3.3.7.2 *MATIDIA* Thorell, 1878

Genus *Matidia* is a less-rich genus distributed in the Oriental region (World Spider Catalog, 2021). The genus is represented by 16 nominal species globally, and only one is currently known from India (World Spider Catalog, 2021).

Diagnosis: *Matidia* species can be distinguished by the following combination of characters: leg I longer than IV and II, the narrow head, chelicerae with promarginal teeth shifted distally; abdomen is thin and elongate, dark spots on ventral sides in males; male palpal embolus is ribbon-shaped; epigyne with central depression and short ducts (Deeleman-Reinhold, 2001; Versteirt et al., 2010).

Type species: *Matidia virens* Thorell, 1878

Species sampled from the Muriyad Kol Wetland

Matidia sp. 1

3.3.8 FAMILY CORINNIDAE Karsch, 1880

DARK SAC SPIDERS

Family Corinnidae represents small to medium sized araneomorph spiders, ecribellate, entelegyne, two-clawed with distinct claw tufts, eight-eyed with worldwide distribution (Jocqué & Dippenaar-Schoeman, 2006). They are commonly known as Dark Sac spiders or Ant-like sac spiders, mostly encountered on foliage or on the ground. Members of the family are generally wandering spiders that builds silken retreats or sacs on plant, between leaves, barks or under rocks. Colour varies from dark to red-orange in subfamily Castianeirinae and dark to yellowish in Corinninae. The family currently has 793 nominal species in 70 genera globally, and 16 of them are presently known from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following characters: Carapace ovoid, in some ant mimicks it is elongated; abdomen elongate in ant-like species, with scuta, transverse bands or patches of white setae, mostly sclerotised; male palp usaually without median apophysis, tegulum tapering in Castianeirinae, with conspicuous loop in proximal tegulum and complex in Corinninae (Jocqué & Dippenaar-Schoeman, 2006).

Type genus: *Corinna* C. L. Koch, 1841

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3.3.8.1 *CASTIANEIRA* Keyserling, 1879

Genus *Castianeira* is a moderately species-rich genus with a widespread distribution, except in Australia (World Spider Catalog, 2021). The genus is represented by 122 nominal species globally and only 4 species are currently known from India (World Spider Catalog, 2021). Most species have generic body modifications such as elongated body or patterns mimicking third body segment as in ants. They also modify their behaviour by bobbing their abdomen as well as waving their first legs mimicking the antennae of ants.

Diagnosis: *Castianeira* species can be distinguished by the following characters: Medium-sized (4-8mm), elongated body and thin legs, heavily sclerotized body, sometimes shiny carapace and abdomen, AER recurved, AME closeer to laterals than each other, PER distinctly recurved, chelicerae with two promarginal and two or three retromarginal teeth; abdomen elongated with dorsal band of white scale-like setae, ventral epigastric scutum present; male palpal tibia with strong retroventral ridge bearing small teeth, tegulum like cymbium, with one or two loops of sperm duct,

Type species: *Castianeira rubicunda* Keyserling, 1879

Species sampled from the Muriyad Kol Wetland.

Castianeira zetes Simon, 1897

Fig. 3.A.4G

Castianeira zetes Simon, 1897b: 294 (♀); Gravely, 1921a: 273, Figs 20A–B (♂♀); Tikader and Biswas, 1981: 73, Figs 129–130 (♀); Tikader, 1981: 258, Figs 1–4 (♂♀); Majumder and Tikader, 1991: 132, Figs 264–269 (♂♀); Biswas and Raychaudhuri, 2000: 132, Figs 1–7 (♂♀); Sen, Dhali, et al., 2015: 72, Figs 399–403, pl. 18 (♀); Dhali et al., 2017: 55, Figs 214–218, pl. 20 (♀); Sankaran, Malamel, et al., 2018: 497, Figs 1A–G, 2A–E (♂♀).

Habitat: *Castianeira zetes* were frequently found in the foliage around wetlands, sometimes in paddy fields and shrubs close to the fringes of wetland.

Natural history: *Castianeira zetes* are wandering spiders seen in foliage, they are ant-mimicking, agile and mostly diurnal spiders. They build silken leaf retreat on the upper surface of leaves during nighttime.

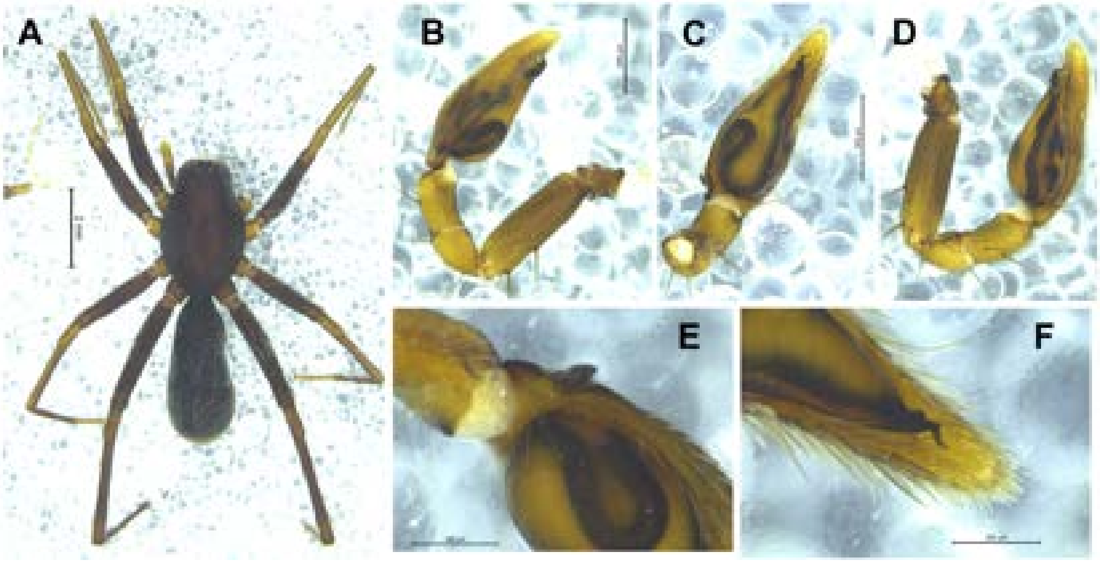

Figure 3.5: Male of *Corinnomma severum.* **A**, general appearance, dorsal view. **B**, left palp, prolateral view. **C**, same, ventral view. **D**, same, retrolateral view. **E**, same, close up view. **E**, embolus. Scale bars. **A**, 2 mm. **B–D**, 0.5 mm. **E–F**, 0.2 mm.

3.3.8.2 *CORINNOMMA* Karsch, 1880

Genus *Corinnomma* is a less species-rich genus with distribution limited to the Old World (World Spider Catalog, 2021). The genus is represented by 14 nominal species globally and 3 species are currently known from India (World Spider Catalog, 2021).

Diagnosis: *Corinnomma* species can be distinguished by the following characters: Resemble *Castianeira* but more elongated and slender; retrocoxal window small; eyes relatively small, AME much larger than ALE; abdomen widere poteriorly and truncate; spermathecae anterodorsally replicate and male palpal cymbium with distinct proximal retrolateral apophysis (Deeleman-Reinhold, 2001).

Type species: *Corinnomma severum* (Thorell, 1877)

Species sampled from the Muriyad Kol Wetland.

Corinnomma severum (Thorell, 1877)
(Fig. 3.5)

Corinna severa Thorell, 1877: 481 (♂).

Corinnomma severum Sankaran, Caleb, et al., 2019: 334, Figs 2A–C,E (♀); Caleb, 2020: 15720, Figs 6G–J, 25K (♀).
Castianeira himalayensis Gravely, 1931: 275, Fig. 20C (♀); Tikader and Biswas, 1981: 72, Figs 127–128 (♀); Tikader, 1981: 265, Figs 14–16; Sen, Dhali, et al., 2015: 71, Figs 394–398, pl. 18 (♀); Dhali et al., 2017: 55, Figs 219–223, pl. 20 (♀).
Castianeira tiranglupa Barrion and Litsinger, 1995: 172, Figs 98a–f (♂).
(For complete list of references, see World Spider Catalog, 2021)

Habitat: Uncultivated plots.

3.3.9 FAMILY CTENIDAE Keyserling, 1877

TROPICAL WOLF SPIDERS

Family Ctenidae represents small to very large araneomorph spiders, ecribellate, rarely cribellate, entelegyne, two-clawed, eight-eyed arranged in three rows, with worldwide distribution, except New Zealand (Jocqué & Dippenaar-Schoeman, 2006). They are commonly known as Tropical wolf spiders or wandering spiders. The family currently has 521 species in 48 genera globally, and 18 of them are presently known from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following characters: Carapace ovoid, with deep depression or longitudinal groove in the posterior half, eyes arranged in three rows (2:4:2 or 4:2:2), PER strongly recurved; abdomen ovoid, sometimes with median bands or spots; epigyne with broad median septum; male palp with tibial apophysis, modified cymbium, median apophysis cup-shaped ventrally (Barrion & Litsinger, 1995; Jocqué & Dippenaar-Schoeman, 2006).

Type genus: *Ctenus* Walckenaer, 1805

3.3.9.1 *CTENUS* Walckenaer, 1805

Genus *Ctenus* is a species-rich genus with a widespread distribution (World Spider Catalog, 2021). The genus is represented by 212 nominal species globally and 12 species are currently known from India (World Spider Catalog, 2021).

Diagnosis: *Ctenus* species can be distinguished by the following characters: Both rows of eyes recurved, but the AER strongly recurved, so that anterior laterals meet posterior medians, forming three rows of eyes; chelicerae with four or five teeth on retromarginal margin; male palp always with the tibial apophysis and lamina.

Type species: *Ctenus dubius* (Walckenaer, 1805)

Species sampled from the Muriyad Kol Wetland.

Ctenus cochinensis Gravely, 1931
Fig. 3.A.4H

Ctenus cochinensis Gravely, 1931: 235, Figs 1E, 3C (♂♀); Tikader and Malhotra, 1981: 112, Figs 5A–D (♂♀); Sankaran and Sebastian, 2018a: 400, Figs 1B, D–E, 5A–G (♂♀).

Habitat: *Ctenus cochinensis* found among the litter in riparian and uncultivated plots in the study area.

Natural history: *Ctenus cochinensis* are large spiders, nocturnal, seen foraging among the litter on the ground. They are usually clumpsy and easy to collect manually. These spiders are known to inflict mildly painful bites when captured carelessly.

3.3.10 FAMILY CHEIRACANTHIIDAE Wagner,1887

YELLOW SAC SPIDERS

Family Cheiracanthiidae represents small to medium sized araneomorph spiders, ecribellate, entelegyne, two-clawed, eight-eyed with cosmopolitan distribution (Jocqué & Dippenaar-Schoeman, 2006). They are commonly known as Yellow sac spiders, most commonly encountered on foliages. It currently includes 362 species in 14 genera globally and 31 of them are presently known from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following characters: Carapace lateral margins parallel, head wide, eye rows parallel, equidistant and similar sized; trochanters deeply nootched; anterior spinnerets juxtaposed; male palpal cymbium with retrolateral spur; epigyne with central or posterior depression and funnel-shaped duct, bursae absent (Deeleman-Reinhold, 2001).

Type genus: *Cheiracanthium* C. L. Koch, 1839

3.3.10.1 *CHEIRACANTHIUM* C. L. Koch, 1839

Genus *Cheiracanthium* is a species-rich genus with a widespread distribution (World Spider Catalog, 2021). The genus is represented by 213 nominal species globally and 29 are currently known from India (World Spider Catalog, 2021). They are commonly referred to as yellow sac spiders and commonly found in the foliages. Species of the group are abundant in agricultural ecosystems.

Diagnosis: *Cheiracanthium* species can be distinguished by the following characters: Creamish-yellow bodies, two-clawed, medium size; chelicerae and eye area blackish-brown; cephalic region wide, eyes in two rows; legs relatively long and slender, leg I longer than IV, without dorsal setae; epigyne with well-spaced spermatheca; male palp with long cymbial and RTA.

Type species: *Cheiracanthium punctorium* (Villers, 1789)

Species sampled from the Muriyad Kol Wetland.

Cheiracanthium danieli Tikader, 1975

Cheiracanthium danieli Tikader, 1975: 43, Figs 1–4 (♂♀); Majumder and Tikader, 1991: 69, Figs 134–139 (♂♀).

Habitat: *Cheiracanthium danieli* were collected from different sites in and around the wetland.

Natural history: *Cheiracanthium danieli* are nocturnal foliage runners, found moving around in the foliages at night and resting inside silken tube retreat made on leaves during day time.

Cheiracanthium melanostomum (Thorell, 1895)

Eutittha melanostoma Thorell, 1895: 44 (♂♀).

Chiracanthium melanostomum Simon, 1901b: 67; Gravely, 1931: 264, Figs 17 C–D (♂♀); Tikader and Biswas, 1981: 71, Figs 123–124 (♀); Majumder and Tikader, 1991: 62, Figs 117–112 (♂♀); Okuma, Kamal, et al., 1993: 57, Fig. 51A (♂); Deeleman-Reinhold, 2001: 231, 254, Figs 280–281 (♀); Biswas and Raychaudhuri, 2003: 116, Figs 1–7 (♂♀); Sen, Dhali, et al., 2015: 74, Figs 414–418, pl. 18 (♀); Dhali et al., 2017: 51, Figs 185–189, pl. 20 (♀).

Habitat: *Cheiracanthium melanostomum* were collected from different sites in and around the wetland.

Natural history: *Cheiracanthium melanostomum* are nocturnal foliage runners, found moving around in the foliages at night and resting inside silken tube retreat made on leaves during day time.

3.3.11 FAMILY DEINOPIDAE C. L. Koch, 1850

NET-CASTING SPIDERS

Family Deinopidae represents medium to large araneomorph spiders, cribellate, entelegyne, three clawed and eight-eyed (Jocqué & Dippenaar-Schoeman, 2006). They are commonly known as net-casting spiders or ogre-faced spiders, and distributed throughout the tropical regions of the world. The stick-like elongated spiders catch prey by stretching a web across their first two pairs of legs, propelling them forward when a prey moves below them. These casting webs have the ability to stretch three or four times their length and are extremely sticky, entangling any unfortunate insects that come in touch with it. The very large PME provide excellent night vision allowing them to ambush at night. The family is represented by 68 species in 3 genera globally, and two of them are presently known from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following characters: Carapace longer than wide, fovea a deep oval pit to a shallow depression, eyes in three rows, PME enlarged, AME smallest, ALE on small tubercles; legs I and II longest, tarsi IV with ventral macrosetae; abdomen covered in dense plumose setae,long and oval; cribellum narrow and undivided; epigyne with triangular or semicircular plate; male palp with spiral embolus, palpal tibia varies from very long to cylindrical or club-shaped (Jocqué & Dippenaar-Schoeman, 2006).

Type genus: *Deinopis* Macleay, 1839

3.3.11.1 *ASIANOPIS* Lin & Li, 2020

Genus *Asianopis* is a less species-rich genus with a widespread distribution (World Spider Catalog, 2021). The genus is represented by 8 nominal species globally and only 2 are currently known from India (World Spider Catalog, 2021).

Diagnosis: *Asianopis* species can be distinguished from *Deinopis* by the following characters: Prominent setal fringe above the PMEs; embolic tip of male with an embolic middle apophysis, an embolic terminal apophysis or is weakly folded apically; female chelicerae with many denticles or without denticles; epigynal median plate lateral margins anchor-shaped; sperm duct narrow (Lin et al., 2020).

Type species: *Asianopis zhuanghaoyuni* Lin & Li, 2020

Species sampled from the Muriyad Kol Wetland.

Asianopis liukuensis (Yin, Griswold & Yan, 2002)

(Figs 3.6 to 3.8)

Deinopis liukuensis Yin, Griswold, et al., 2002: 610, Figs 1 –7 (♂).

Deinopis scrubjunglei Caleb and Mathai, 2014: 2, Figs 1–20 (♂♀).

Deinopis liukuensis Zhang and Wang, 2017: 238, Fig. 7 (♂♀).

Asianopis liukuensis Lin et al., 2020: 74, Figs 2B,E–F, I, 4A–F, 5A–B, 6A–B, 7A–B, 8A–B, 19A–C, 21A, 22A, G (♂♀).

Habitat: *A. liukuensis* found in understory and lower vegetation in uncultivated plots.

Natural history: *A. liukuensis* are nocturnal spiders, found in the understory and lower vegetation. They hang upside down and hunt by casting a sticky web stretched between their front legs on unsuspecting prey passing below them.

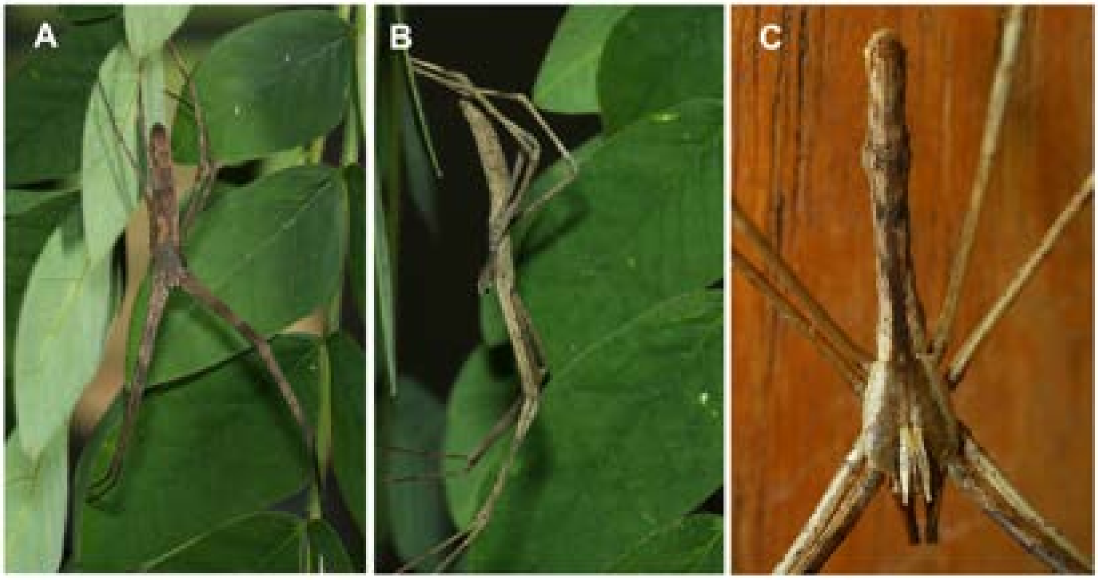

Figure 3.6: Live images of *Asianopis liukuensis*. **A**, Male, dorsal view. **B**, same, lateral view. **C**, same, dorsal view.

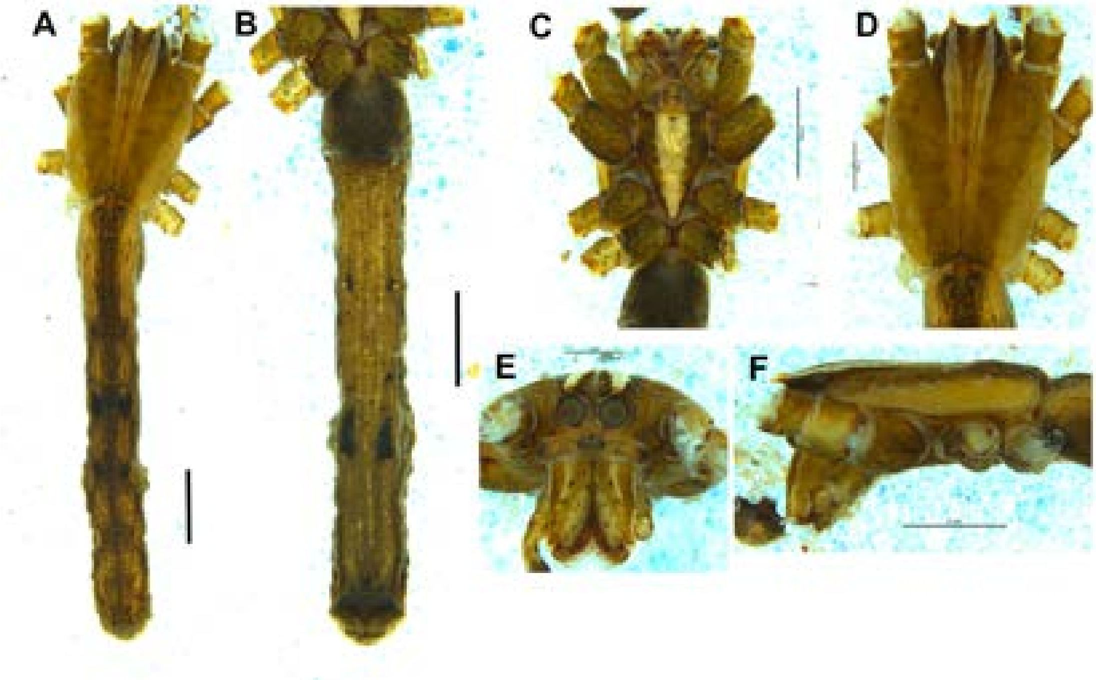

Figure 3.7: Male of *Asianopis liukuensis*. **A**, general appearance, dorsal view. **B**, abdomen, ventral view. **C**, carapace, ventral view. **D**, same, dorsal view. **E**, same, frontal view. **F**, same, lateral view. Scale bars. **A–C, F**, 2 mm. **D, E**, 1 mm.

3.3.12 FAMILY ERESIDAE C. L. Koch, 1845

VELVET SPIDERS OR SOCIAL SPIDERS

Family Eresidae represents small to large araneomorph spiders, cribellate, entelegyne, three clawed, eight-eyed with cosmopolitan distribution (Jocqué & Dippenaar-Schoeman, 2006). They are a small group of spiders, commonly known as velvet spiders or social spiders , mostly distributed in the Old World and a few species in the Neotropics. Some members of the *Stegodyphus* are sub-social, they cooperate in brood rearing and mass-attacks on prey. Many of the members are cryptic ambush predators in deserts, others build silken nests in vegetation or live in silken tubes under bark, stones or underground (Miller et al., 2012). The family currently has 100 species in 9 genera globally and 5 of them are presently known from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following characters: Carapace sub-rectangular, with clypeal hood, median eyes situated close together, lateral eyes widely spaced, body with dense plumose setae. It can

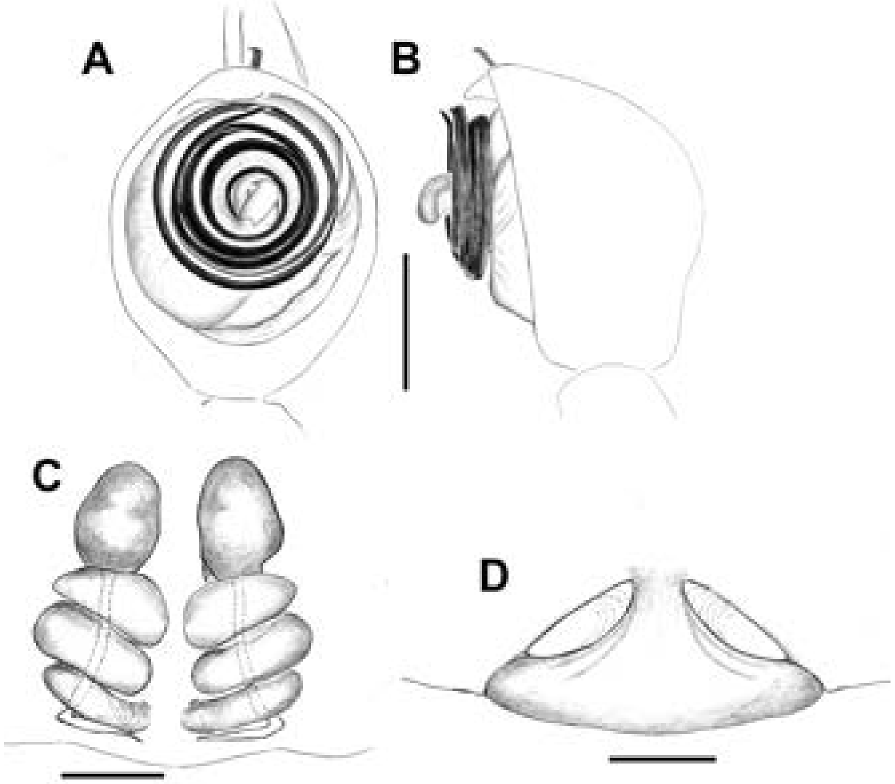

Figure 3.8: Male and female genitalia of *Asianopis liukuensis*. **A**, male left palp, ventral view. **B**, same, retrolateral view. **C**, vulva, dorsal view. **D**, epigyne, ventral view. Scale bars. **A–D**, 0.5 mm.

be distinguished from Penestomidae by the absence of retrolateral tibial apophysis on male palpal tibia, absence of median apophysis, absence of epigynal posterior lobe and absence of tapetum in eyes; AER straight and PER strongly recurved. (Jocqué & Dippenaar-Schoeman, 2006; Miller et al., 2012).

Type genus: *Eresus* Walckenaer, 1805

3.3.12.1 *STEGODYPHUS* C. L. Koch, 1839

Genus *Stegodyphus* is a less species-rich genus distributed in the Oriental, Ethiopian, paleartic and Neotropical regions (World Spider Catalog, 2021). The genus is represented by 20 nominal species globally and 5 are currently known from India (World Spider Catalog, 2021).

Diagnosis: *Stegodyphus* species can be distinguished by the following characters: social spiders; ocular quadrangle formed by ALE and PLE visibly narrower posteriorly; diameter of AME and PME not strikingly different (Kraus & Kraus, 1989).

Type species: *Stegodyphus lineatus* (Latreille, 1817)

Species sampled from the Muriyad Kol Wetland.

Stegodyphus sarasinorum Karsch, 1892
Fig. 3.A.5B

Stegodyphus sarasinorum Karsch, 1892: 275, pl. 10, Figs 4 (♀); Pocock, 1900: 209, Figs 65 (♀); Tikader and Biswas, 1981: 15, Figs 5–7 (♀); Gajbe, 2007: 428, Figs 16–19 (♂♀); Miller et al., 2012: 116, Figs 11I–L, 15J–L, 18I, L, 89A–J, 90A–F, 91A–F, 92A–F, 93A–F, 94A–F, 95A–F (♂♀); Schendel et al., 2018: 241, Figs 3E–H (♀).

Habitat: Communal webs of *S. sarasinorum* were found on shrubs and tree canopies in uncultivated plots.

Natural history: Also called Indian cooperative spiders, *S. sarasinorum* are social spiders known for their communal predation and feeding. They live in large colonies with nest or retreats made of silk mixed with twigs, carcasses, and large sheet webs for prey capture.

3.3.13 FAMILY GNAPHOSIDAE Pocock, 1898

FLAT BELLIED GROUND SPIDERS

Family Gnaphosidae represents small to medium sized araneomorph spiders, ecribellate, entelegyne, two clawed, eight-eyed with worldwide distribution (Jocqué & Dippenaar-Schoeman, 2006). They are commonly known as flat bellied ground spiders or ground spiders. They usually run-down prey and lacks a prey capture web. The family currently comprises of 2547 species in 162 genera globally which makes them the seventh largest spider family, and 154 of them are presently recorded from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following characters: Carapace ovoid, smoothly convex, with distinct fovea; eyes in two rows (4:4), PME conspicuously flattened or irregular, all eyes except AME with silvery sheen; legs prograde; abdomen oval, scutum present in some males; Epigyne with conspicuous circular margins. (Jocqué & Dippenaar-Schoeman, 2006).

Type genus: *Gnaphosa* Latreille, 1804

3.3.13.1 ***GNAPHOSA*** **C. L. Koch, 1839**

Genus *Gnaphosa* is a species-rich genus with a widespread distribution (World Spider Catalog, 2021). The genus is represented by 150 nominal species globally and only 7 are currently known from India (World Spider Catalog, 2021).

Diagnosis: *Gnaphosa* species can be distinguished by the following characters: AER procurved, while PER is much longer and more strongly recurved, irregularly shaped medians; chelicerae weak and vertical, with several long bristles forming a scopula on the inner apical surface, inner margin characterized by a prominent chitinous ridge with a concave and serrated edge, while the outer margin has two teeth.

Type species: *Gnaphosa lucifuga* (Walckenaer, 1802)

Species sampled from the Muriyad Kol Wetland.

Gnaphosa pauriensis Tikader & Gajbe, 1977

Gnaphosa pauriensis Tikader and Gajbe, 1977: 44, Figs 1A–E (♀); Tikader, 1982a: 334, fig. 90–95 (♀); Gajbe, 2007: 457, Figs 71–76 (♀).

Habitat: *Gnaphosa pauriensis* were found among the litter and ground in plots surrounding the wetland.

3.3.13.2 ***UROZELOTES*** **C. L. Koch, 1839**

Genus *Urozelotes* is a less species-rich genus with a worldwide distribution, probably introduced in Australia and New World (World Spider Catalog, 2021). The genus is represented by 5 nominal species globally and only 2 are currently known from India (World Spider Catalog, 2021).

Diagnosis: *Urozelotes* species can be distinguished by the following characters: Presence of a cluster of stiff setae on the anteromedian surface of the chelicerae (Platnick & Murphy, 1984).

Type species: *Urozelotes rusticus* (L. Koch, 1872)

Species sampled from the Muriyad Kol Wetland.

Urozelotes patulusus Sankaran & Sebastian, 2018

Urozelotes patulusus Sankaran and Sebastian, 2018b: 1739, Figs 1c–d, 4a–e (♂♀).

Habitat: *Urozelotes patulusus* found in samples from uncultivated and riparian plots.

Natural history: *Urozelotes patulusus* are nocturnal, collected from litter and ground.

3.3.13.3 *ZELOTES* C. L. Koch, 1839

Genus *Zelotes* is a speciose genus with a worldwide distribution (World Spider Catalog, 2021). The genus is represented by 393 nominal species globally and 27 are currently known from India (World Spider Catalog, 2021).

Diagnosis: *Zelotes* species can be distinguished by the following characters: Eyes close together, PER is slightly longer than AER; chelicerae moderately strong; legs relatively long, with ventral spines on tibia and metatarsi III and IV.

Type species: *Zelotes subterraneus* (C. L. Koch, 1833)

Species sampled from the Muriyad Kol Wetland.

Zelotes sp. 1

3.3.14 FAMILY HERSILIIDAE Thorell, 1870

TWO TAILED SPIDERS

Family Hersiliidae represents small to medium sized araneomorph spiders, ecribellate, entelegyne, three clawed, eight-eyed,distributed in the tropical and subtropical regions of the world (Jocqué & Dippenaar-Schoeman, 2006). They are commonly known as two-tailed spiders, and they are encountered on tree barks. These highly camouflaged spiders use their silken thread around an area of tree bark and wait for its prey to approach. The family currently includes 182 species in 16 genera globally and 12 of them are presently known from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following characters: Carapace ovoid and flatenned, densely covered with plumose setae;

eyes on a large tubercle, both eye rows recurved; very long legs; abdomen flat, wider in the posterior, densely covered with plumose seate; epigyne with broad central septum; male palp with no tibial apophysis, filiform conductor and pointed; posterior spinnerets as long as abdomen in arboreal genera, cylindrical with inner margin with a series of long tubules producing silk (Jocqué & Dippenaar-Schoeman, 2006).

Type genus: *Hersilia* Audouin, 1826

3.3.14.1 ***HERSILIA*** Audouin, 1826

Genus *Hersilia* is a moderately speciose genus with a widespread distribution in the Old World (World Spider Catalog, 2021). The genus is represented by 78 nominal species globally and only 7 are currently known from India (World Spider Catalog, 2021).

Diagnosis: *Hersilia* species can be distinguished by the following characters: Very long posterior lateral spinnerets, longer than the carapace width, and the presence of armed chelicerae with teeth on the pro- and retromargin (Foord & Dippenaar-Schoeman, 2006).

Type species: *Hersilia caudata* Audouin, 1826

Species sampled from the Muriyad Kol Wetland.

Hersilia savignyi Lucas, 1836
Figs 3.A.5D and 3.A.5E

Hersilia savignyi Simon, 1885d Simon, 1885: 19, pl. 10, Figs 18-19 (♂); Simon, 1893: 414, Figs 417, 426 (♂♀); Caleb, 2020: 15723, Figs 8A–E, 26C (♂♀).
(For complete list of references, see World Spider Catalog, 2021)

Habitat: *H. savignyi* inhabits the trunks of medium and large trees.

Natural history: The highly camouflaged *H. savignyi* are frequently seen on the trunks of coconut and other large trees, where they sit and wait for prey using their sensing web.

3.3.15 FAMILY LINYPHIIDAE Blackwall, 1859

DWARF SPIDERS OR MONEY SPIDERS

Family Linyphiidae represents very small to small sized araneomorphs, ecribellate, entelegyne, three-clawed, eight-eyed spiders with cosmopolitan distribution particularly well represented in temperate regions (Jocqué & Dippenaar-Schoeman, 2006). They are commonly known as dwarf spiders or money spiders, and build sheet webs for prey capture. The sheet web with or without lines above it, is distinctive of the family. It is the second largest spider family and currently comprises of 4671 species in 619 genera globally, and 61 of them are reported from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following characters: Carapace variable in shape, eyes in two rows, heterogeneous with AME darker; chelicerae robust with strong teeth, stridulating files present; tarsi IV without serrated ventral bristles; male palp with usually with intersegmental paracymbium which is U-shaped, bulb without median apophysis and conductor, but has distally grouped apophyses such as embolic membrane (Barrion & Litsinger, 1995; Jocqué & Dippenaar-Schoeman, 2006).

Type genus: *Linyphia* Latreille, 1804

3.3.15.1 *ATYPENA* Audouin, 1826

Genus *Atypena* is a less species-rich genus distributed in South-East Asia and Indian subcontinent(World Spider Catalog, 2021). The genus is represented by 8 nominal species globally and only one is currently known from India (World Spider Catalog, 2021).

Diagnosis: *Atypena* species can be distinguished by the following characters: Carapace slightly high in the cephalic region and broadest between coxae II and III, lateral eyes contiguous, AER strongly recurved and PER straight, PME largest and AME smallest; clypeus high; epigyne simple; males have elevated head forming a transverse lobe bearing the PME, pit present in PME and PLE, area between PME and AME hairy; palp complex with embolic portion rather wide apically; Tibiae III and IV of both sexes bear a single spine each (Barrion & Litsinger, 1995).

Type species: *Atypena superciliosa* Simon, 1894

Species sampled from the Muriyad Kol Wetland.

Atypena cirrifrons (Heimer, 1984)

Paranasoona cirrifrons Heimer, 1984a: 87, Figs 1–8 (♂♀); Zhu and Sha, 1992: 42, Figs 1–8 (♂♀); Song et al., 1999: 203, Figs 114N–Q (♂♀).

Atypena cirrifrons Tanasevitch, 2014: 72; Komisarenko et al., 2019: 27, Figs 1–2 (♂).

Habitat: Common in paddy fields and grasslands surrounding the wetland.

Natural history: *A. cirrifrons* are small spiders, found among the lower one-third part of paddy plants and tall grasses.

3.3.15.2 *ERIGONE* Audouin, 1826

Genus *Erigone* is a speciose genus with a worldwide distribution (World Spider Catalog, 2021). The genus is represented by 111 nominal species globally and only 3 are currently known from India (World Spider Catalog, 2021).

Diagnosis: *Erigone* species can be distinguished by the following characters: Presence of teeth in the margin of carapace and anterior of chelicerae; male head elevated with no definite lobe; male maxillae with warts; metatarsus IV without trichobothrium; tibiae I–III with two dorsal spines and one in tibia IV; metatarsi longer than tarsi; male palpal patella with a terminal ventral process, tip of tibia with a deep pit; embolic division consists of elongate central body armed with three teeth; epigyne simple, usually with a procurved rebordered posterior edge (Barrion & Litsinger, 1995).

Type species: *Erigone longipalpis* (Sundevall, 1830)

Species sampled from the Muriyad Kol Wetland.

Erigone bifurca Locket, 1982

Erigone bifurca Locket, 1982: 366, Figs 16–21 (♂♀); Jocqué, 1985: 203, Figs 15–16 (♂); Barrion and Litsinger, 1995: 482, Figs 296a–h, 297a–b (♂♀).

Habitat: *E. bifurca* were collected commonly in paddy fields and grasslands surrounding the wetland.

Natural history: *E. bifurca* are small spiders, found among the lower one-third part of paddy plants and tall grasses.

3.3.15.3 *NASOONA* Locket, 1982

Nasoona is a less species-rich genus mostly distributed in the Oriental region, except for one species known in the Neotropical region (Venezuela) (World Spider

Catalog, 2021). The genus currently comprises 17 nominal species globally, with 4 species known from India (World Spider Catalog, 2021).

Diagnosis: *Nasoona* species can be distinguished from other Araneids by the following characters: Male palp with poorly expressed distal suprategular apophysis, median membrane and radix reduced, presence of convector, presence of an additional sclerite in embolic division, named paraconvector; epigyne with a shallow cavity,sometimes divided by a septum and in a few species partially covered from above by an overhanging, visor-like outgrowth of the anterior epigynal wall, spermathecae are relatively small, subspherical or bean-like (Tanasevitch, 2018).

Type species: *Nasoona prominula* Locket, 1982

Species sampled from the Muriyad Kol Wetland.

Nasoona crucifera (Thorell, 1895)

Erigone crucifera Thorell, 1895: 110 (♀); Thorell, 1895: 114 (♂).

Nasoona eustylis Tu and Li, 2004: 426, Figs 6A–I, 7A–F; Han and Zhu, 2008: 207, Figs 1a–k (♂♀).

Nasoona eustylis Tanasevitch, 2010: 104; Tanasevitch, 2014: 81, Figs 39–43 (♂); Malamel, 2018: 114, Figs 2C–D, 4A–F, 5A–F (♂♀).

Habitat: *N. crucifera* were found in paddy and grasslands.

Natural history: *N. crucifera* are small spiders, found among lower levels of the paddy plants.

3.3.15.4 *NERIENE* Blackwall, 1833

Neriene is a moderately species-rich genus distributed worldwide (World Spider Catalog, 2021). The genus currently comprises 60 nominal species globally, with 2 species known from India (World Spider Catalog, 2021).

Diagnosis: *Neriene* species can be distinguished by the following characters: Male palp with coiled terminal apophyses, curved and narrow embolus; vulva with spirally coiled groves (van Helsdingen, 1969).

Type species: *Neriene clathrata* (Sundevall, 1830)

Species sampled from the Muriyad Kol Wetland.

Neriene macella (Thorell, 1898)

Fig. 3.A.5G

Linyphia macella Thorell, 1898: 319 (♂).

Linyphia multidens Thorell, 1898: 321 (♀).

Neriene macella van Helsdingen, 1969: 186, Figs 257–262; Locket, 1982: 383, Figs 106–111 (♂♀); Chen, Li, et al., 1995: 137, Figs 1–10 (♂♀); Song et al., 1999: 194, Figs 111C–D, K–L (♂♀); Tanasevitch, 2014: 85, Figs 66–74 (♂♀); Li, Liu, et al., 2018: 57, Figs 44A–H, 45A–F, 46A–F (♂♀).

Habitat: *N. macella* were collected from Mixed crops, uncultivated and riparian habitats.

Natural history: *N. macella* are small spiders, found among lower vegetation mostly above a quarter of a meter above the ground level.

3.3.16 FAMILY LIOCRANIDAE Simon, 1897

SPINY-LEGGED SAC SPIDERS

Family Liocranidae represents small to medium sized araneomorph spiders, ecribellate, entelegyne, two-clawed, eight-eyed but sometimes reduced, with worldwide distribution (Jocqué & Dippenaar-Schoeman, 2006). They are commonly known as spiny-legged sac spiders. The family currently comprises of 290 species in 32 genera globally and 29 of them are presently known from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following characters: Carapace narrower in eye region, eyes in two rows; abdomen oval, dorsal scutum in some groups; male palpal tibia with apophysis; posterior and median spinnerets with cylindrical gland spigots, median spinnerets of females flattened, colulus unpaired with setae (Jocqué & Dippenaar-Schoeman, 2006).

Type genus: *Liocranum* L. Koch, 1866

3.3.16.1 *OEDIGNATHA* Thorell, 1881

Genus *Oedignatha* is a moderately speciose genus limited to South East Asia, with some species introduced in Madagascar, Seychelles, Reunion and Germany (World Spider Catalog, 2021). The genus is represented by 39 nominal species globally and 18 are currently known from India (World Spider Catalog, 2021).

Diagnosis: *Oedignatha* species can be distinguished by the following combination of characters: Carapace granulated or pitted, clypeus with conical hump in front of AME, chelicerae massive, with a median stiff seta on the frontal surface; femur I with strong prolateral spine; brush of dark hair near the median base of posterior lateral spinnerets.

Type species: *Oedignatha scrobiculata* Thorell, 1881

Species sampled from the Muriyad Kol Wetland.

***Oedignatha* sp.**

3.3.17 FAMILY LYCOSIDAE Sundevall, 1833

WOLF SPIDERS

Family Lycosidae represents small to very large araneomorph spiders, ecribellate, entelegyne, three clawed, eight-eyed in three rows, with worldwide distribution (Jocqué & Dippenaar-Schoeman, 2006). They are commonly known as wolf spiders, are ground-dwelling hunters with some living in burrows or make sheet webs with funnel leading to there retreat. They carry their egg sacs or cocoons attached to their spinnerets and emergent spiderlings spent their first days on the back of the mother's abdomen. They occupy almost every terrestrial habitats, some are amphibious living close to water and able to skate or dive under water. The family currently has 2430 species in 124 genera globally, and 131 of them are known from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following characters: Carapace longer than wide, narrow and high in the cephalic region, elongated fovea; eyes in three rows (4:2:2), unequal size, anterior row with small eyes, second row with large eyes, followed by eyes of intermediate size; chelicerae with prominant condyle, epigyne with hignly sclerotised median septum, inverted T-shaped; male palp without tibial apophysis (Jocqué & Dippenaar-Schoeman, 2006).

Type genus: *Lycosa* Latreille, 1804

3.3.17.1 *HIPPASA* Simon, 1885

Genus *Hippasa* is a moderately species-rich genus distributed in the Oriental, Ethiopian and lower latitudes of Palaearctic regions (World Spider Catalog, 2021). The genus is represented by 37 nominal species globally and 17 are currently known from India (World Spider Catalog, 2021).

Diagnosis: *Hippasa* species can be distinguished by the following characters: Body slender; sternum with dark median stripe; bi-segmented posterior lateral spinnerets with elongated basal segment; male palpal patellae swollen palpal, forked median apophysis; epigyne with scape or atrium (Barrion & Litsinger, 1995).

Type species: *Hippasa agelenoides* (Simon, 1884)

Species sampled from the Muriyad Kol Wetland.

Hippasa agelenoides (Simon, 1884)
Fig. 3.A.5H

Pirata agelenoides Simon, 1884: 334 (♀).

Hippasa agelenoides Simon, 1885: 31.

Diapontia agelenoides Thorell, 1887: 300 (♂).

Hippasa agelenoides Simon, 1898: 326, Fig. 334; Gravely, 1924: 594, Fig. 1G (♀); Dyal, 1935: 142, pl. 13, Figs 49–52 (♂♀); Sen, Dhali, et al., 2015: 46, Figs 183–187, pl. 14 (♀); Dhali et al., 2017: 69, Figs 312–316, pl. 23 (♀).

Habitat: *Hippasa agelenoides* were common in grasslands and paddy fields post-harvest.

Natural history: *Hippasa agelenoides* erects characteristic funnel webs among the grass closer to the gound in order to capture prey, and the spider itself stays inside the funnel protected from predators. They are commonly found along roads sides, open grasslands and even among areas of dense vegetation. Their web is one of the most distinctive among the spiders in the region.

Hippasa greenalliae (Blackwall, 1867)

Lycosa greenalliae Blackwall, 1867: 387 (♀).

Hippasa greenalliae Simon, 1885: 31, pl. 10, Fig. 6 (♂♀); Tikader and Malhotra, 1980: 277, Figs 72-76 (♂♀); Barrion and Litsinger, 1994: 307, Figs 1588-1590 (♂); Biswas and Raychaudhuri', 2007: 244, Figs 1–7 (♂♀); Sen, Dhali, et al., 2015: 47, Figs 188–192, pl. 14 (♀); Dhali et al., 2017:

69, Figs 317–321, pl. 23 (♀); Caleb, 2020: 15725, Figs 11A–G, 26I (♀).
Hippasa pantherina Pocock, 1899: 752 (♀); Gravely, 1924: 594, Figs 1F (♀).
(For complete list of references, see World Spider Catalog, 2021)

Habitat: *H. greenalliae* were found in grasslands and uncultivated lands.

3.3.17.2 *LYCOSA* Latreille, 1804

Genus *Lycosa* is a speciose genus with a worldwide distribution (World Spider Catalog, 2021). The genus is represented by 225 nominal species globally and 31 are currently known from India (World Spider Catalog, 2021).

Diagnosis: *Lycosa* species can be distinguished by the following characters: Carapace long, dark brown with light wide longitudinal median stripe; four posterior eyes larger and arranged in a quadrangle which is slightly wider behind than in front; Clypeus not vertical; leg tibiae I and II with three pairs of ventral spines.

Type species: *Lycosa tarantula* (Linnaeus, 1758)

Species sampled from the Muriyad Kol Wetland.

***Lycosa* sp.**

3.3.17.3 *PARDOSA* C. L. Koch, 1847

Genus *Pardosa* is a speciose genus with a worldwide distribution (World Spider Catalog, 2021). The genus is represented by 539 nominal species globally and 35 are currently known from India (World Spider Catalog, 2021).

Diagnosis: *Pardosa* species can be distinguished by the following combination of characters: Carapace high and narrow, convex in the eye area, and commonly dark with pale median and submedian bands; AER usually procurved, distinctly shorter than PER; male palpal cymbium with one to three short stout spines apically, terminal apophysis tooth-like, projected towards tip of embolus and conductor; embolus long to short, angled or straight, with tip on apex of conductor or canal along distal margin of tegulum, shaft-like conductor; epigyne with distinct hoods, broad and deep atrium, copulatory openings usually laterad of median septum (Barrion & Litsinger, 1995).

Type species: *Pardosa alacris* (C. L. Koch, 1833)

Species sampled from the Muriyad Kol Wetland.

Pardosa pseudoannulata (Bösenberg & Strand, 1906)
Figs 3.A.6A and 3.A.6B

Lycosa pseudoannulata Feng, 1990: 148, Figs 123.1–3 (♂♀); Biswas and Raychaudhuri, 2003: 109, Figs 1–6 (♀) ; Gajbe, 2007: 503, Figs 248–251 (♂♀).

Pardosa annandalei Tikader and Malhotra, 1980: 351, Figs 207–210; Tikader and Biswas, 1981: 54, Figs 86–87 (♀); Barrion and Litsinger, 1994: 311, Figs 1610–1613 (♂♀); Barrion and Litsinger, 1995: 379, Figs 224a–k, 225a–e (♂♀).

Pardosa pseudoannulata Yin, Peng, et al., 2012: 852, Figs 427a-h, 3-16c-d (♂♀); Baba and Tanikawa, 2015: 74, Fig. 7 (♂♀); Dhali et al., 2017: 73, Figs 343-347, pl. 25 (♀); Omelko and Marusik, 2020: 486, Figs 37–39 (♂♀); Buchar and Dolejš, 2021: 942, figs 8A–G (♂♀); Wang et al., 2021: 48, Figs 43A–I, 44A–F (♂♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Pardosa pseudoannulata* were abundantly found in all of the studied habitats.

Natural history: *Pardosa pseudoannulata* are one of the most abundant spiders in the study area. They are ground spiders adapted to wet ecosystems including paddy fields. The ability to float and run over water surfaces puts them on top of the list of most successful spiders of paddy fields. The spiders burrow into the soil or use litter as natural shelter. The spiders are mostly seen resting inside shallow burrows in the paddy fields before sunrise and during colder periods. They were observed to perch on paddy tillers and leaves usually after sunset and early morning hours. They play a vital role in insect pest population in the paddy fields and grasslands in general. Insects such as green leafhoppers (*Nephotettix* sp.) and brown planthoppers (*Nilaparvata lugens*) constituted a major portion of their diet. They exhibit high degree of sexual cannibalism where the females lunges aggressively and attack the much smaller bodied males.

Other species sampled:

***Pardosa* sp. 1**

***Pardosa* sp. 2**

3.3.17.4 *WADICOSA* Zyuzin, 1985

Genus *Wadicosa* is a less species-rich genus distributed in the Ethiopian, Oriental and Palaearctic regions (World Spider Catalog, 2021). The genus is represented by 13 nominal species globally and 4 are currently known from India (World Spider

Catalog, 2021).

Diagnosis: *Wadicosa* species can be distinguished by the following characters: Male palpal tegulum with anterior retrolateral process pointing ventrad; epigyne with two more or less separated pockets (Kronestedt, 2015).

Type species: *Wadicosa fidelis* (O. Pickard-Cambridge, 1872)

Species sampled from the Muriyad Kol Wetland.

Wadicosa fidelis (Bösenberg & Strand, 1906)

Lycosa fidelis Pickard-Cambridge, 1872: 319 (♂).
Sankaran, Caleb, et al., 2021: 169, Figs 10A–C (♀).
(For complete list of references, see World Spider Catalog, 2021)

Habitat: *W. fidelis* found in riparian and uncultivated lands around the wetlands.

3.3.18 FAMILY MIMETIDAE Simon, 1881

PIRATE SPIDER

Family Mimetidae represents small to medium-sized, araneomorph, ecribellate, entelegyne or secondary haplogyne, three-clawed, eight-eyed spiders with cosmopolitan distribution (Jocqué & Dippenaar-Schoeman, 2006). They typically feed on other spiders by pecking at their webs to simulate entrapment which leads the prey spider to investigate. The family currently has 159 species in 8 genera globally (World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following characters: Prolateral spination on tibiae; metatarsi I and II modified; chelicerae with peg teeth. Epigyne distinct, simple, heavily sclerotized, usually with lobed posterior extension; male palp long, with developed paracymbial process, embolus strongly curved (Jocqué & Dippenaar-Schoeman, 2006).

Type genus: *Mimetus* Hentz, 1832.

3.3.18.1 *MIMETUS* Hentz, 1832

Genus *Mimetus* is a moderately species-rich genus with a widespread distribution (World Spider Catalog, 2021). The genus is represented by 68 nominal species globally and 3 are currently known from India (World Spider Catalog, 2021).

Diagnosis: *Mimetus* species can be distinguished from other genera by the following combination of characters: Male palp bearing a shovel-like appendage on the dorsal edge of the cymbium, and a distal sclerotized extension of the shovel; three longitudinal lines of spines on the carapace (Harms and Dunlop 2009). Female epigyne simple but distinct, with two inconspicuous copulatory opening, spermatheca strongly sclerotized (Heimer, 1986).

Type species: *Mimetus syllepsicus* Hentz, 1832

Species sampled from the Muriyad Kol Wetland.

***Mimetus* sp.**

3.3.19 FAMILY OECOBIIDAE Blackwall,1862

DISC WEB SPIDERS OR DWARF-ROUND-HEADED SPIDERS

Family Oecobiidae represents small to medium sized araneomorphs, both cribellate and ecribellate genera, entelegyne, three clawed, six or eight-eyed , with cosmopolitan distribution (Jocqué & Dippenaar-Schoeman, 2006). They are commonly known as disc web spiders or dwarf-round-headed spiders, commonly found on the ground, walls or between rocks or gravel. Some species are synanthropic. They spin small star-shaped webs or multilayered webs over cracks or crevices on walls or rocks, and the spider rests under it. Their legs are usually placed evenly around their carapace, with the first two pairs curved backwards. The family currently has 119 species in 6 genera globally, and 6 of them are known from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following characters: Carapace subcircular, wider than long, without fovea, sternum heart-shaped; eyes six to eighht in a group near the centre of carpace; abdomen more or less flattened, ovid or round,anal tubercle large, two segmented provided with double rows of tufts of setae; epigyne with variable plate, mostly with caudal notch, anterior pit in some, epigynal region with transverse furrow; male palp with globular to unmodified tibia, without apophysis (Jocqué & Dippenaar-Schoeman, 2006).

Type genus: *Oecobius* Lucas , 1846

3.3.19.1 *OECOBIUS* Lucas, 1846

Genus *Oecobius* is a moderately species-rich genus with a worldwide distribution (World Spider Catalog, 2021). Commonly known as Wall spiders, they are found inside human dwellings most commonly on walls. The genus is represented by 90 nominal species globally and 3 of them are currently known from India (World Spider Catalog, 2021).

Diagnosis: *Oecobius* species can be distinguished from *Uroctea* Dufour, 1820, *Urocteana* Roewer, 1820 and *Uroecobius* Kullmann & Zimmermann, 1976 by the presence of a cribellum and calamistrum; ocular quadrangle as long as or longer than wide as in *Paroecobius*. *Oecobius* species differ from *Paroecobius* by the eyes with approximately the same size, ALE and PME opalescent. The AME and PLE are dark with a black ring on cuticular base (Santos & Gonzaga, 2008).

Type species: *Oecobius cellariorum* (Dugès, 1836)

Species sampled from the Muriyad Kol Wetland.

Oecobius marathaus Tikader, 1962

Oecobius marathaus Tikader, 1962: 684, Figs 2a-b (♀); Saaristo, 2010: 106, Figs 21.1-6 (♂♀); Baba, Ohno, et al., 2017: 17, Figs 1–3 (♀).
Oecobius formosensis Lee, 1966: 18, Figs 3a–d (♂).
Maitreja marathaus Lehtinen, 1967: 246, Fig. 31 (♀).
Oecobius reefi Saaristo, 1978: 104, Figs 46–51 (♂).
(For complete list of references, see World Spider Catalog, 2021)

Habitat: *O. marathaus* found on walls of human dwellings.

Natural history: *O. marathaus* are small, cribillate spiders that create flat webs over crevasses and depressions on walls and undisturbed areas inside homes.

3.3.20 FAMILY OONOPIDAE Simon,1890

GOBLIN SPIDERS OR DWARF HUNTING SPIDERS

Family Oonopidae represents very small araneomorph spiders, ecribellate, haplogyne, two clawed, six eyed or absent, with cosmopolitan distribution (Jocqué & Dippenaar-Schoeman, 2006). Commonly known as goblin spiders or dwarf hunting spiders, they are free-living, nocturnal ground dwellers found in a multitude of habitats from forests to deserts. They are tiny spiders and too small to be easily noticed by people. They are found in leaf litter layer, beneath rocks and even in canopies of tropical forests. The family currently has 1871 species in 114 genera globally, and 46 of them are known from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following characters: Carapace convex to flat, fovea absent; six eyes close together, median eyes large, contigious with anterior lateral eyes, eyes absent in species living in termite nests; abdomen oval, enclosed in dorsal anf ventral shields, some with anal plate; epigyne a sclerotised slit; male palpal organ small, bulb pear-shaped or cylindrical with terminal embolus, conductor absent (Jocqué & Dippenaar-Schoeman, 2006).

Type genus: *Oonops* Keyserling, 1835

Species sampled from the Muriyad Kol Wetland.

***Oonops* sp. 1**
***Oonops* sp. 2**

3.3.21 FAMILY OXYOPIDAE Thorell,1870

LYNX SPIDERS

Family Oxyopidae represents small to large araneomorphs, ecribellate, entelegyne, three clawed, eight-eyed spiders, with cosmopolitan distribution (Jocqué & Dippenaar-Schoeman, 2006). Commonly known as lynx spiders, they are free-living, plant dwelling hunting spiders. Lynx spiders are fast runners and very alert spiders, with many species ambush pollinators that frequent flowers just like members of thomisids do. Members of the groups are abundant in agricultural ecosystems and are possibly good biological control agents. The family currently represents 438 species in 9 genera globally, and 83 of them are known from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following characters: Carapace longer than wide, high and convex anteriorly, clypeus with conspicuous stripes and spots; eyes on the edge of carapace, eyes form a hexagonal shape; abdomen tapering to a point posteriorly; legs with prominent setae; male palp with tibial apophysis and paracymbium, with spoon-shape median apophysis in *Peucetia* (Jocqué & Dippenaar-Schoeman, 2006).

Type genus: *Oxyopes* Latreille, 1804

3.3.21.1 ***HAMADRUAS*** Deeleman-Reinhold, 2009

Genus *Hamadruas* is a less species-rich genus distributed in the Oriental region(World Spider Catalog, 2021). The genus is represented by 9 nominal species globally and 2 of them are currently known from India (World Spider Catalog, 2021).

Diagnosis: *Hamadruas* species can be distinguished by the following characters: Carapace low, head has straight sides, sinuating the thorax; abdomen lower than carapace; epigyne indistinguishable from other genera; male palp is distinguished by the presence of a flange on the basal part of the embolus, tegular lobe in which the spermduct loops around, crossing itself around a pit.

Type species: *Hamadruas hieroglyphica* (Thorell, 1887)

Species sampled from the Muriyad Kol Wetland.

Hamadruas sikkimensis Tikader, 1962
Fig. 3.A.6D

Oxyopes sikkimensis Tikader, 1970: 76, Figs. 47a–c (♂♀); Tikader and Biswas, 1981: 64, Figs 108–109 (♂♀); Hu, Zhang, et al., 1983: 9, Figs 2A–C (♀); Hu & Zhang, 1984: 49, Figs 1–4 (♂); Song et al., 1999: 400, Figs 234O–P, 235K, 237B (♂♀); Gajbe, 1999: 47, Figs 34–36 (♂♀).

Hamataliwa sikkimensis Gajbe, 2008: 97, Figs 203–205 (♂♀)

Hamadruas sikkimensis Deeleman-Reinhold, 2009: 693; Yin, Peng, et al., 2012: 900, Figs 453a–f (♂♀); Sen, Dhali, et al., 2015: 81, Figs 464–468, pl. 19 (♀); Biswas and Raychaudhuri, 2015: 228, Figs 5a–f (♂♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *H. sikkimensis* were collected from foliages in uncultivated lands and home gardens.

Natural history: *H. sikkimensis* are medium-sized, diurnal, ambush hunters found in foliages. Its body is covered in peculiar coloured patterns that distinguishes them from other members of the family. They prey on a variety of insects including *Musca* species.

3.3.21.2 *HAMATALIWA* Keyserling, 1887

Genus *Hamataliwa* is a moderately species-rich genus with worldwide distribution (World Spider Catalog, 2021). The genus is represented by 83 nominal species globally and 6 of them are currently known from India (World Spider Catalog, 2021).

Diagnosis: *Hamataliwa* species can be distinguished by the following combination of characters: AME close together, separated by less than their diameter, situated in front of the space between the ALEs; carapace high, almost square; female epigyne with a shallow median depression surrounded by a semicircular or U-shaped, heavily sclerotized rim; copulatory ducts usually short, spermathecae round or oval; male palpal embolus with a characteristic twist or loop near the base; edge of cymbium with a basal outgrowth, finger-like in lateral view.

Type species: *Hamataliwa grisea* Keyserling, 1887

Species sampled from the Muriyad Kol Wetland.

Hamataliwa helia (Chamberlin, 1929)

Hamataliwa helia Brady, 1964: 497, Figs 112–114, 119–121, 124–125, 130–133; Deeleman-Reinhold, 2009: 682, Figs 19–24 (♂♀).

Habitat: *Hamataliwa helia* were collected from foliages in grasslands, uncultivated and mixed crops.

Natural history: *Hamataliwa helia* are medium-sized, active hunters found in foliages.

3.3.21.3 *OXYOPES* Latreille, 1804

Genus *Oxyopes* is a speciose genus with worldwide distribution (World Spider Catalog, 2021). The genus is represented by 286 nominal species globally and 54 of them are currently known from India (World Spider Catalog, 2021).

Diagnosis: *Oxyopes* species can be distinguished by the following characters: Carapace high and rounded, clypeus vertical, and continues flat for the majority of its length to a steep thoracic part; eyes in four rows, PER strongly procurved and equidistant from one another; a thin black straight line extends from each of the anterior medians down the vertical face to the tip of the long pale chelicerae; abdomen long and thin, rounded and widest in the front, and tapering all the way to the spinnerets.

Type species: *Oxyopes heterophthalmus* (Latreille, 1804)

Species sampled from the Muriyad Kol Wetland.

Oxyopes birmanicus Thorell, 1887

Oxyopes birmanicus Thorell, 1887: 325 (♂♀); Song et al., 1999: 399, Figs 235B, 236A (♂); Hu, 2001: 221, Figs 117.1–2 (♀); Gajbe, 2008: 44, Figs 84–87 (♂♀).; Jäger and Praxaysombath, 2009: 43, Figs 80–89 (♂♀); Yin, Peng, et al., 2012: 923, Figs 467a–d (♂♀); Tyagi et al., 2019: Supplement, Figs S2.34, S3.31–32 (♂♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Oxyopes birmanicus* commonly found in foliages, especially common in grasslands.

Natural history: *Oxyopes birmanicus* are ambush hunters and actively hunt prey.

Oxyopes javanus Thorell, 1887

Figs 3.A.6E and 3.A.6F

Oxyopes lineatipes Simon, 1885: 441.

Oxyopes javanus Thorell, 1887: 329 (♀); Tikader and Biswas, 1981: 62, Figs 100–101 (♂♀); Song, 1987: 249, Fig. 203 (♂♀); Okuma, Kamal, et al., 1993: 55, Figs 49A–B (♂♀); Barrion and Litsinger, 1994: 299, Figs 1537–1538 (♂♀); Barrion and Litsinger, 1995: 326, Figs 193a–c, 194a–s (♂♀); Song et al., 1999: 399, Figs 233Q–R, 236F (♂♀); Gajbe, 2008: 54, Figs 110–113 (♂♀); Sen, Dhali, et al., 2015: 76, Figs 423–428, pl. 18 (♂); Biswas and Raychaudhuri, 2015: 225, Figs 2a–g

(♂♀); Dhali et al., 2017: 65, Figs 290–295, pl. 22 (♂); Nentwig et al., 2019: 41.

Oxyopes javanus nicobaricus Strand, 1907: 447 (♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Oxyopes javanus* commonly found in low vegetations, especially in paddy fields and grasslands.

Natural history: *Oxyopes javanus* are ambush hunters and actively hunt prey. They play a major role in pest control in the paddy fields by their numerous numbers.

Oxyopes shweta Tikader, 1970

Fig. 3.A.6G

Oxyopes shweta Tikader, 1970: 78, Figs 48a–c (♂♀); Tikader and Biswas, 1981: 61, Figs 105–107 (♂♀); Hu and Li, 1987: 295, Figs 27.3–4, 28.1–2 (♂♀); Gajbe, 1999: 46, Figs 31–33; Hu, 2001: 225, Figs 121.1–4 (♂♀); Gajbe, 2008: 84, Figs 176–178; Sen, Dhali, et al., 2015: 78, Figs 444–448, pl. 18 (♀); Dhali et al., 2017: 66, Figs 301–305, pl. 22 (♀).

Habitat: *Oxyopes shweta* found in foliages of trees and shrubs, but uncommon in grasslands and paddy fields.

Natural history: *Oxyopes shweta* are ambush hunters and actively hunt prey.

3.3.21.4 ***PEUCETIA*** Thorell, 1869

Genus *Peucetia* is a moderately species-rich genus with worldwide distribution (World Spider Catalog, 2021). The genus is represented by 47 nominal species globally and 21 of them are currently known from India (World Spider Catalog, 2021).

Diagnosis: *Peucetia* species can be distinguished by the following combination of characters: Differs from *Oxyopes* and *Hamataliwa* by the absence of cheliceral teeth and male palp with a paracymbium, and a long and articulated median apophysis. Differs from *Schaenicoscelis* by having the thoracic region of the carapace as high as the cephalic region, and by the presence of 5 spines at the apex of the metatarsi. It can be distinguished from *Tapinillus* by having the clypeal height larger than the ocular area length and procurved PER (Santos & Brescovit, 2003)

Type species: *Oxyopes heterophthalmus* (Latreille, 1804)

Species sampled from the Muriyad Kol Wetland.

Peucetia viridana Stoliczka, 1869

Fig. 3.A.6H

Sphasus viridanus Stoliczka, 1869: 220, pl. 20, Fig. 1 (♀).

Peucetia viridana Simon, 1884: 326 (♂); Thorell, 1887: 321; Pocock, 1900: 255, Fig. 86 (♂♀); Tikader and Biswas, 1981: 65, Figs 110–111 (♀).

Peucetia nigropunctata Simon, 1884: 365 (♂♀).

Peucetia prasina Thorell, 1887: 321.

Habitat: *P. viridana* found in foliages of trees and shrubs in densely vegetated areas.

Natural history: *P. viridana* are large bodied green coloured ambush hunters, with characteristic light greenish patterns on the abdomen.

3.3.22 FAMILY PALPIMANIDAE Thorell, 1870

PALP-FOOTED SPIDERS

Family Palpimanidae represents small to very large araneomorph spiders, ecribellate, entelegyne, two to three clawed, six or eight-eyed, distributed in the tropical and subtropical regions of the world except Australia (Jocqué & Dippenaar-Schoeman, 2006). They are commonly known as palp-footed spiders, and are free-living ground dwellers and do not spin webs. The members usually exhibits high degree of endemism. They generally keep their strong first legs raised up in front of themselves while moving on the ground at night. The family currently represents 156 species in 20 genera globally, and 3 of them are known from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following characters: Carapace suboval outline or anteriorly truncated, cephalic region rounded, sloping towards the thoracic region, fovea distinct, integument with coriaceous granular surface; eyes in two rows, position varies with genera, posterior median eyes irregularly shaped; leg I enlarged and stronger than other three pairs, femur I expanded dorsally, patella elongated, metatarsi and tarsi reduced in size, prolateral tibia distally with thick scopula of spatulate setae; abdomen oval, coriaceous cuticle with highly sclerotized epigastric region; spinnerets encirlcled by a sclerotized ring; epigyne with simple internal structure; male palpal tibia frequently bulbous, bulb with elaborate conductor and other terminal accessory sclerites (Jocqué & Dippenaar-Schoeman, 2006).

Type genus: *Palpimanus* Dufoure, 1820

3.3.22.1 *SARASCELIS* Simon, 1887

Genus *Sarascelis* is a less species-rich genus with a worldwide distribution (World Spider Catalog, 2021). The genus is represented by 7 nominal species globally and only one is currently known from India (World Spider Catalog, 2021).

Diagnosis: *Sarascelis* species can be distinguished by the following combination of characters: Carapace oval, front very narrow. AER clearly recurved; male bulb are either prolonged by a single curved process (Jézéquel, 1964).

Type species: *Sarascelis chaperi* Simon, 1887

Species sampled from the Muriyad Kol Wetland.

***Sarascelis* sp.**

3.3.23 FAMILY PHILODROMIDAE Thorell,1870

SMALL HUNTSMAN SPIDERS OR RUNNING CRAB SPIDERS

Family Philodromidae represents small to medium sized araneomorph spiders, ecribellate, entelegyne, two clawed with distinct claw tufts, eight-eyed, with cosmopolitan distribution (Jocqué & Dippenaar-Schoeman, 2006). They are commonly known as small huntsman spiders or running crab spiders, are free-living spiders commonly found on plants and soil surfaces. The family currently represents 538 species in 31 genera globally, and 45 of them are known from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021). The genera *Bacillocnemis* Mello-Leitão, *Eminella* Özdikmen, *Metacleocnemis* Mello-Leitão, *Philodromops* Mello-Leitão, *Procleocnemis* Mello-Leitão, *Psellonus* Simon, *Pseudopsellonus* Balogh and *Vacchellia* Caporiacco are monotypic, most are known from single sex only.

Diagnosis: Members of the family can be distinguished by the following characters: Carapace slightly flattened with no fovea present, elongate or as long as wide; eyes in two rows, not on large tubercles, eye rows recurved, secondary eyes lack a tapetum; cheliceral furrow without teeth; legs laterigrade, leg II usually longer; abdomen variable shape, usually with dark heart marks; epigyne small, mostly with median septum; male palp with small tibial apophysis, embolus variable, usually short (Jocqué & Dippenaar-Schoeman, 2006).

Type genus: *Philodromus* Walckenaer, 1826

3.3.23.1 *PSELLONUS* Simon, 1897

Taxonomic revision of the monotypic genus *Psellonus* Simon, 1897 (Araneae, Philodromidae)

Genus *Psellonus* is a monotypic genus endemic to south India (World Spider Catalog, 2021). *Psellonus* is a poorly known genus erected by Simon in 1897 based on a male from Madurai, Tamil Nadu. Until now, the genus remains exclusively known from the original description, and no species has been added and the female of type species remains undescribed. The details that accompanied the original description and illustrations of *Psellonus* (Simon, 1897a: figs 9–10) focused exclusively on somatic morphology without any information on genitalic morphology. Newly collected specimens from Thirumangalam (located in the Madurai District of Tamil Nadu, 23 km from the type locality), Kayipuram, Irinjalakuda, Muriyadu, Pathiramanal Island, Perumbalam Island, Thevara and Wayanad (all belonging to the Kerala state) all belong to the same species. The monotypic genus *Psellonus* is revised here with detailed illustration of the genitalic morphology and the first description of male of *Psellonus planus.* The somatic morphology is also illustrated to complement Simon's detailed description. Also, *Philodromus kendrabatai* Tikader, 1966 is synonymised with *Psellonus planus* on the basis of somatic and genitalic similarity.

Diagnosis: *Psellonus* can be distinguished from all other genera of Philodromidae by the following features: flat, frontally truncated carapace, in combination with a unique eye configuration (both eye rows occupying full width of cephalothorax, MEQ strongly trapezoid, more than 3 times wider than long, AER straight, PER slightly recurved, AER much narrower than PER, PME smaller than other eyes and strongly elongated mouthparts (labium more than 3 times longer than wide, endites elongated, convergent blades. A similar eye configuration is found in *Pseudopsellonus* Balogh, but labium and endites are not elongated in this genus. Further diagnostic characters are seen in the chelicerae, which show strong bulges in both sexes. In the male, however, the chelicerae are strongly divergent and modified.

Type species: *Psellonus planus* Simon, 1897, by monotypy.

***Psellonus planus* Simon, 1897**
(Figs 3.A.7D, 3.9 and 3.10)

Psellonus planus Simon, 1897a: 14, Figs 9–10 (Holotype ♂from Madurai, Tamil Nadu, India, not traceable at MNHN [Muséum national d'histoire naturelle, Paris], personal communication through C. Rollard, not examined).
Philodromus kendrabatai Tikader, 1966b: 38, Figs 3a–b (Holotype ♀from Peacock bay, N. D. A., Kharakvasla, Poona, Maharashtra, India, deposited in National Zoological Collections, Zoological Survey of India, Calcutta, No. 3134/18, examined). Tikader, 1971: 72, Figs 19A–B (♀). Tikader, Tikader, 1980b: 191, Figs 261–262 (♀).Syn. nov.

Materials examined: INDIA: Kerala: 1 ♂, 2 ♀, 4 subadult ♀, Thrissur, Irinjalakuda [10°20´40.80″N, 76°12´33.74″E], 15 m, 12 November 2015, from foliage, by hand, leg., K.S Nafin; 2 ♀, Thrissur, Muriyad [10°21´48.95″N, 76°15´44.62″E], 8 m, 7 December 2015, from foliage, by hand, leg., K.S Nafin; 2 ♀, Wayanad, Wayanad Wildlife Sanctuary [11°40´17.76″N, 76o22'07.16"E], 863 m, 7 January 2016, from foliage, by hand, leg., K.S Nafin & Sudhin. Tamil Nadu: 1 ♂, 2 ♀, 10 subadult ♂, 14 subadult ♀, Madurai, Thirumangalam [9°49´24.09″N, 77°59´17.13″E], 130 m, 22 December 2015, from foliage, by hand, leg., M.J. Jobi (CATE); 11 ♂, 25 ♀, Alappuzha, Pathiramanal Island [9°37´08.27″N, 76°23´23.86″E], 0 m, 15 March 2014, 22 April 2014, 17 May 2014, 8 November 2014, January 2015, from foliage, by hand, leg., M.J. Jobi & Jimmy Paul;14 males, 27 ♀, 12 subadult ♂, 20 subadult ♀, Alappuzha, Perumbalam [9°50´54.13″N, 76°21´39.00″E], 10 m, 24 November 2015, 16 December 2015, 9 January 2016, 11 February 2016, 7 March 2016, from foliage, by hand, leg., M.J. Jobi & Jimmy Paul; 8 ♂, 16 ♀, 7 subadult ♂, 13 subadult ♀, Alappuzha, Kayipuram [9°37´41.22″N, 76°22´10.03″E], 12 m, 12 October 2015, 16 November 2015, 16 January 2016, 18 February 2016, 19 March 2016, from foliage, by hand, leg., M.J. Jobi & Jimmy Paul; 13 ♂, 18 ♀, 11 subadult ♂, 19 subadult ♀, Ernakulam, Thevara [9°56´33.40″N, 76°17´54.94″E], 7 m, 16 September 2015, 22 November 2015, 16 December 2016, 3 January 2016, 9 February 2016, from foliage, by hand, leg., M.J. Jobi (ADSH).

Description: Male (from Thirumangalam, Fig. 3.10A–F): Carapace orange-yellow colored, hirsute, wider than long, forehead straight and truncated in the front, gradually expanded towards the back and largely truncated at the posterior, surface of the carapace marked by fine stripes like rainbow, carapace laterally

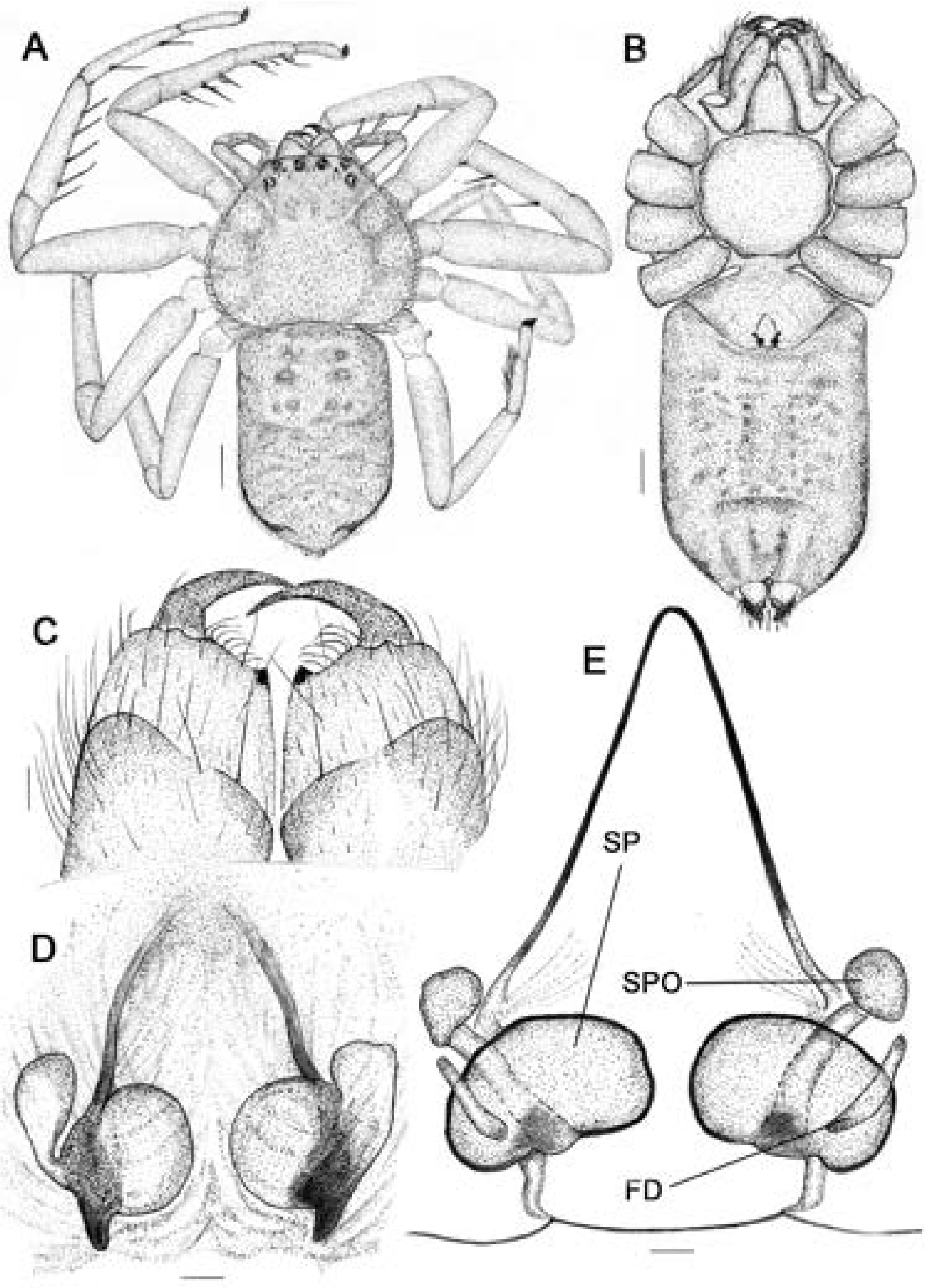

Figure 3.9: *Psellonus planus*, female. **A**, habitus, dorsal. **B**, habitus. ventral. **C**, chelicerae, dorsal. **D**, epigyne, ventral. **E**, vulva, dorsal. Scale bars. A, 0.5 mm. B, 0.3 mm. C, 0.2 mm. D, 0.1 mm. E, 0.05 mm. Abbreviations: FD—fertilization duct, SPM—spermathecae, SPO—spermathecal organ.

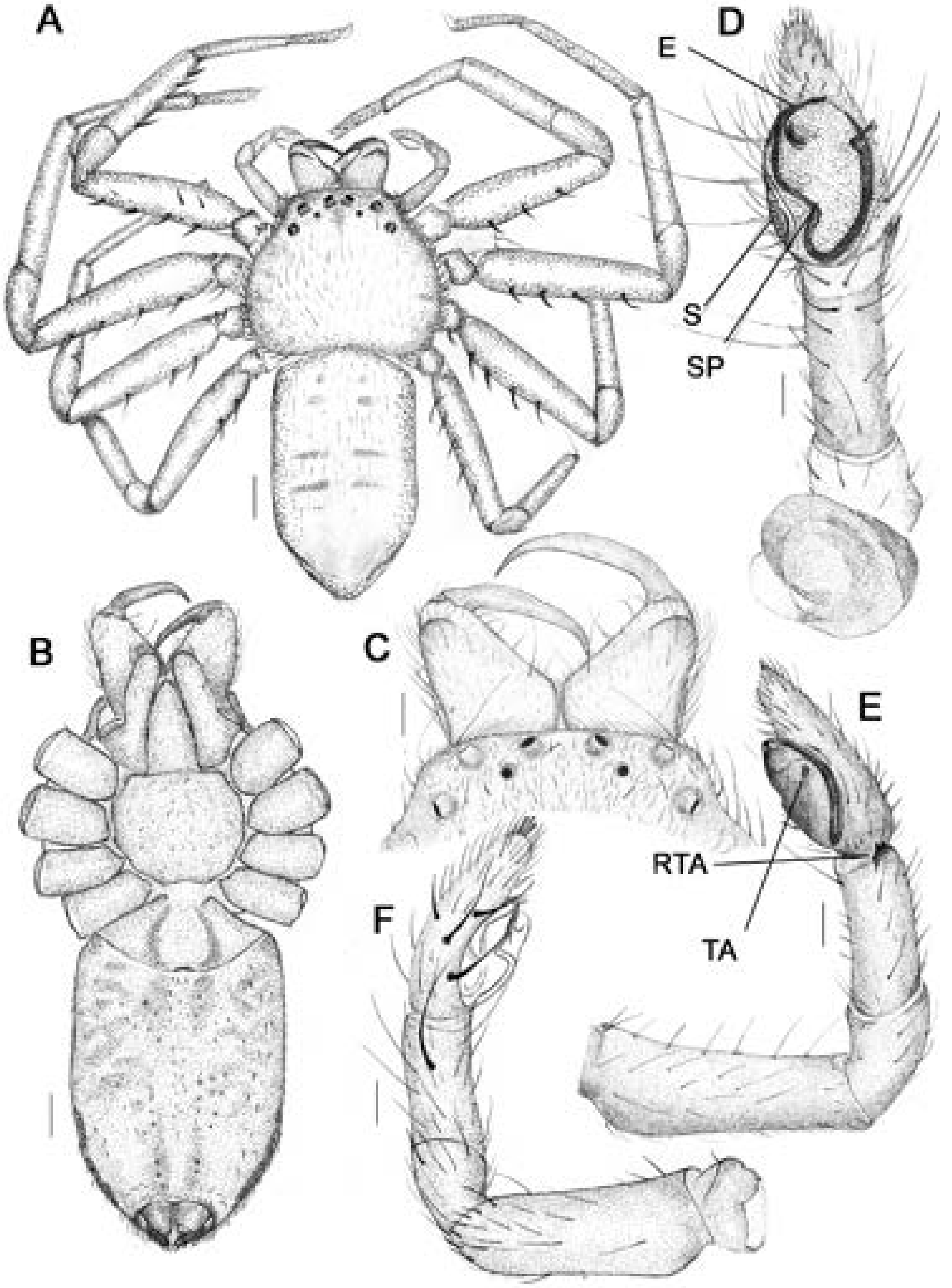

Figure 3.10: *Psellonus planus*, male. **A**, habitus, dorsal. **B**, habitus. ventral. **C**, chelicerae, dorsal. **D**, left pedipalp, ventral. **E**, same, retro-lateral. **F**, same, prolateral. Scale bars. A, 0.5 mm. B, 0.3 mm. C, 0.1 mm. D–F, 0.2 mm. Abbreviations: E—embolus, RTA—retrolateral tibial apophysis, S—subtegulum, SP—sperm duct, T—tegulum, TA—tegular apophysis.

Table 3.3: *Psellonus planus.* Measurements of legs and palp

Male						
	Leg segments	**I**	**II**	**III**	**IV**	**Palp**
	Femur	1.51	1.7	1.6	1.43	0.53
	Patella	0.55	0.63	0.52	0.35	0.28
	Tibia	1.1	1.56	1.07	0.84	0.29
	Metatarsus	0.88	1.31	0.9	0.56	–
	Tarsus	0.53	0.58	0.55	0.39	0.46
	Total	4.57	5.78	4.64	3.57	1.56
Female						
	Leg segments	**I**	**II**	**III**	**IV**	**Palp**
	Femur	1.13	1.34	1,27	1.24	–
	Patella	0.46	0.66	0.45	0.36	–
	Tibia	0.84	1.16	0.79	0.66	–
	Metatarsus	0.69	0.94	0.7	0.39	–
	Tarsus	0.36	0.56	0.39	0.3	–
	Total	3.48	4.66	3.6	2.95	–

clothed with fine bristles; eyes occupying the entire width of clypeus, anterior eye row almost a straight line, equally spaced, posterior eye row recurved, all eyes equal in size except for the very small PME; chelicerae strongly divergent, basal segment almost triangular with prominent dorsal hump, cheliceral furrow teethless; sternum straw colored, anteriorly broadly truncated; gnathocoxae strongly elongated, labium tongue like, twice as long as wide; leg formula 2314, spination variable and often asymmetric, but generally femora with 3–5 dorsal spines, tibiae I–II with 3–5 pairs of ventral spines and metatarsi I–II with two pairs of ventral spines. Opisthosoma straw coloured, hirsute, longer than wide, narrow and parallel, wedge-shaped at the back, with tuft of hairs at the posterior end, two pairs of depression spots in the anterior half; venter smooth, a pair of depressions just before the spinnerets. *Palp.* Femur long, patella thick, tibia more than twice as long as wide, with numerous macrosetae and 2-3 trichobothria, RTA short, bifurcated; cymbium drop-like, covered with fine hairs, apical region with a bunch of tenent setae; tegulum oval with retrolaterally projecting apophysis; embolus with wide embolic base and narrow bent tip; sperm duct convoluted. Measurements of legs and palps as in Table 3.3. **Female** (from Thirumangalam, Fig. 3.9A–E): Carapace straw coloured, appearing transparent; eyes on white tubercles, except PME that are very small, largely separated from the lateral ones (Fig. 3A); venter smooth, sternum almost round; chelicerae conical shaped with very large, prominent dorsal hump, cheliceral promargin with one apical tooth; dorsum of tibiae, metatarsi and tarsi of the first three legs irregularly covered with short bristles, spination as in male, legs III and IV without spines, metatarsus of leg IV with conspicuous hair tuft; opisthosoma less hairy than in male, not smooth, with comma-shaped black patches posteriolaterally; median spinnerets covered with some black spots. Epigyne: Epigynal groove with anteriorly elongated, sclerotized epigynal sutures, spermathecae globular, spermathecal organ on distinct stalks, fertilisation duct elongated, copulatory duct very short, indistinct. Measurements of legs as in Table 3.3.

Habitat: *Psellonus planus* found on foliages and branches of shrubs and trees in the mixed croplands, riparian and uncultivated lands.

Natural history: *Psellonus planus* are nocturnal, foliage dwelling and cryptic in nature. During daytime, adult spiders rests in retreats made from two adjacent leaves joined together with silk, the extremely flat spider easily slips in the narrow gap between the leaf surfaces conviniently hidding from plain sight. The spiders were found moving on the barks and branches of the shrubs and tress nocturnally searching for potential prey.

Distribution: South India: Tamil Nadu (Madurai, Thirumangalam) and Kerala (Kayipuram, Irinjalakuda, Muriyad, Pathiramanal Island, Perumbalam Island, Thevara, Wayanad). Additionally, Tikader, 1966a reported *Philodromus kendrabatai* from the Indian states of Maharashtra and Karnataka.

3.3.23.2 *TIBELLUS* Simon, 1875

Genus *Tibellus* is a moderately species-rich genus with a worldwide distribution (World Spider Catalog, 2021). The genus is represented by 51 nominal species globally and 8 of them are currently reported from India (World Spider Catalog, 2021).

Diagnosis: *Tibellus* species can be distinguished by the following combination of characters: Carapace flat and broad, longer than wide; AER together with PMEs form a small compact hexagonal group from which the PLEs are conspicuously absent; legs relatively long, with scopulae and short spines on both the tarsi and metatarsi; abdomen long and cylindrical or cigar-shaped, with anterior slightly blunted and indented, posterior very gentle taper to the spinnerets.

Type species: *Tibellus oblongus* (Walckenaer, 1802)

Species sampled from the Muriyad Kol Wetland.

Tibellus elongatus Tikader, 1960
Fig. 3.A.7F

Tibellus elongatus Tikader, 1960: 176, Figs 3a–b (♀); Tikader, 1971: 82, Figs 20E–F (f); Tikader, 1980b: 217, Figs 288–289 (♀);Tikader and Biswas, 1981: 88, Figs 152–153 (♀).

Habitat: *T. elongatus* found at ground level in habitats like grasslands (including fallows) and uncultivated plots with grassy undergrowth.

Natural history: *T. elongatus* are commonly encountered above the soil surface among the grass and herbaceous undergrowth. The light brown to yellowish colour of the spider enables it to blend in with the soil surface. The spider has elongated body with slender equally long legs and usually encountered sitting on leaves or grass blades with their frontal pair of legs forwardly directed.

3.3.24 FAMILY PHOLCIDAE C. L. Koch, 1850

DADDY LONG-LEGS SPIDERS

Family Pholcidae represents very small to medium sized araneomorphs, ecribellate, haplogyne, three clawed with dense claw tufts, six or eight-eyed, with cosmopolitan distribution (Jocqué & Dippenaar-Schoeman, 2006). They are commonly known as daddy long-legs spiders, and are thin, delicate aranids hanging inverted in their irregularly shaped webs. They usually construct webs in dark, undisturbed areas in caves, under rocks, barks and burrows. Some members of the family are synanthropic spiders, preferring to build their webs in areas such as roof corners, attics or abandoned spaces. The family currently has 1812 species in 94 genera globally, and 13 of them are known from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following characters: Carapace short, broad, almost circular, cephalic region mostly raised, deep striae, thoracic region sometimes with longitudinal deep fovea; eyes often covering the entire width of carapcae, AME shortest or absent; abdomen globose or sylindrical to elongate; females with epigyne like sclerotisation covering the internal genitalia; male palp complex, tibia large, swollen (Jocqué & Dippenaar-Schoeman, 2006).

Type genus: *Pholcus* Walckenaer, 1805

3.3.24.1 *ARTEMA* Walckenaer, 1837

Genus *Artema* is a moderately species-rich genus distributed in Oriental, Ethiopian and Paleartic regions (World Spider Catalog, 2021). The genus is represented by 11 nominal species globally and only one is currently known from India (World Spider Catalog, 2021).

Diagnosis: *Artema* species can be distinguished by the following combination of characters: Carapace circular and flat with a tall, slightly protruding clypeus; eight eyes, two in front and two compact groups of three to the side; AME not significantly smaller than the rest, AER slightly recurved, and the PER strongly recurved; chelicerae with two teeth on their inner margin; abdomen tall, globular, higher than wide, rounded at the top, and gradually tapering below to the spinnerets.

Type species: *Artema atlanta* Walckenaer, 1837

Species sampled from the Muriyad Kol Wetland.

Artema atlanta Walckenaer, 1837

Fig. 3.A.7A

Artema atlanta Walckenaer, 1837: 656 (♂♀); Tikader and Biswas, 1981: 18, Fig. 12 (♀); Huber, 2000: 12, Figs 12–13, 48, 56–57, 99, 121, 145, 169, 195 (♂); Aharon et al., 2017: 8, Figs 3, 15–34, 201, 208 (♂♀).

Artema mauriciana Walckenaer, 1837: 657, pl. 15, Fig. 1 (♂♀)

Pholcus rotundatus Karsch, 1879a: 106 (♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Artema atlanta* found in and around human habitations, especially on ceilings of houses and buildings in the study area.

Natural history: *Artema atlanta* commonly known as giant daddy-long legs, and considered the largest Pholicid spider in the world, measuring about 8–10 mm in bodylength. It is a synanthropic spider usually encountered in the region. And both sexes of the species share similar body length.

3.3.24.2 *CROSSOPRIZA* Simon, 1893

Genus *Crossopriza* is a less species-rich genus with worldwide distribution (World Spider Catalog, 2021). The genus is represented by 7 nominal species globally and only one is currently known from India (World Spider Catalog, 2021).

Diagnosis: *Crossopriza* species can be distinguished by the following combination of characters: Male chelicerae with two pairs of apophyses, one lateral, one frontal and directed inwards; legs with many short, dark, longitudinal spots; female with stridulatory apparatus in the form of a pair of protuberances on posterior side of carapace, and a corresponding pair of sclerotized plates on abdomen (Huber et al., 1999).

Type species: *Crossopriza pristina* (Simon, 1890)

Species sampled from the Muriyad Kol Wetland.

Crossopriza lyoni (Blackwall, 1867)
Fig. 3.A.7B

Pholcus lyoni Blackwall, 1867 392 (♂♀).

Smeringopus lyoni Thorell, 1895: 70.

Crossopriza lyoni Pocock, 1900: 240; Tikader and Biswas, 1981: 18, Figs 13–15 (♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Crossopriza lyoni* inhabit human dwellings, especially on surfaces of walls and shrubs.

Natural history: *Crossopriza lyoni* commonly called box spiders or tailed daddy long legs or tailed cellar spiders, measures around 2.5 to 7 mm in body length, and they possess extremely fragile and elongated legs. Distributed pan tropically, they are considered a nuisance by human due to prolific web building insides homes, however, they are also found to be excellent in controlling populations of insects such as mosquitoes.

3.3.24.3 *PHOLCUS* Walckenaer, 1805

Genus *Pholcus* is a speciose genus with worldwide distribution (World Spider Catalog, 2021). The genus is represented by 339 nominal species globally and 8 of them are currently known from India (World Spider Catalog, 2021).

Diagnosis: *Pholcus* species can be distinguished from other Araneids by the following combination of characters: Mostly fairly large and long-legged spiders; male chelicerae with pair of proximal frontal apophyses; male bulb usually with uncus and appendix; epigyne usually strongly sclerotized with knob; most species have eight eyes, but the AME are absent in some species; Ocular region in males usually with many stronger hairs posteriorly, rarely with median or paired modifications; Male chelicerae usually with three pairs of apophyses: proximal lateral, proximal frontal, and distal frontal (Huber, 2011).

Type species: *Pholcus phalangioides* (Fuesslin, 1775)

Species sampled from the Muriyad Kol Wetland.

Pholcus phalangioides (Fuesslin, 1775)

Aranea phalangoides Fuesslin, 1775: 61 (D).

Aranea meticulosa Fourcroy, 1785 Fourcroy, 1785: 537 (D).

Pholcus phalangioides Walckenaer, 1805: 80, pl. 8, Fig. 79 (♀); Walckenaer, 1837: 652 (♂); Pickard-Cambridge, 1879: 77, pl. 1, Fig. 14, pl. 6, Fig. 3 (♂♀); Huber, 2000: 77, Fig. 100; Sen, Dhali, et al., 2015: 88, Figs 509–513, pl. 19 (♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *P. phalangioides* are synathropic spiders found inside human dwellings.

Natural history: *P. phalangioides*, also known as daddy long-legs spider or long-bodied cellar spider or skull spiders, are found commonly on the ceilings or walls of houses and caves.

Other species sampled:

***Pholcus* sp. 1**

***Pholcus* sp. 2**

3.3.24.4 ***SMERINGOPUS* Simon, 1890**

Genus *Smeringopus* is a moderately species-rich genus distributed mostly restricted in the Ethiopian region, but introduced in Oriental, Australasia and Polynesia (World Spider Catalog, 2021). The genus is represented by 55 nominal species globally and only one is currently reported from India (World Spider Catalog, 2021).

Diagnosis: *Smeringopus* species can be distinguished by the following combination of characters: Relatively large pholcids with elongate abdomen, usually with vivid dark pattern and deep thoracic pit; male palpal femur usually with deep retrolateral furrow with distinct proximal rim; legs usually with curved hairs on tibiae and metatarsi, without spines on male femora (Huber, 2012).

Type species: *Smeringopus pallidus* (Blackwall, 1858)

Species sampled from the Muriyad Kol Wetland.

Smeringopus pallidus (Blackwall, 1858)

Pholcus pallidus Blackwall, 1858: 433 (♀).

Pholcus phalangioides Doleschall, 1859: 47, pl. 16, Fig. 8.

Smeringopus pallidus Mello-Leitão, 1918: 119 (♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *S. pallidus* are synathropic spiders found sheltered and shady areas, including human dwellings.

Natural history: *S. pallidus* , also known as pale daddy long-legs, builds irregular webs to capture prey including other spiders. They tend to hang upside down in the web and vibrate vigorously when disturbed.

3.3.25 FAMILY PISAURIDAE Simon,1890

NURSERY WEB SPIDERS OR FISHING SPIDERS

Family Pisauridae represents medium-sized to very large araneomorph spiders, ecribellate, entelegyne, three clawed, eight-eyed in three rows, with cosmopolitan distribution (Jocqué & Dippenaar-Schoeman, 2006). They are commonly known as nursery web spiders or fishing spiders, and they resemble wolf spiders (see section 3.3.17) except for many differences. Many species can walk on the surface of water and even dive underwater for several minutes to evade predators. The family currently has 353 species in 51 genera globally, and 18 of them are known from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following characters: Carapace longer than wide, clothed in plumose setae; eyes in two rows(4:4), three (4:2:2), or three (2:2:2) , atleast one pair on tubercles, secondary eyes with grate shaped tapetum; cheliceral furrow with teeth; legs relatively long, slightly laterigrade sometimes, tarsi with pseudosegment; abdomen elongated, tapering posteriorly, with plumose setae; epigyne with two integumental folds creating lateral elevations with a median area, vulva complex; male palp with tibial apophysis in most cases, median apophysis present, cymbium elongated anteriorly (Jocqué & Dippenaar-Schoeman, 2006).

Type genus: *Pisaura* Simon, 1885

3.3.25.1 ***PERENETHIS*** **L. Koch, 1878**

Genus *Perenethis* is a less species-rich genus distributed in the Oriental, Ethiopian and Australian regions (World Spider Catalog, 2021). The genus is represented by 6 nominal species globally and 3 of them are currently known from India (World Spider Catalog, 2021).

Diagnosis: *Perenethis* species can be distinguished by the following combination of characters: Carapace and abdomen each with a distinct, moderately broad, and continuous longitudinal band; two cheliceral teeth retrolaterally (Sierwald, 1989).

Type species: *Perenethis venusta* L. Koch, 1878

Species sampled from the Muriyad Kol Wetland.

Perenethis venusta (L. Koch, 1878)

Fig. 3.A.7G

Perenethis venusta Koch, 1878: 980, pl. 85, Fig. 7 (♀); Raven and Hebron, 2018: 287, Figs 4f, 5a, 75a–c, 76a–d (♂♀)

Dolomedes stilatus Karsch, 1878: 814 (♂).

Perenethis unifasciata Chrysanthus, 1967: 422, Figs 53–57 (♂♀); Sunil Jose and Sebastian, 2007: 127, Figs 1a–f (♀).

Perenethis kawangisa Barrion and Litsinger, 1995: Figs 205a–i (♂).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Perenethis venusta* found in the undergrowth in grasslands and uncultivated areas.

Natural history: *Perenethis venusta* are medium bodied spiders, inhabiting the lower undergrowth above the ground and among the litter.

Other species sampled:

***Pisaura* sp. 1**

3.3.26 FAMILY SALTICIDAE Blackwall,1841

JUMPING SPIDERS

Family Salticidae represents small to large araneomorph spiders, ecribellate, entelegyne, two tarsal clawed, eight-eyed with large anterior median eyes, with cosmopolitan distribution (Jocqué & Dippenaar-Schoeman, 2006). Commonly known as jumping spiders, they are diurnal with cursorial hunting habits endowed with well-developed vision. Jumping spiders have the best vision among spiders which they use during courtship, hunting and navigation. The shape of the cephalothorax and peculiar eye pattern easily give away their identity and distinguish them from similar families. They survive in a variety of habitats, with a majority of them found in tropical forests around the world. The family currently represents 6264 species in 653 genera globally, and 269 of them are known from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021). It is the largest family of spiders encompassing around 13 percent of all species.

Diagnosis: Members of the family can be distinguished by the following characters: Carapace front sqaure-shaped, eye region decorated with long setae; eyes in three or four rows, anterior median eyes large, anterior lateral eyes smaller, both pairs directed forward; legs tarsi with two claws, usually with claw tufts; abdomen short to oblong, elongate in some genera; male palp with tibial apophysis, femoral protuberance in some (Jocqué & Dippenaar-Schoeman, 2006).

Type genus: *Salticus* Latreille, 1804

3.3.26.1 *ASEMONEA* L. Koch, 1878

Asemonea is a less species-rich genus distributed in the Oriental, Ethiopian and Australian regions (World Spider Catalog, 2021). The genus is represented by 23 nominal species globally and 2 of them are currently known from India (World Spider Catalog, 2021).

Diagnosis: *Asemonea* species can be distinguished from other salticids by the following combination of characters: From *Pandisus* and *Macopaeus* by the eye pattern,moderately well developed tubercles arranged in four transverse rows; and from *Goleba* by the presence of the palpal femoral furrow in males ; epigyne atrium undivided, with median septum, or covered by median scape; introductory ducts, sometimes coiled; primary spermathecae more or less ovoid with lanceolate fertilization ducts; secondary spermathecae lacking; tubular gland-like ducts sometimes present (Wanless, 1980).

Type species: *Asemonea tenuipes* (O. Pickard-Cambridge, 1869)

Species sampled from the Muriyad Kol Wetland.

Asemonea tenuipes (O. Pickard-Cambridge, 1869)
Fig. 3.A.8A

Lyssomanes tenuipes Pickard-Cambridge, 1869b: 65, pl. 5, Figs 50–52 (♂).
Asemonea tenuipes Peckham and Peckham, 1886: 340.
Lyssomanes bengalensis Tikader and Biswas, 1981: 107, Figs 21–23 (♀).
Lyssomanes andamanensis Tikader and Biswas, 1981: 109, Figs 201–203 (♂♀).
(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Asemonea tenuipes* found among the foliages of understorey in most of the wooded habitats in the region.

Natural history: *Asemonea tenuipes*, commonly known as tailed jumper, are found moving on leaves in the understorey. They exhibit sexual dimorphism, wherein the males appear ornate and attractive than the females which looks dull greenish. The distribution range spans across the Indian subcontinent and the south-east Asia.

3.3.26.2 ***BIANOR*** Peckham & Peckham, 1886

Bianor is a less species-rich genus distributed in the Oriental, Australian, Paleartic, Ethiopian and Neartic regions (World Spider Catalog, 2021). The genus is represented by 27 nominal species globally and 8 of them are currently known from India (World Spider Catalog, 2021).

Diagnosis: *Bianor* species can be distinguished from *Sibianor* by the following combination of characters: Absence of fringes on leg I; absence of tegular knob; absence of ventral scutum; ocular area narrower than the carapace windth; elevated PLE, second eye row slightly closer to AME. From *Modunda* by the high carapace and presence of spines on leg IV (Logunov, 2001).

Type species: *Bianor maculatus* (Keyserling, 1883)

Species sampled from the Muriyad Kol Wetland.

Bianor angulosus (Karsch, 1879)

(Figs 3.11 and 3.12)

Ballus angulosus Karsch, 1879b: 553 (♀).

Bianor leucostictus Thorell, 1890b: 158 (♂)

Bianor hotingchiehi Schenkel, 1963: 434, Figs 249a–f (♂)

Bianor angulosus Babu et al., 2021: 19177, Figs 1–6 (♂♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: Paddy fields and grasslands.

Natural history: *B. angulosus* are abundantly found on grasses and paddy plants. They move around during day time on the flag leaves and panicles of paddy plants and construct retreats under flag leaves.

Figure 3.11: Live images of *Bianor angulosus*. **A**, male, dorsal view. **B**, female, dorsal view.

Bianor kolensis sp. nov.

(Figs 3.13 to 3.15)

Type: Holotype ♂(CATE 8719A), India, Kerala, Thrissur, Muriyad (10°21´06.9″N, 76°15´06.2″E), 2 m a.s.l., 15.03.2014, K. S. Nafin. Paratype: 4♀(CATE 8719B),

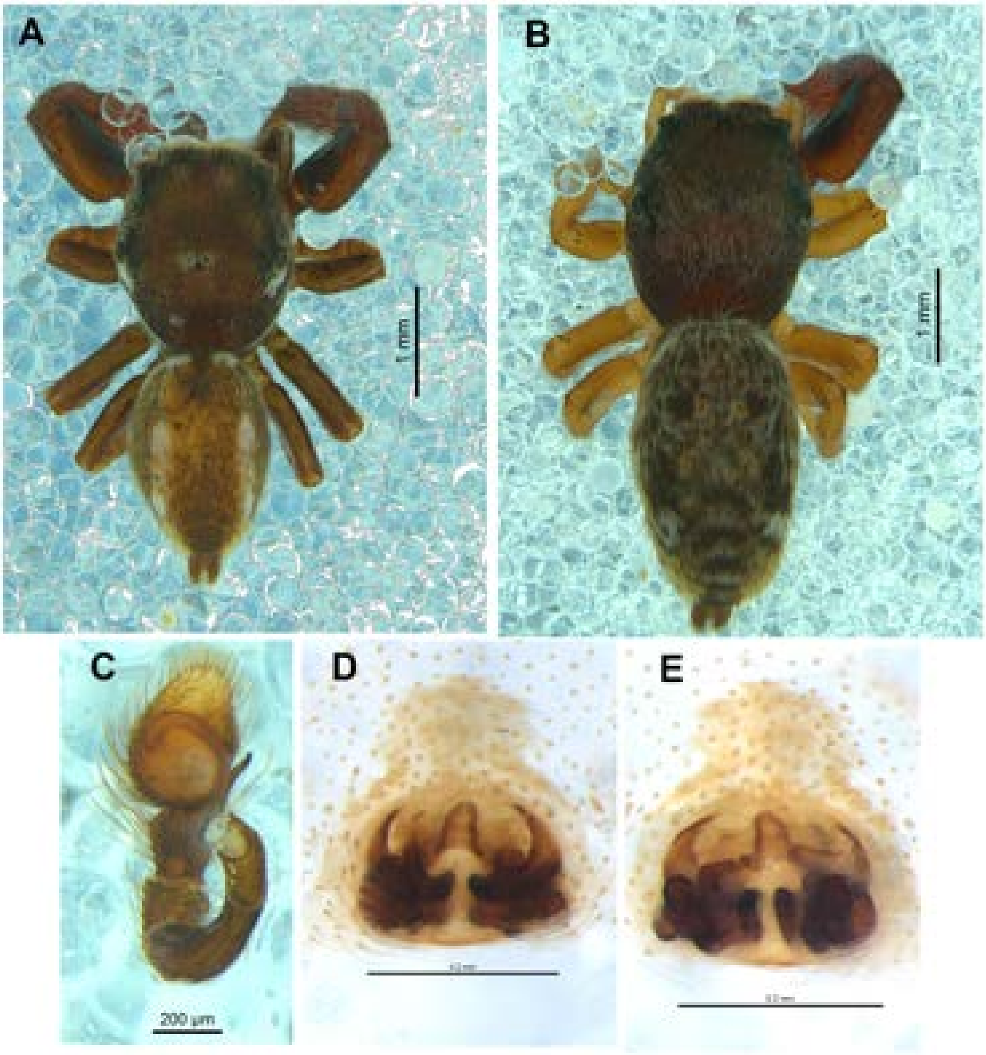

Figure 3.12: Habitus and genitalia of *Bianor angulosus*. Male (**A, C**) and female (**B, D, E**). **A**, general appearance, dorsal view. **B**, same, dorsal view. **C**, male left palp, ventral view. **D**, epigyne, ventral view. **E**, vulva, dorsal view. Scale bars. **A–B**, 1 mm. **C–E**, 0.2 mm.

same data as holotype.

Etymology: The specific name is an adjective derived from the name of the wetland from where the species was collected.

Diagnosis: *Bianor kolensis* sp. nov. can be easily distinguished from other congeners by the following characters: Males with golden metallic lustrous body, abdomen without white spots, palpal tegulum slanting distally; females with pale metallic lustrous carapace, abdomen with distinct pattern, copulatory duct forming a posterior loop (Figs 3.13, 3.14E, 3.15G). It can be distinguished from *B. angulosus* by the absence of longitudinal lines in male abdomen, different colour pattern on

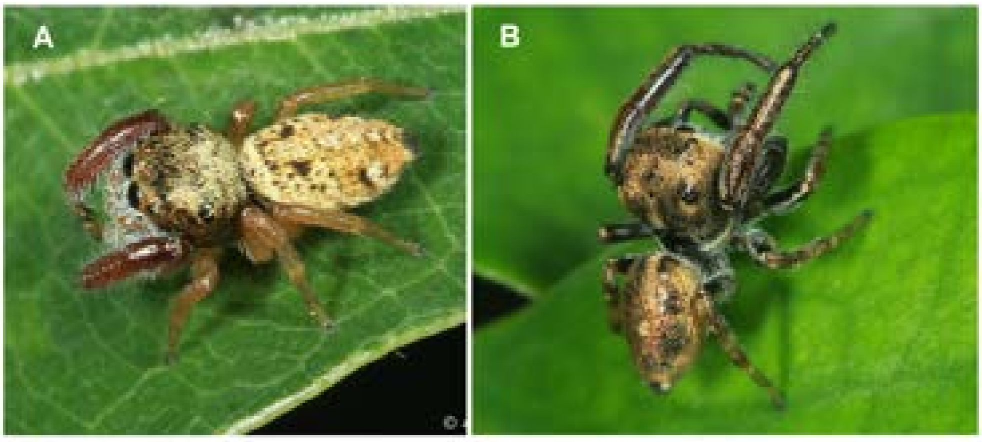

Figure 3.13: Live images of *Bianor kolensis* sp. nov. **A**, female, dorsal view. **B**, male, dorsal view.

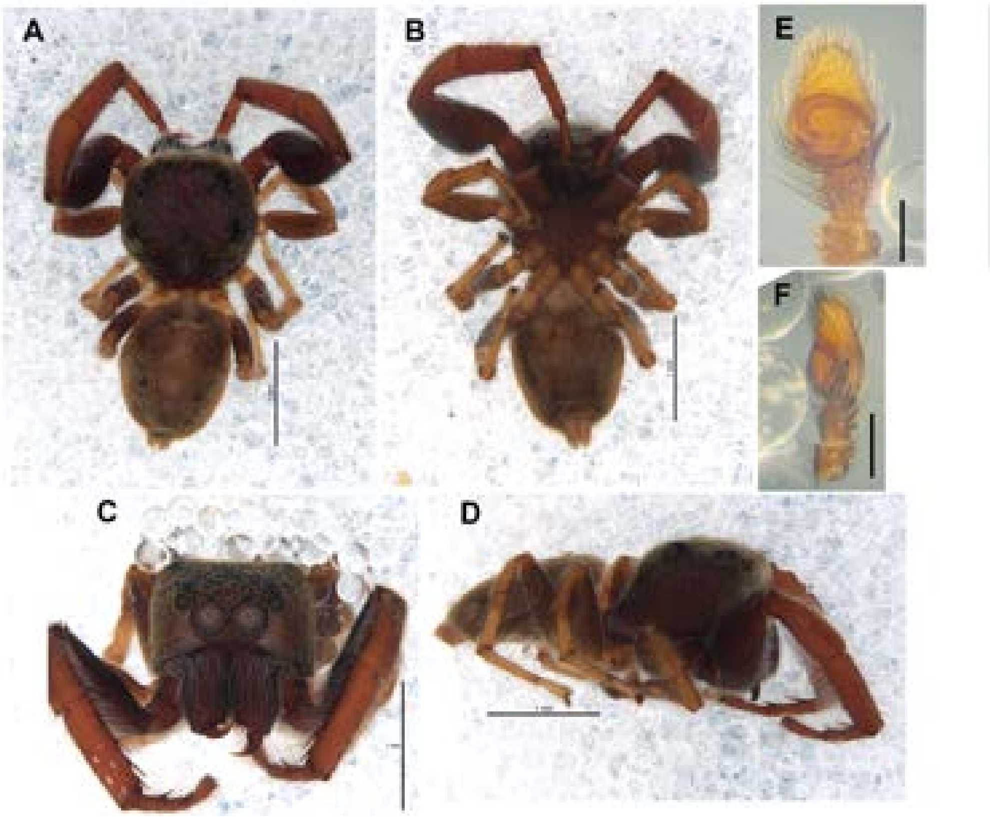

Figure 3.14: Holotype male of *Bianor kolensis* sp. nov. **A**, general appearance, dorsal view. **B**, same, ventral view. **C**, same, frontal view. **D**, same, lateral view. **E**, left palp, ventral view. **F**, same, retrolateral view. Scale bars. **A–D**, 1 mm. **E, F**, 0.2 mm.

abdomen in female(Figs 3.11A–B, 3.13A–B); male palpal tegulum different (cf. Fig. 3.14E with Fig. 1 in Żabka, 1985); copulatory duct without posterior loop in *B. angulosus* (cf. Fig. 3.15G, 3.12C–E with Fig. 11 in Żabka, 1985).

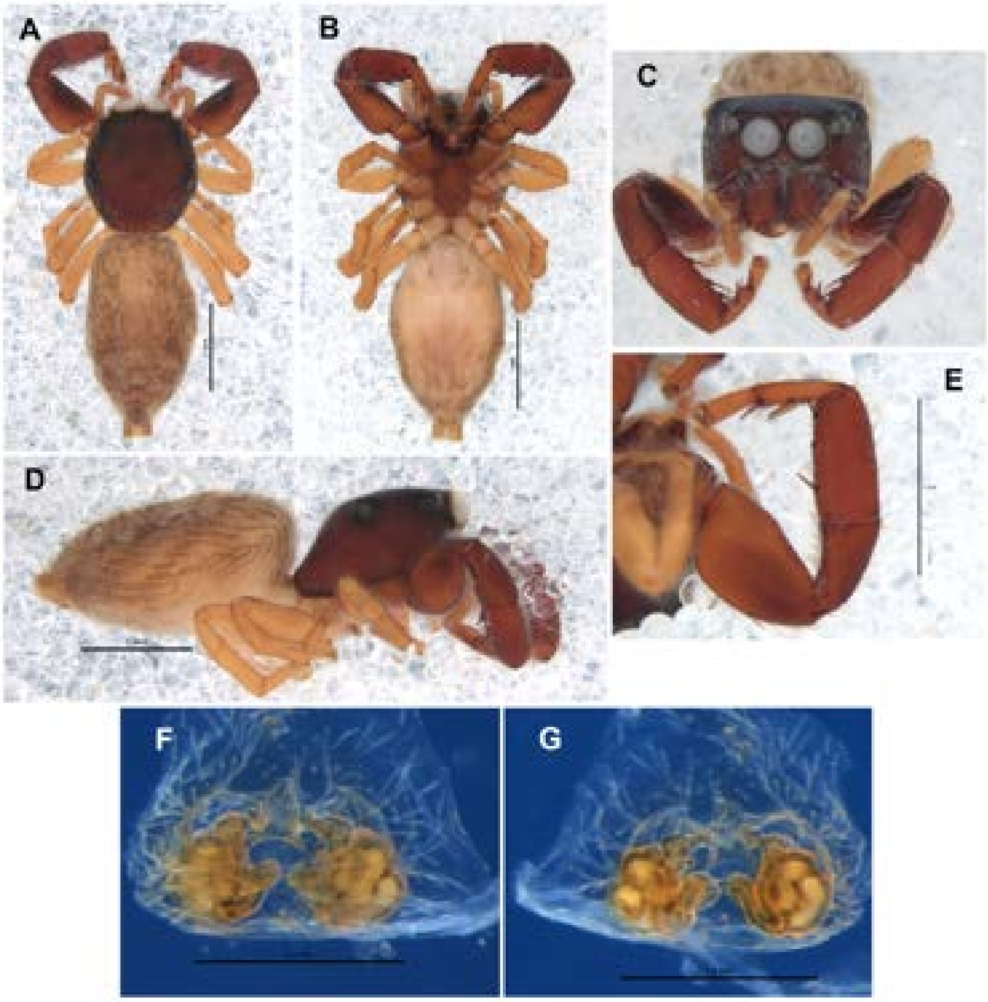

Figure 3.15: Paratype female of *Bianor kolensis* sp. nov. **A**, general appearance, dorsal view. **B**, same, ventral view. **C**, same, frontal view. **D**, same, lateral view. **E**, left leg I, retrolateral view. **F**, epigyne, ventral. **G**, vulva, dorsal view. Scale bars. **A–E**, 1 mm. **F, G**, 0.2 mm.

Description: MALE (Figs 3.13 and 3.14). Measurements. Carapace 2.00 long, 1.22 wide and 0.7 high at PLE. Chelicera length 0.5. Abdomen 1.92 long, 0.81 wide. Eyes diameters: AME 0.3. ALE 0.10. PME 0.02. PLE 0.22. Carapace elevated, russet covered with pale brown setae, lateral margin with band of white setae, ocular area dark; chelicerae reddish brown. Fovea indistinct. Leg I thick, femur I dark russet, rest dark brown, legs II–IV brown to light brown. Abdomen oval, light brown, two pairs of sigilla visible, venter light brown.

Palp (Figs 3.14E–F). Embolus thin, distal tegulum sloping, RTA long, thick, constriction at the tip.

FEMALE (Figs 3.15A–G). In all details like male except the following: Carapace russet with fewer setae, no lateral white margin; leg I dark red-orange, legs II–IV pale yellow; abdomen grey, with dark mottling; epigyne pocket shape variable, spermathecae as in Fig. 3.15G, copulatory duct with a posterior loop.

Habitat: Collected from grasslands and paddy fields.

Natural history: The spiders were collected from the paddy plants and grasses in the wetlands. They construct silken retreats under paddy flag leaves and grass inflorescence and rests at night. Females are numerous than males.

Distribution: India: Kerala (Thrissur).

3.3.26.3 *BRETTUS* Thorell, 1895

Brettus is a less species-rich genus distributed in the Oriental and Ethiopian regions (Madagascar) (World Spider Catalog, 2021). The genus is represented by 6 nominal species globally and 2 of them are known from India (World Spider Catalog, 2021).

Diagnosis: *Brettus* species can be distinguished by the following combination of characters: Leg I possees gutter like femoral organs, male palpal tibia with a tubular process near the RTA (Wanless, 1979).

Type species: *Brettus cingulatus* Thorell, 1895

Species sampled from the Muriyad Kol Wetland.

Brettus cingulatus Thorell, 1895

Figs 3.A.8D and 3.A.8E

Brettus cingulatus Thorell, 1895: 355 (♂).

Brettus albolimbatus Simon, 1900: 31 (♀).

Brettus semifimbriatus Simon, 1900: 31 (♀).

Brettus cingulatus Wanless, 1978: 83.

Brettus albolimbatus Wanless, 1979: 188, Figs 2C; 3C–D; 4A–B.

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Brettus cingulatus* found in wooded habitats in the study area.

Natural history: *Brettus cingulatus* are mostly araneophagic, usually found in the branches of trees and shrubs. They occasionally prey on insects, by stalking the prey carefully. The spider prefers web-building spiders and they use specialised tactics to lure the host towards them, failing which they pounce on the host spiders vertically. The interesting behaviour of the spiders has been documented (Jackson, 2000; Jackson & Hallas, 1986). The spider uses aggressive mimicry to lure prey, striking with their pedipalp on the edge of webs mimicking the vibrations produced by insect prey or potential mate, often tries a variety of patterns of vibrations or rhythms until successfully luring the host nearer to them, at which point they stab or immobilise the host spider.

3.3.26.4 *CARRHOTUS* Thorell, 1891

Carrhotus is a less species-rich genus distributed in the Oriental, Palearctic, Ethiopian and Neotropical regions (World Spider Catalog, 2021). The genus is represented by 32 nominal species globally and 6 of them are known from India (World Spider Catalog, 2021).

Diagnosis: *Carrhotus* species can be distinguished by the following combination of characters: Carapace longer than wide sloping posterior; PME located midway between the anterior and posterior laterals; abdomen perfectly oval, with a blackish or brownish general colouration and a chevron pattern in some cases; chelicerae unidentate with two teeth on promargin and one on retromargin.

Type species: *Carrhotus viduus* (C. L. Koch, 1846)

Species sampled from the Muriyad Kol Wetland.

Carrhotus viduus (C. L. Koch, 1846)

Figs 3.A.8F and 3.A.8G

Plexippus viduus Koch, 1846: 104, Fig. 1166 (♂).

Carrhotus viduus Thorell, 1891: 142; Caleb, Bera, et al., 2020: 61, Figs 57–73, 76–78, 80–82 (♂♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *C. viduus* found in foliages of shrubs and bushes in habitats associated with the wetland, also found in paddy fields.

Natural history: *C. viduus* exhibit sexual dimorphism–males are black wih white longitudinal stripes and the females have varying shades of yellow to orange or black colouration with white markings on the carapace and abdomen. In paddy fields, they are found along the bordering vegetations, they are agile jumpers but can be easily caught due to their larger body.

3.3.26.5 *CHALCOTROPIS* Thorell, 1891

Chalcotropis is a less species-rich genus distributed in the Oriental and Oceania (World Spider Catalog, 2021). The genus is represented by 10 nominal species globally, with only one species known from India (World Spider Catalog, 2021).

Diagnosis: *Chalcotropis* species can be distinguished by the following combination of characters: PMEs almost midway between the posterior lateral and anterior lateral eyes; male chelicerae oblique, with a longitudinal ridge that usually ends in a spur apically; embolus short pointed; RTA strongly developed.

Type species: *Chalcotropis acutefrenata* Simon, 1902

Species sampled from the Muriyad Kol Wetland.

Chalcotropis pennata Simon, 1902
Fig. 3.A.8H

Chalcotropis pennata Simon, 1902: 378 (♂); Prószyński, 1984a: 18 (♂♀); Prószyński, 2017: 80, Fig. 35A (♂♀).

Pristobaeus jocosus Asalatha et al., 2018: 69, Figs 1–3 (♀; misidentified per Caleb, 2019).

Habitat: *C. pennata* were found in foliages in wooded habitats around the wetlands.

Natural history: *C. pennata* were commonly encountered foraging on leaf surfaces during day time.

3.3.26.6 *CHINATTUS* Logunov, 1999

Chinattus is a less species-rich genus distributed in the Oriental, Palearctic and Nearctic regions (World Spider Catalog, 2021). The genus is represented by 19 nominal species globally, with only one species known from India (World Spider Catalog, 2021).

Diagnosis: *Chinattus* species can be distinguished from other Salticids by the following combination of characters: Carapace moderately high, eye field flat and horizontal; PME closer to PLE than ALE; chelicerae with 2 promarginal and 1 retromarginal teeth; abdomen oval, without scutum; male palpal bulb expanded at basal part, tegulum lateral outrowth of the bulb, compound terminal apophysis absent, embolus well sclerotised and not long, with one or two RTA; epigyne simple, epigynal plate with round internal structure, copulatory opening widely seperated (Suguro, 2014).

Type species: *Chinattus undulatus* (Song & Chai, 1992)

Species sampled from the Muriyad Kol Wetland.

Figure 3.16: Live images of male *Chinattus thamannae* sp. nov. **A**, Male, dorsal view. **B**, same, lateral view. **C**, same, frontal view. **D**, same, frontolateral view.

Chinattus thamannae sp. nov.

(Figs 3.16 to 3.18)

Type: Holotype ♂(CATE 8716A), India, Kerala, Thrissur, Muriyad (10°24´39.80″N, 76°13´56.60″E), 4 m a.s.l., 3.03.2017, K. S. Nafin & Varun Das Manakkatt. Paratype: 2 ♀(CATE 8716B), same data as holotype.

Etymology: The specific epithet is a patronym in honour of my wife Dr. Thamanna Salim A. S.

Diagnosis: Males of *C. thamannae* sp. nov. is closer to *C. dactyloides* (Xie,

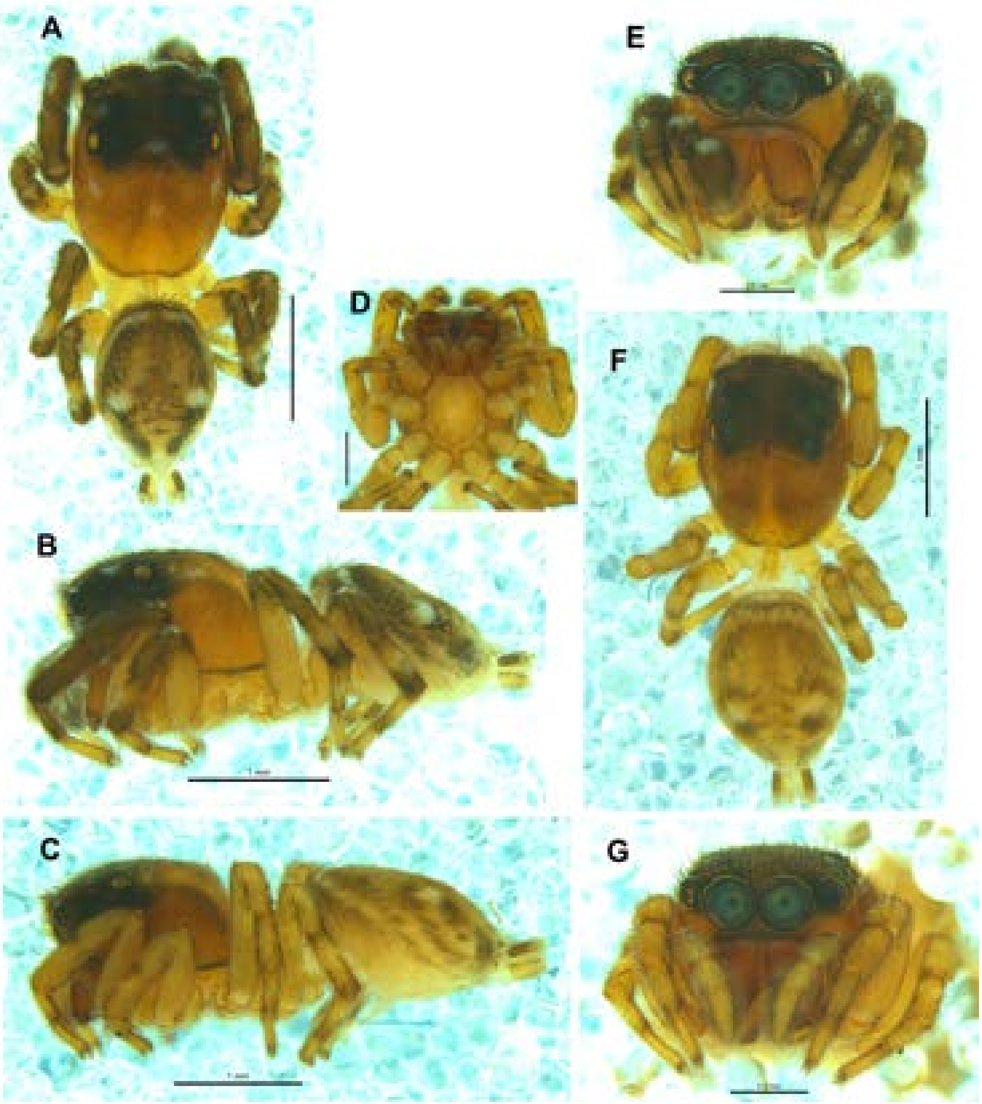

Figure 3.17: Holotype male and paratype female of *Chinattus thamannae* sp. nov. Male (**A, B, E**) and female (**C, D, F, G**). **A, F**, general appearance, dorsal view. **B, C**, same, lateral view. **D**, sternum. **E, G**, carapace, frontal view. Scale bars. **A–C, F**, 1 mm. **D, E, G**, 0.5 mm.

Peng & Kim, 1993), but can be distinguished from the later by the following charecters: proximal tegulum narrow (broader in *C. dactyloides*); embolus with strong anti clockwise spiral and tip pointed at 11 o'clock (spiral narrow, clockwise direction and tip pointed at 1 o'clock in *C. dactyloides*)(cf. Figs 3.18A–C with Figs D5076–5077 in Peng and Xie, 1995). Female epigyne with posteriorly drawn out wide U-shaped pocket (Figs 3.18D–E).

Description: Male (Holotype; Figs 3.16, 3.17A, B, E, 3.18A–C). Measurements. Carapace 1.53 long, 1.22 wide and 0.95 high at PLE. Chelicera length 0.54. Abdomen 1.52 long, 0.91 wide. Eyes diameters: AME 0.32. ALE 0.17. PME 0.06. PLE 0.15. Eye

Table 3.4: *Chinattus thamannae* sp. nov. Measurements of legs and palp

Male	**Leg segments**	**I**	**II**	**III**	**IV**	**Palp**
	Femur	0.86	0.69	0.91	0.74	0.45
	Patella	0.53	0.38	0.44	0.34	0.21
	Tibia	0.63	0.41	0.47	0.49	0.11
	Metatarsus	0.36	0.34	0.57	0.64	–
	Tarsus	0.40	0.33	0.31	0.29	0.50
	Total	0.40	2.15	2.7	2.5	1.27
Female	**Leg segments**	**I**	**II**	**III**	**IV**	**Palp**
	Femur	0.83	0.69	0.97	0.93	–
	Patella	0.47	0.45	0.35	0.40	–
	Tibia	0.49	0.41	0.43	0.57	–
	Metatarsus	0.35	0.37	0.62	0.66	–
	Tarsus	0.34	0.29	0.29	0.39	–
	Total	2.48	2.21	2.66	2.95	–

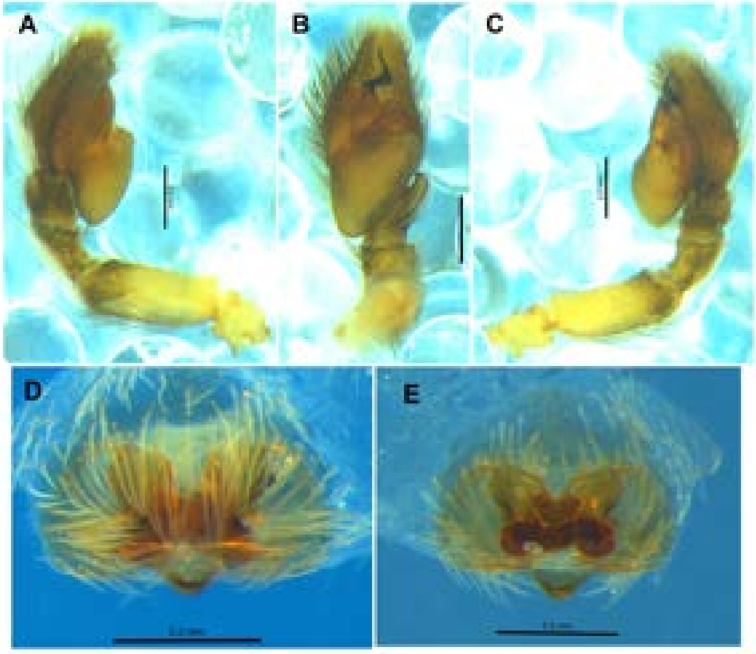

Figure 3.18: Male and female genitalia of *Chinattus thamannae* sp. nov. **A**, Male left palp, prolateral view. **B**, same, ventral view. **C**, same, retrolateral view. **D**, epigyne, ventral view. **E**, vulva, dorsal view. Scale bars. **A–D**, 0.2 mm.

interdistances: AME–ALE 0.12. PME–PLE 0.12. PME–PME 1.13. Leg formula: 1342

Carapce moderately high, light orange-brown, eye region black with six prominent white spots, eye region with man medium-sized dark setae; AME and ALE encircled by white fringe of setae; clypeus with two dark setae, cheeks naked; chelicerae orange-brown;

sternum yellow and endites light yellow. Abdomen fawn, covered with dark setae, margin white, a pair white spots in the middle and one spot posteriorly, dark mottling interior to the white margins; ventrum pale yellow. Leg I with trichobothria on tibia and metatarsi, tibia II with trichobothria; white spots on patella, tibia and metatarsi of all legs.

Palp (Figs 3.18A–C). Femur yellowish, rest orange-brown, distal region of femur, patella and proximal portion of cymbium thickly covered by white setae dorsally; tegulum characteristic of the genus, embolus thick, two-coiled, rotating anti-clockwise from the base, tip pointing at 11 o'clock.

FEMALE (Paratype; Figs 3.17C, D, F, G, 3.18D–E). Measurements. Carapace 1.64 long, 1.27 wide and 1.25 high at PLE. Chelicera length 0.59. Abdomen 1.81 long, 1.17 wide. Eyes diameters: AME 0.34. ALE 0.21. PME 0.05. PLE 0.15. Eye interdistances: AME–ALE 0.02. PME–PLE 0.14. PME–PME 0.94. Leg formula: 4312

In all details like male except the following: Carapace lacking white spots seen in males, covered in fine setae, fovea present; AME and ALE surrounded by fawn setae, legs yellow, without white spots, palp white setae on patella, tibia and tarsi, with macrosetae on patella and tibia. Abdomen with a pair of pale yellow spots in the middle. Epigyne (Figs 3.18D–E). Copulatory opening large ventrally, pocket on wide U-shaped protrusion posteriorly; copulatory duct wide, with two coils before entering the spermathecae; fertilisation duct anterolatrally oriented.

Habitat: *C. thamannae* sp. nov. were collected from grasslands and paddy fields.

Natural history: The spiders were collected from the undergrowth and among grasses in paddy fields and grasslands.

Distribution: India: Kerala (Thrissur district).

3.3.26.7 *CHRYSILLA* Thorell, 1887

Chrysilla is a less species-rich genus distributed in the Oriental, Ethiopian and Australian regions (World Spider Catalog, 2021). The genus is represented by 10 nominal species globally, with two species known from India (World Spider Catalog, 2021). It was erected by Thorell in 1887, with *C. lauta* Thorell, 1887 as its generotype. Of the ten described species, only *C. acerosa* Wang & Zhang, 2012 and *C. jesudasi* Caleb & Mathai, 2014 are known from both sexes (World Spider Catalog, 2021). Three species — *C. acerosa* Wang & Zhang, 2012, *C. jesudasi* Caleb & Mathai, 2014 and *C. volupe* (Karsch, 1879) — have been recorded from India to date (Caleb, 2016; Caleb, Christudhas, et al., 2014; World Spider Catalog, 2021). *C. volupe* was originally described as *Attus volupe* from an unknown locality in Sri Lanka (Karsch, 1879b). A century later, the species was redescribed and placed in *Phintella* based on the re-examination of the holotype, and its range was extended to the mainland of the Indian subcontinent (Caleb, Christudhas, et al., 2014; Żabka, 1988). Later it was transferred to the genus *Chrysilla* (Caleb, 2016). However, the species has remained known from the males only for about 139 years, since its original description. Here, the first description of the female of *C. volupe* and a detailed redescription of its male are provided, based on fresh material collected from India.

Diagnosis: *Chrysilla* species can be distinguished from other Salticids by the following combination of characters: Separated from *Phintella* by the bright, metallic colouration of body, narrower and longer abdomen, comparably slender, quite longer and gently bent embolus, elongated oval-shaped apical tegulum, much longer than wide genital bulb, elongated cymbium single and strong RTA nearly half of the tegulum, and pyriform or rounded spermathecae of epigyne (Kanesharatnam & Benjamin, 2019).

Type species: *Chrysilla lauta* Thorell, 1887

Species sampled from the Muriyad Kol Wetland.

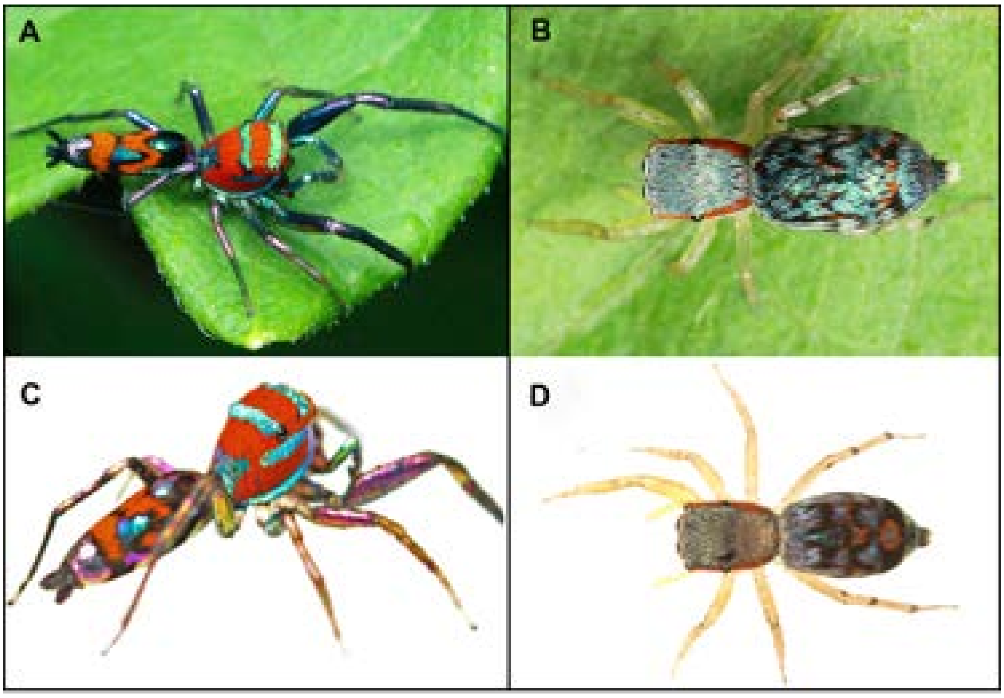

Figure 3.19: Live images of *Chrysilla volupe* from Kerala (**A–B**) and Maharashtra (**C–D**). **A**, Male, dorsolateral view. **B**, female, dorsal view. **C**, male, lateral view. **D**, female, dorsal view.

***Chrysilla volupe* (Karsch, 1879)**

Attus volupe Karsch, 1879b:: 552 (Description of ♂).

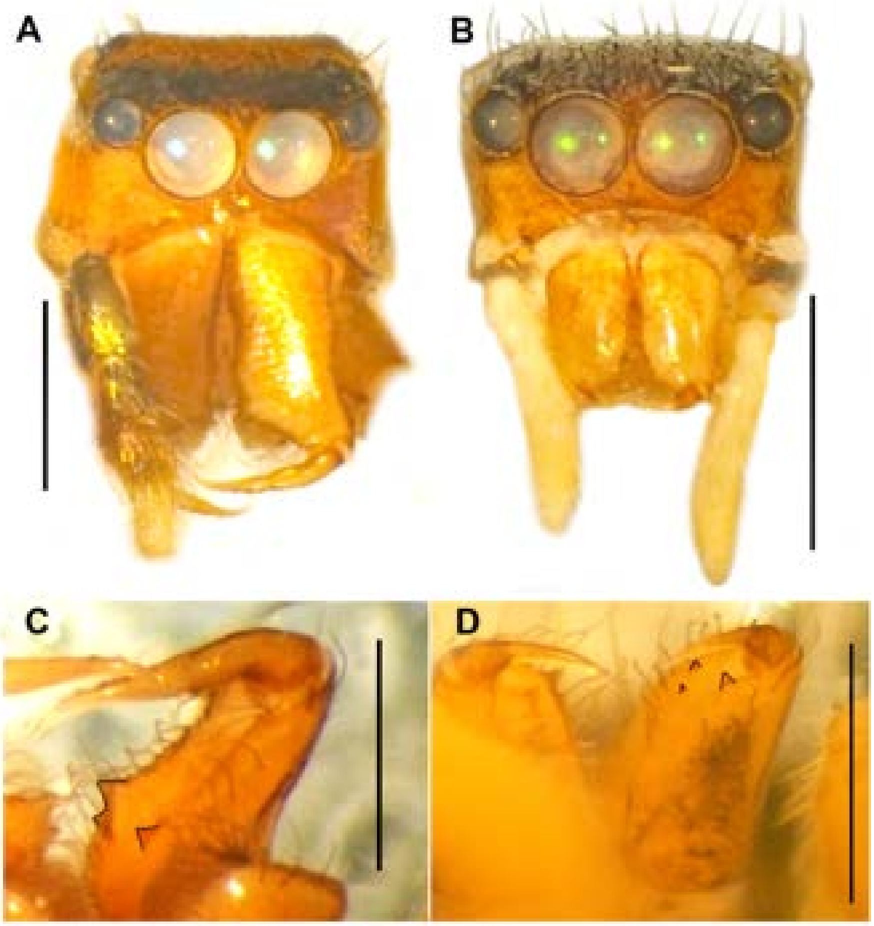

Figure 3.20: Male (A, C) and female (B, D) of *Chrysilla volupe*. **A, B**, carapace, frontal view. **C, D**, cheliceral teeth, ventral view. Scale bars. **A–B**, 1 mm. **C–D**, 0.5 mm.

Phintella volupe Żabka, 1988: 465, Figs 122–125 (Description and transfer of ♂from *Attus* to *Phintella*); Caleb, Christudhas, et al., 2014: 64, Figs 15–23 (Description of ♂).

Siler semiglaucus Prószyński, 1985: 73, Figs 16–17 (Misidentified, ♀only; Prószyński, 2016 raises doubts on the conspecificity of the illustrated ♀).

Chrysilla volupe Caleb, 2016: 271 (Transfer from *Phintella*).

Material examined: INDIA: 12 , 5 (CATE, 8412A), Kerala, Wayanad Wildlife Sanctuary, Bathery range (11°42´09.8″N, 76°20´39.6″E). 868 m a.s.l., 12.06.2015, P.P. Sudhin & K.S. Nafin; 9 , 4 (CATE 8412B), same range (11°42´01.7″N, 76°20´28.1″E), 866 m a.s.l., 12.06.2015, P.P. Sudhin & K.S. Nafin; 1 ♀(CATE,8412C), Kerala, Thrissur, Nedumpal, Konthipulam (10°23´20.2″N 76°14´31.7″E) 2 m a.s.l., 11.10.2016, K.S. Nafin; 1 ♂(NCBS-AR048), Bengaluru, Karnataka, NCBS campus (13°04´15.585″N, 77°34´50. 113″E), 936 m a.s.l., 18.05.2015, R.V. Sanap & J. Caleb; 1 ♀(NCBS-AU141), same locality (13°04´21.4098″N, 77°34´44. 3994″E), 933 m a.s.l., 3.06.2016, R.V. Sanap; 1

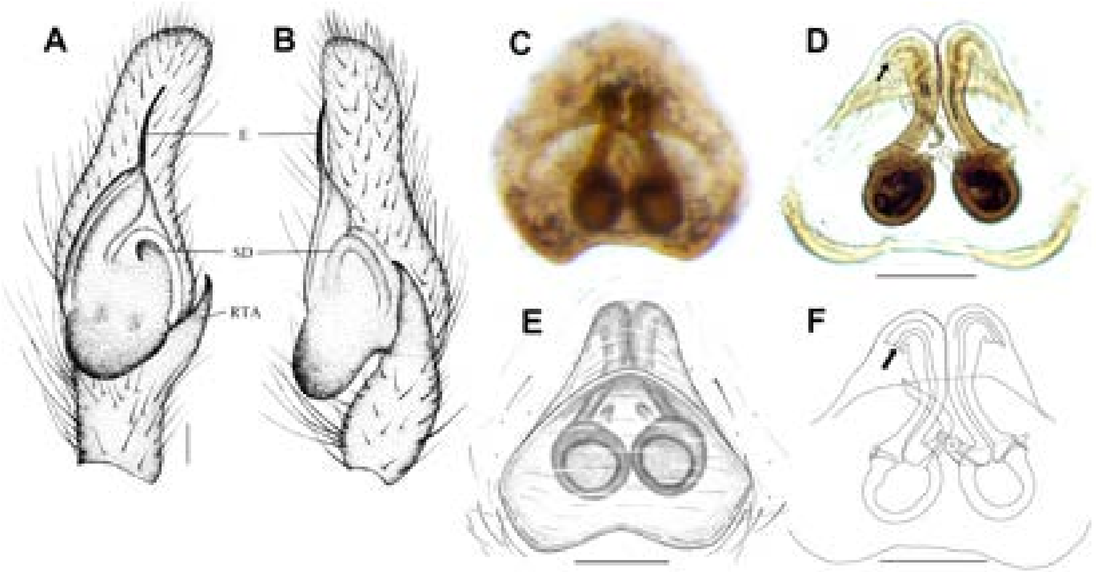

Figure 3.21: Male and female genitalia of *Chrysilla volupe*. Male (**A, C**) and female (**B, C**).**A–B**, carapace, frontal view. **C–D**, chelicerae showing teeth. Scale bars. **A–B**, 1 mm. **C–D**, 0.5 mm.

♂(NCBS-AC756), 3 ♀♀(NCBS-AC757-759), Mumbai, Maharashtra, Aarey milk colony (19°08´32.0″N, 72°52´03.3″E), 37 m a.s.l., 5.07.2017, R.V. Sanap & Imran Udat; 1 ♂(NCBS-AC760), Gujarat, Pariyej Lake, near a bird watch tower (22°32´58.0158″N, 72°37´23.952″E), 16 m a.s.l., 16.06.2017, K.G. Patel.

Diagnosis: Based on somatic morphology and palpal structure, *C. volupe* is closely related to *C. lauta* Thorell, 1887, from which it can be readily distinguished by the following characters: Dorsum with a distinct reddish orange pattern (Figs 1, 3, 5, 7, 9) (Caleb, 2016; Żabka, 1988: fig. 125); proximal protrusion of palpal tegulum sac-like (more elongated and 'U'-shaped in *C. lauta*). *C. volupe* is also similar to *C. guineensis*, but can be distinguished from it by the following characters: distal tip of palpal tegulum wide (narrowing distally in *C. guineensis*); anterior half of the copulatory ducts parallel (sub-parallel in *C. guineensis*); copulatory openings directed laterally (arrowed in Figs 23, 25) (directed anteriorly in *C. guineensis*) (cf. Figs 22–25 with Wesołowska and Wiśniewski, 2013, Figs 8, 9).

Description: MALE. Total length: 5.44; carapace: 2.14 long, 1.76 wide; abdomen: 3.30 long, 1.30 wide. Carapace covered with reddish orange scales; a pair of broad bluish iridescent transverse stripes present, one behind the anterior eye row and the other between PLEs; a broad quadrangular patch present on the posterior slope (Figs 3.19A, C). Anterior eyes surrounded with reddish-orange orbital setae in the upper half and white orbital setae in the lower half; clypeus covered by bluish iridescent scales which diverge laterally, one branching below the lateral eyes almost reaching the posterior patch, the other runs along outer edge of the carapace. Eye measurements: AME 0.46, ALE 0.27, PME 0.09, PLE 0.26, AER 1.61, PER 1.73, EFL 1.13; AME–AME 0.02, AME–ALE 0.04, ALE–PME 0.38, PME–PME 1.45, PME–PLE 0.21, PLE–PLE 1.38. Clypeus height 0.15. Sternum oval, brownish covered with iridescent scales. Chelicerae unidentate, reddish brown (Fig. 3.20C); labium and maxillae brownish. Measurements of legs as in table 3.5. Leg I robust, black; legs II–III yellow; tarsi II–IV white; leg IV with dark brown femur and blackish annulation at joints of each segment, tarsus with blackish proximal half; all legs covered with iridescent scales reflecting metallic shades of golden and purplish tinge (Figs 3.19A, C). Leg formula: 1423. Abdomen elongate and narrow; covered with fine iridescent hairs; reddish orange scales present mid-dorsally, forming a M-shaped patch resting on a broad transverse patch below. Spinnerets blackish.

Palp. Femur, patella, tibia and the proximal half of cymbium black, dorsally covered with iridescent scales reflecting bluish tinge; cymbium apically yellow; embolus needle-like, arising at 12 o´clock position; proximal protrusion of palpal tegulum sac-like; tegular bump present retrolaterally; RTA long with broad base narrowing toward the tip, curving ventrad (Figs 3.21A, B).

Table 3.5: *Chrysilla volupe.* Measurements of legs and palp

Male	**Leg segments**	**I**	**II**	**III**	**IV**	**Palp**
	Femur	1.97	1.38	1.35	1.70	0.73
	Patella	1.05	0.72	0.59	0.66	0.27
	Tibia	1.46	1.98	0.86	1.28	0.23
	Metatarsus	1.11	0.83	1.01	1.61	–
	Tarsus	0.61	0.48	0.55	0.57	0.64
	Total	6.20	4.39	4.36	5.82	1.87
Female	**Leg segments**	**I**	**II**	**III**	**IV**	**Palp**
	Femur	0.66	0.60	0.63	0.85	–
	Patella	0.41	0.32	0.31	0.34	–
	Tibia	0.48	0.37	0.37	0.57	–
	Metatarsus	0.36	0.33	0.45	0.67	–
	Tarsus	0.23	0.20	0.23	0.30	–
	Total	2.14	1.82	1.99	2.73	–

FEMALE. Total length: 2.61; carapace: 1.10 long, 0.86 wide; abdomen: 1.51 long, 0.88 wide. Eye measurements: AME 0.26, ALE 0.15, PME 0.17, PLE 0.30, AER 0.82, PER 0.88, EFL 0.56; AME–AME 0.01, AME–ALE 0.01, ALE–PME 0.20, PME–PME 0.72, PME–PLE 0.12, PLE–PLE 0.69. Clypeus height 0.04. Leg formula: 4132.

Colour pattern as in the male, but differs as follows: carapace covered with greyish scales dorsally and devoid of bluish stripes laterally; carapace rim outlined by white scales (Figs 3.19B, D); clypeus uniformly covered with reddish orange scales. Anterior eyes with grey eyebrows (Fig. 3.20B). Measurements of legs as in table 3.5. All legs yellowish; leg IV with dark annulations near the joints of femur, patella and tibia. Epigyne with the closely positioned copulatory openings, facing laterally, situated under a wide anterior flap; posterior margin sclerotized, wide W-shaped; copulatory ducts long, anterior half of the copulatory ducts parallel; spermathecae spherical, contiguous (Figs 3.21C–F).

Distribution: Sri Lanka; Bhutan; India (Tamil Nadu, Kerala, Karnataka, Maharashtra, Gujarat, Uttarakhand). Caleb, Christudhas, et al., 2014 erroneously mentioned Burma instead of Bhutan in the species distribution.

3.3.26.8 *COCALUS* C. L. Koch 1846

Cocalus is a less species-rich genus distributed in the Oriental and Australian regions (World Spider Catalog, 2021). The genus is represented by 6 nominal species globally, with two species known from India (World Spider Catalog, 2021).

Diagnosis: *Cocalus* species can be distinguished from other salticids by the following combination of characters: Presence of an elevation in the posterior ocular quadrangle in both sexes and the sinuous finger-like projection resting on the male palpal retrolateral tibial apophysis (Wanless, 1981).

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

Species sampled from the Muriyad Kol Wetland.

Cocalus lacinia sp. nov.

(Figs 3.19A, B, 3.23A–H, 3.24A–E)

Types: Holotype ♂(CATE, 8402A) from India, Kerala, Wayanad Wildlife Sanctuary (11°45´27.6″N, 76°14´50.5″E), , Kurichiad Range, Wayanad District, 916 m a.s.l., 10.06.2015, P.P. Sudhin & K.S. Nafin. **Paratypes:** 1 ♀(CATE, 8402B), the same locality (11°45´56.3″N, 76°14´57.9″E), 842 m a.s.l., 9.06.2015, P.P. Sudhin & K.S. Nafin.

Other material: 1 ♂, 1 ♀(CATE 8402C), Kerala, Thrissur, Parappukkara, Thottippal (10°24´22.2″N 76°15´10.8″E), 3 m a.s.l., from foliage by hand, 08–11.2016, K S. Nafin.

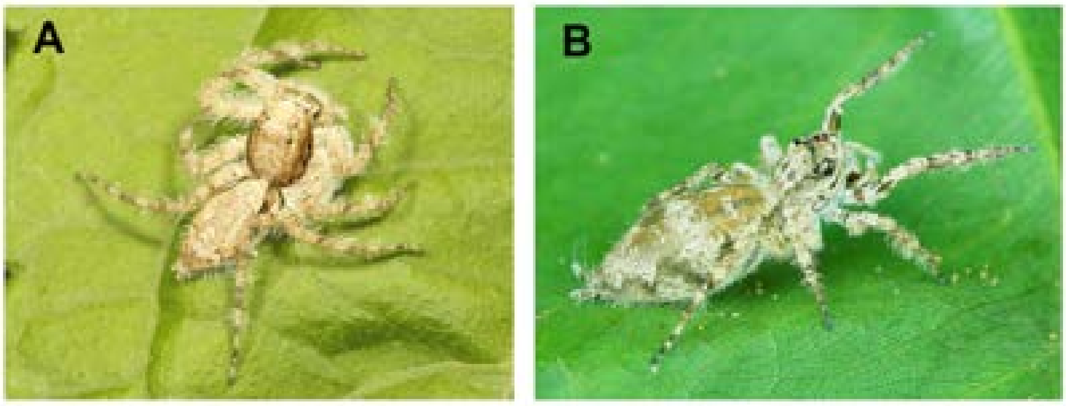

Figure 3.22: Live images of *Cocalus lacinia* sp. nov. **A**, male holotype. **B**, female paratype.

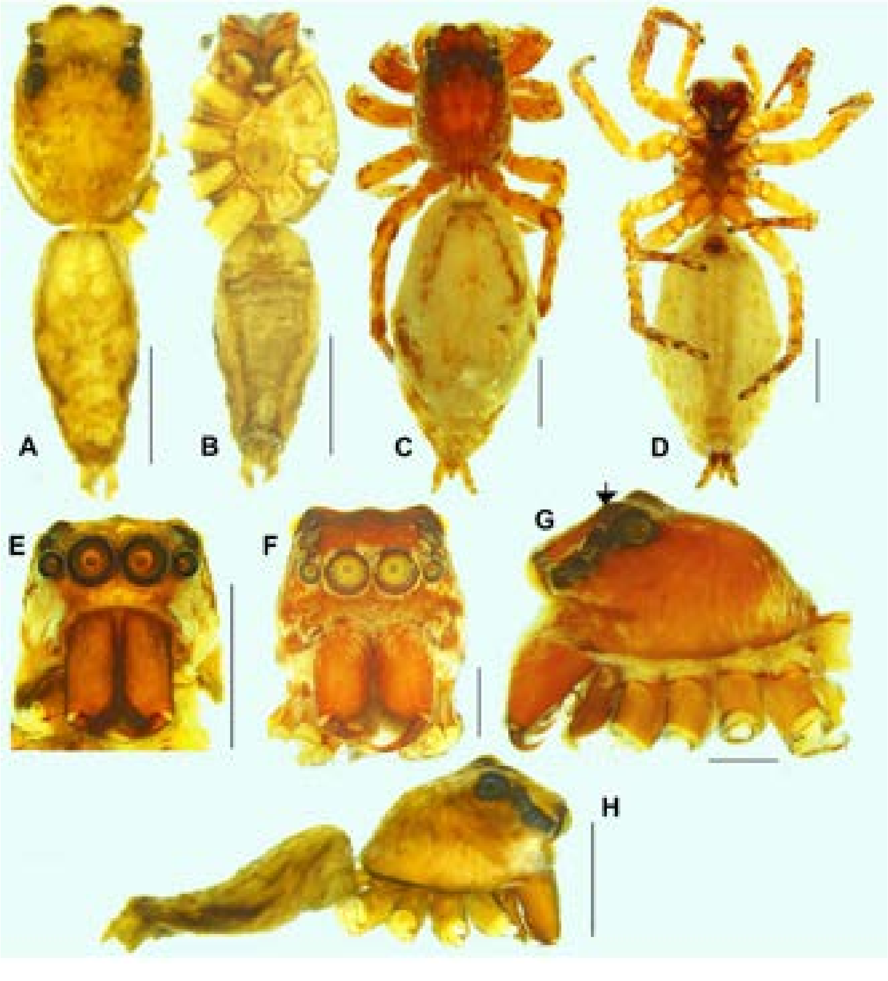

Figure 3.23: Holotype male and female of *Cocalus lacinia* sp. nov. Holotype male (**A, B, E, H**) and paratype female (**C, D, F, G**). **A, C**, general appearance, dorsal view. **B, D**, same, ventral view. **E, F**, capapace, frontal view. **G**, same, lateral view. **H**, body, lateral view. Scale bars. **A–E, H**, 2 mm. **F, G**, 1 mm.

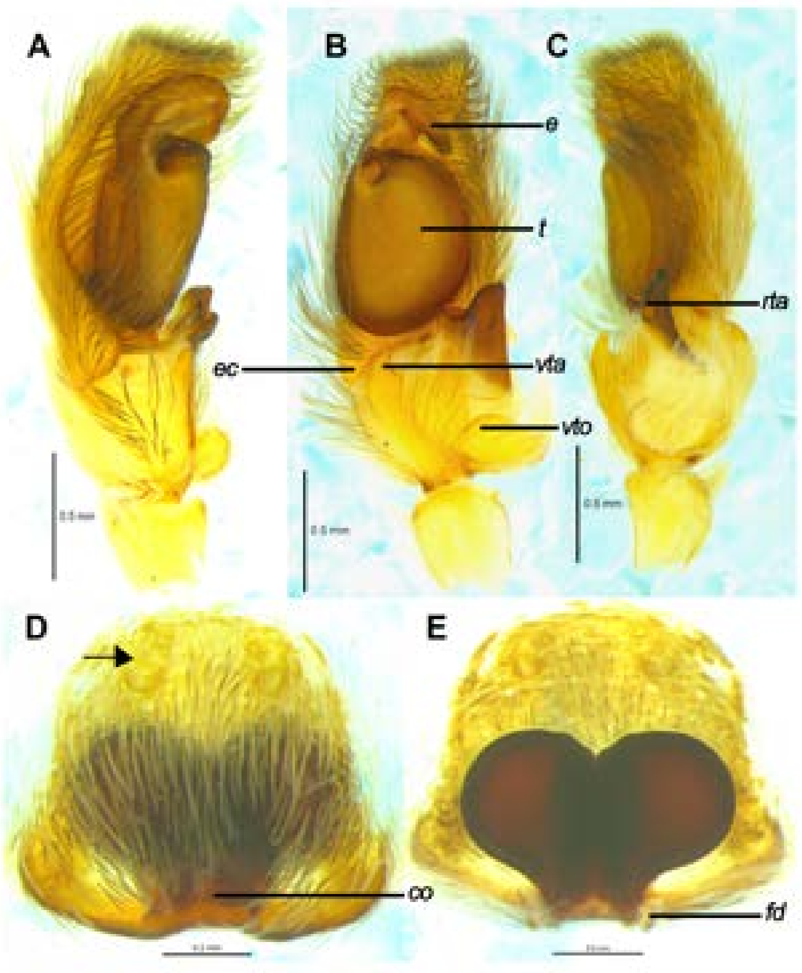

Figure 3.24: Genitalia of *Cocalus lacinia* sp. nov. **A**, male left palp, prolateral view. **B**, same, ventral view. **C**, same, retrolateral view. **D**, epigyne, ventral view. **E**, vulva, dorsal view. Scale bars. **A–C**, 0.5 mm. **D, E**, 0.2 mm.

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

Diagnosis: The male of *C. lacinia* sp. nov. is similar to that of *C. gibbosus* Wanless, 1981 from Australia (Queensland), but differs from it in the following combination of characters: the embolus is positioned almost vertically at the distal end of the tegulum (slightly shifted retrolaterally in *C. gibbosus*); the VTA thumb-shaped, with a sub-acute tip (more stout and truncate in *C. gibbosus*); the palpal tibia basally with a flap-like ventral outgrowth (which is absent from *C. gibbosus*). The female of *C. lacinia* sp. nov. is closest to that of *C. menglaensis* Cao, Li & Żabka, 2016 from China (Yunnan), but can be distinguished by the following characters: the abdomen elongated and robust (slightly shorter and linear

Table 3.6: *Cocalus lacinia* sp. nov. Measurements of legs and palp

Male	**Leg segments**	**I**	**II**	**III**	**IV**	**Palp**
	Femur	2.14	2.41	1.96	2.48	0.84
	Patella	1.2	1.09	0.78	1.05	0.59
	Tibia	2.28	2.69	1.76	2.24	0.52
	Metatarsus	2.28	2.29	1.63	2.42	–
	Tarsus	1.01	1.01	0.87	1.04	1.17
	Total	8.51	9.49	7	9.23	3.12
Female	**Leg segments**	**I**	**II**	**III**	**IV**	**Palp**
	Femur	2.28	2.21	2.21	2.72	–
	Patella	1.30	1.21	0.83	1.19	–
	Tibia	2.18	1.99	1.88	2.43	–
	Metatarsus	1.49	1.44	1.40	2.68	–
	Tarsus	0.86	0.88	0.68	1.01	–
	Total	8.11	7.73	7	10.03	–

in *C. menglaensis*); the epigynal plate without prominent posterior projections (prominent, heavily sclerotized and rectangular in *C. menglaensis*); the copulatory openings are located posteriorly (slightly below the middle area in *C. menglaensis*); the spermathecae globular, with a posterior triangular extension (phaseoliform, without posterior triangular extension in *C. menglaensis*) (cf. Figs 3.23C, D, 3.24B D, E with Figs 4C–D in Wanless ,1981, Fig. 4 in Davies and Żabka, 1989, and Figs 18 A–B, D–E in Cao et al., 2016).

Description: MALE holotype (Holotype; Figs 3.19A, 3.23A, B, E, H, 3.24A–C). Measurements: body length 8.32. Carapace length 3.62, width (at the middle) 2.47, height at PLE 1.79. Abdomen length 4.41, width (at the middle) 1.81. Ocular area length 1.81, width 2.02. Eye diameters: AME 0.59, ALE 0.29, PME 0.16, PLE 0.31. Eye interdistances: AME–ALE 0.08, PME–PME 1.64, ALE–ALE 1.34, PME–PLE 0.47, PLE–PLE 1.64, ALE–PME 0.48. Clypeus height 0.32. Length of chelicera 1.01. Leg formula: 2413. Spination. Palp: femur rl 1, do 2, pl 1; tarsus rl 1 pl 1; Legs: femur I–II rl 1 do 3 pl 2, III–IV rl 1 do 3 pl 2; patellae I–IV rl 1 pl 1; tibia I–II rl 3 rlv 3 do 3 pl 3 plv 3, III–IV rl 3 rlv 3 do 2 pl 3 plv 3; metatarsi I–II rl 3 rlv 2 do 1 pl 2 plv 1 v 1, III–IV rl 3 rlv 2 do 1 pl 3 plv 2 v 1; tarsi I–IV spineless. Carapace light yellowish brown, covered with white, brown and black setae, laterally with a white band extending from ALE to the rear end, narrowing towards it; carapace margins with a row of small black hairs (Figs 3.23A, H); eye field covered with chocolate white hairs; fovea light reddish brown, situated just behind PLEs (Fig. 3.23A); clypeus low, vertical, covered with long white setae (Fig. 3.23E); chelicerae light reddish brown, sub-vertical, frontal face with brown and white hairs (Fig. 3.23E), pro- and retromargins with three teeth, fangs medium-sized, reddish brown; endites yellowish brown, with dull white inner tips and dark grey hairs on inner margin, margin of endites with narrow dark brown lines (Fig. 3.23B). Labium light brown, scopulate, with a dull white tip. Sternum almost oval, yellowish brown, covered with brown and white hairs (Fig. 3.23B). Pedicel light yellowish, with reddish-brown lateral stripes (Figs 3.23A, H). Abdomen pale yellow, ovoid, posteriorly narrowing, covered with black and white hairs, dorsally with irregular light brown transverse patches, laterally with continuous irregular black stripes (Figs 3.23A, H). Venter yellowish brown, covered with numerous brown hairs, its posterior tip with dense white hairs (Figs 3.23B). Spinnerets yellowish brown, covered with dark brown hairs. Legs yellow, covered with hairs, setae and spines, all trochanters with a row of prolateral and retrolateral black setae, tarsal claw with eleven teeth.

Palp as shown in Figs 3.24A–C. Palp moderately long, pale yellowish, densely covered with hairs; tibia base with a flap-like ventral outgrowth, which is retrolaterally oriented; VTA thumb like, wide at the base, with sub-acute tip (Figs 3.24B: vto); RTA dark reddish brown, with wide sinuous edge; cymbium broad, moderately long, distally truncate, with posterior triangular extension (Figs 3.24B: ec); tegulum ovoid, light brown with tegular furrow, retrolateral striae and dark reddish brown peripheral seminal duct; embolus robust, hook-shaped, with the pointed tip curving inwards, towards the alveolar cavity.

FEMALE (Paratype, Figs 3.19B, 3.23C, D, F, G, 3.24D, E). Measurements: body length 12.71. Carapace length 3.88, width (at the middle) 2.83, height at PLE 2.25. Abdomen length 8.34, width (at the middle) 4.01. Ocular area length 1.72, width 2.21. Eye diameters: AME 0.66, ALE 0.33, PME 0.22, PLE 0.32. Eye interdistances: AME–ALE 0.09, PME–PME 1.73, ALE–ALE 1.47, PME–PLE 0.32, PLE–PLE 1.88, ALE–PME 0.31. Clypeus height 0.35. Length of chelicera 1.51. Spination. Palp: femur rl 1 do 2 pl 1, tibia rl 1, tarsus rl 2 rlv 1 pl 1 plv 1 v 1; Legs: femur I–II rl 3 do 3 pl 2, III–IV rl 2 do 2 pl 3; patellae I–IV rl 1 pl 1; tibia I–II rl 3 rlv 3 do 3 pl 3 plv 3, III–IV rl 3, rlv 3 do 2 pl 3 plv 3; metatarsi I–II rl 3 rlv 1 do 1 pl 3 plv 1, III–IV rl 2 rlv 2 do 1 pl 2 plv 2 v 1; tarsi I–IV spineless. In all respects as the male, except as follows: Carapace light reddish brown, covered with white setae, more elongate and oppressed in the ocular quadrangle, margin of carapace with narrow dark reddish brown lines, region around the posterior quadrangle with a wide inverted V-shaped black mottling (Fig. 3.23C); posterior ocular quadrangle elevation more prominent (arrowed in Fig. 3.23G); fovea distinct, longitudinal, dark reddish-brown; clypeus light reddish brown, densely covered with white hairs (Fig. 3.23F); chelicerae reddish brown, promargin with three teeth and retromargin with four teeth; labium dark brown, maxillae and sternum light brown (Fig. 3.23D). Abdomen more elongated, slightly robust, pale yellow, covered with white and brown setae, dorsally with a median light brown longitudinal stripe terminating at the middle, laterally with continuous irregular similar coloured stripes (Fig. 3.23C). Venter pale yellow, medially with three longitudinal light greyish brown stripes and four longitudinal light brown dot lines (Fig. 3.23D). Anterior and median spinnerets light yellowish brown, posterior spinnerets light brown.

Epigyne as shown in Figs 3.24D, E. Epigyne bell-shaped, golden-light brown, covered with long creamy hairs, posterior borderline with a median invagination, anteriorly with a pair of kidney-shaped thickenings (arrowed in Fig. 3.24D); copulatory openings at the lateral margins of the posterior triangular groove (Fig. 3.24, E: co); spermathecae massive, globular, dark reddish brown, compact, with posterior triangular extension; insemination duct short, entering the spermathecae midventrally; fertilization duct short, anterolaterally oriented, located at the posterior tip of the spermathecae.

Natural history: Specimens were collected from barks of trees from the riparian habitats of Muriyad Kol wetlands and the bark of *Tectona grandis* (Lamiaceae) in the Teak plantation of the Wayanad Wildlife Sanctuary.

Distribution: India: Kerala (Wayanad, Thrissur, Ernakulam districts).

3.3.26.9 *CURUBIS* Simon, 1902

Curubis is a less species-rich genus, which is endemic to India and Sri Lanka (World Spider Catalog, 2021). The genus comprises of 4 nominal species, including 3 species from India (World Spider Catalog, 2021).

Diagnosis: *Curubis* species can be distinguished from *Echeclus* by the following combination of characters: less prominent proximal tegular lobe, epigyne with a caudal lobe and S-shaped spermathecae with a median U-like plate (Sankaran, Malamel, et al., 2019).

Type species: *Curubis erratica* Simon, 1902

Species sampled from the Muriyad Kol Wetland.

Curubis tetrica Thorell, 1895

Curubis tetrica Simon, 1902: 373 (♂); Samson and Sebastian, 2013: 695, pl. 1, Figs a–g (♂); Sankaran, Malamel, et al., 20199: 8, Figs 5a–h, 6a–d, 7a–h, 8a–h (♂♀).
(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Curubis tetrica* found in wooded habitats in the study area.

3.3.26.10 ***EPEUS*** Peckham & Peckham, 1886

Epeus is a less species-rich genus which is geographically restricted to the Oriental region (World Spider Catalog, 2021). The genus currently comprises 19 nominal species, including 4 species from India (World Spider Catalog, 2021).

Diagnosis: Species of the Oriental genus *Epeus* have flattened and elongated cymbium in the male palp, with a retrolateral basal apophysis pointing postero-ventrad; the tegulum with a tongue-like process; the filiform embolus; and the epigyne with the long copulatory ducts having several loops (Meng et al., 2015).

Type species: *Epeus tener* (Simon, 1877)

Table 3.7: *Epeus triangulopalpis* sp. nov. Measurements of legs and palp

Male	**Leg segments**	**I**	**II**	**III**	**IV**	**Palp**
	Femur	1.60	1.75	2.22	1.63	0.73
	Patella	0.62	0.51	0.62	0.56	0.27
	Tibia	1.37	1.4	1.5	1.34	0.23
	Metatarsus	1.10	1.21	1.6	1.5	–
	Tarsus	0.65	0.5	0.6	0.62	0.64
	Total	5.34	5.37	6.54	5.65	1.87
Female	**Leg segments**	**I**	**II**	**III**	**IV**	**Palp**
	Femur	2.04	2.27	2.56	1.94	–
	Patella	0.82	0.93	0.9	0.72	–
	Tibia	1.74	1.76	1.6	1.6	–
	Metatarsus	1.60	1.4	2.07	1.69	–
	Tarsus	0.71	0.73	0.75	0.62	–
	Total	6.91	7.09	7.78	6.57	–

Species sampled from the Muriyad Kol Wetland.

Epeus triangulopalpis **sp. nov.**

(Figs 3.25A–D, 3.26 A–F, 3.27 A–G, 3.28 and 3.29 A–D)

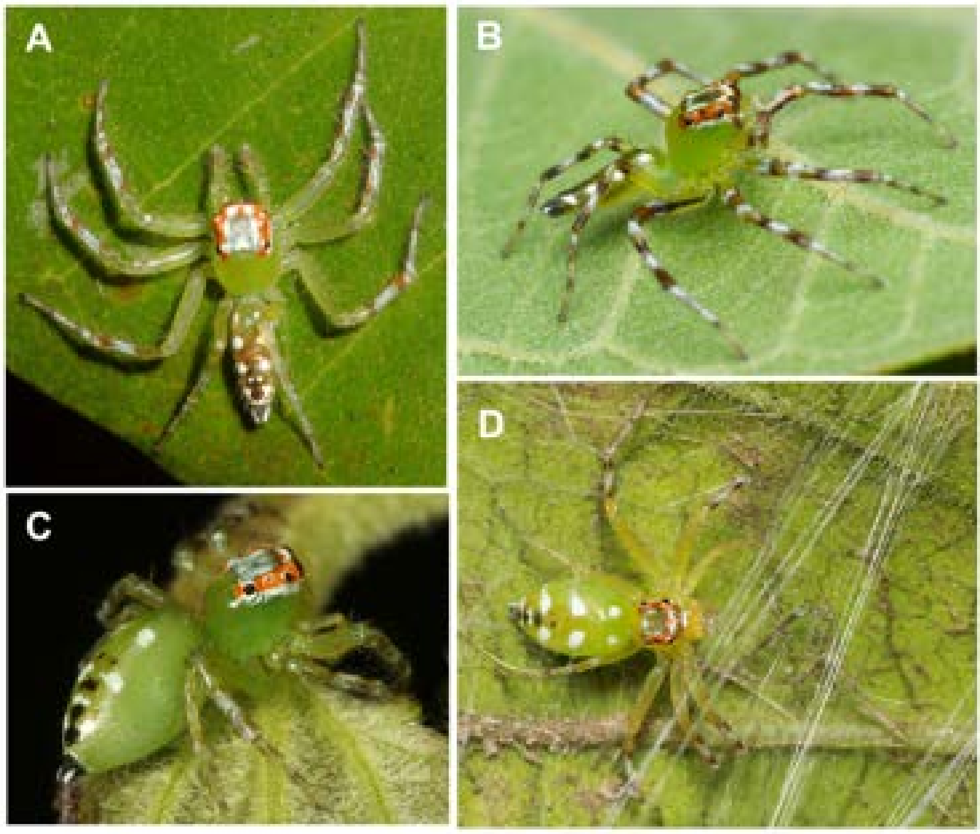

Figure 3.25: Live images of *Epeus triangulopalpis* sp. nov. **A–B**, male. **C–D**, female. Photo **B** used with permission from Atul Varthak. Scale bars. **A–C**, 1 mm.

Types: Holotype ♂(ADSH, 86164A) from India, Kerala, Pathiramanal Island (9°37´07.11″N, 76°23´04.95″E), 4 m a.s.l., 22.08.2015, M.J. Jobi & P. Jimmy. **Paratypes:** 1 ♂(ADSH 8716616A), the same locality as that of the holotype, 11.10.2015, M.J. Jobi & P. Jimmy; 1 ♂, 1 ♀(CATE 8704A), Kerala, Irinjalakuda, Christ college (10°21´28″N, 76°12´47″E), 15 m a.s.l., from foliage by hand, 09–10.2015, A.V. Sudhikumar & K S. Nafin.

Other material: INDIA: 1 ♀(CATE 8704B), Kerala, Bathery Range, Wayanad Wildlife Sanctuary (11°40´48.3″N, 76°20´38.1″E), 850 m a.s.l., from foliage by hand, 17.06.2015, P.P. Sudhin & K.S. Nafin; 1 ♂(CATE 8704C), Kerala, Parambikulam Tiger Reserve, Parambikulam (10°23´53.3″N, 76°46´29.3″E), 585 m a.s.l., from foliage by hand, 22.09.2014, K.S. Nafin, P.P. Sudhin & P.Jimmy; 1 ♀(ADSH 8716616B), Kerala, Pathiramanal Island (9°37´07.11″N, 76°23´04.95″E), 4 m a.s.l., 17.01.2018, Jithin & Aneesh.

Etymology: The specific name refers to the fact that the new species has the triangular cymbial apophysis.

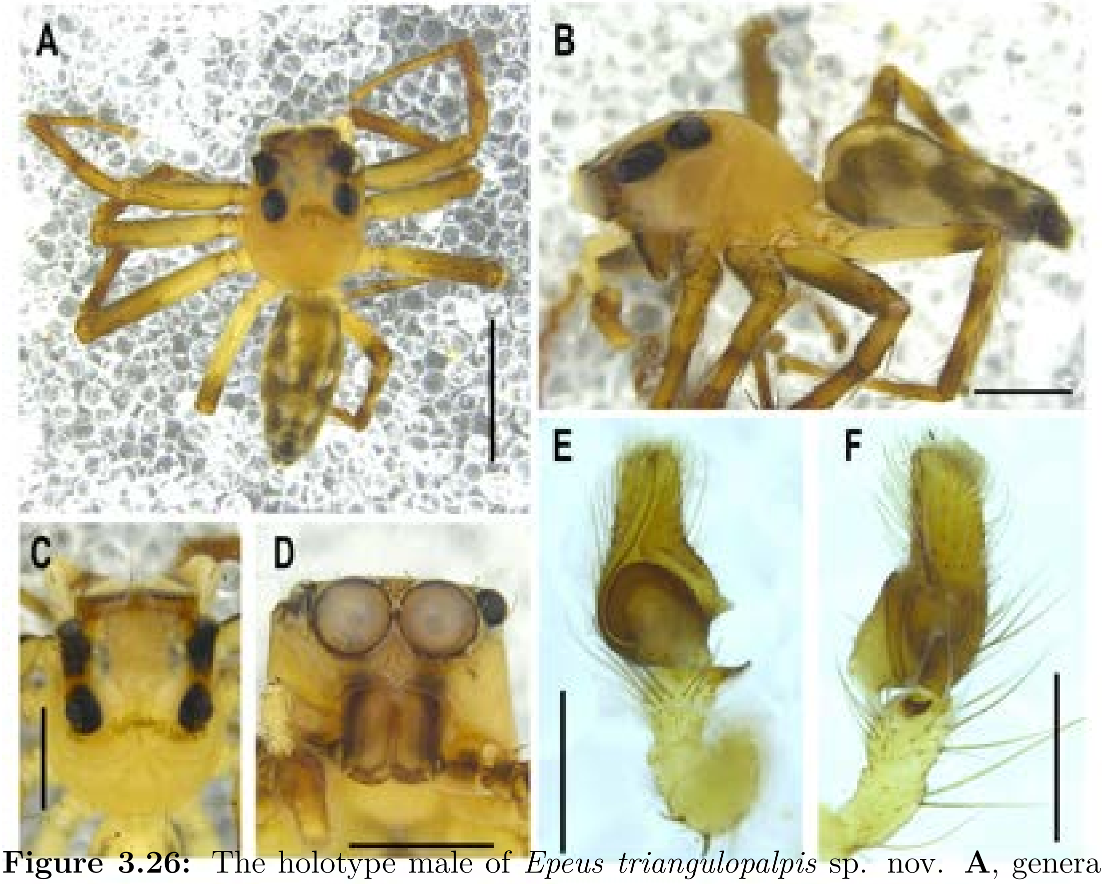

Figure 3.26: The holotype male of *Epeus triangulopalpis* sp. nov. **A**, general appearance, dorsal view. **B**, same, lateral view. **C**, carapace, dorsal view. **D**, same, frontal view. **E**, palp, ventral view. **F**, same, retrolateral view. Scale bars. **A–B**, 2 mm. **C–D**, 1 mm. **E–F**, 0.5 mm.

Diagnosis: The new species can be easily distinguished from its closest congener, *E. alboguttatus*, and all other Indian species by the following characters: the eye field in the males without a conical comb of long upright setae (a prominent comb of orange upright setae in *E. alboguttatus*); dorsum with four pairs of distinct white markings (a median dark grey streak in *E. alboguttatus*); the palpal cymbial apophysis triangular, directed laterad (markedly shorter and directed posteriad in *E. alboguttatus*); the insemination ducts form large lateral loops (such loops are absent from *E. alboguttatus*) (cf.Figs 3.26 A–F, 3.27 A–G, 3.28A–D with Figs 109–114, 116–120 in Żabka, 1985).

Description: MALE holotype (Figs 3.26 A–F, 3.28A–B). Measurements. Body length: 4.6. Carapace: 2.0 long, 1.8 wide, 1.2 height. Abdomen: 2.6 long, 1.1 wide, 0.8 height. Clypeus: 0.5 height. Chelicerae: 1.5 long. Eyes diameters: AME 0.51. ALE 0.19. PME 0.08. PLE 0.35. Eye interdistances: AME–AME 0.11. AME–ALE 0.18. PME–PLE 0.24. PME–PME 1.82. AME–PME 0.50.

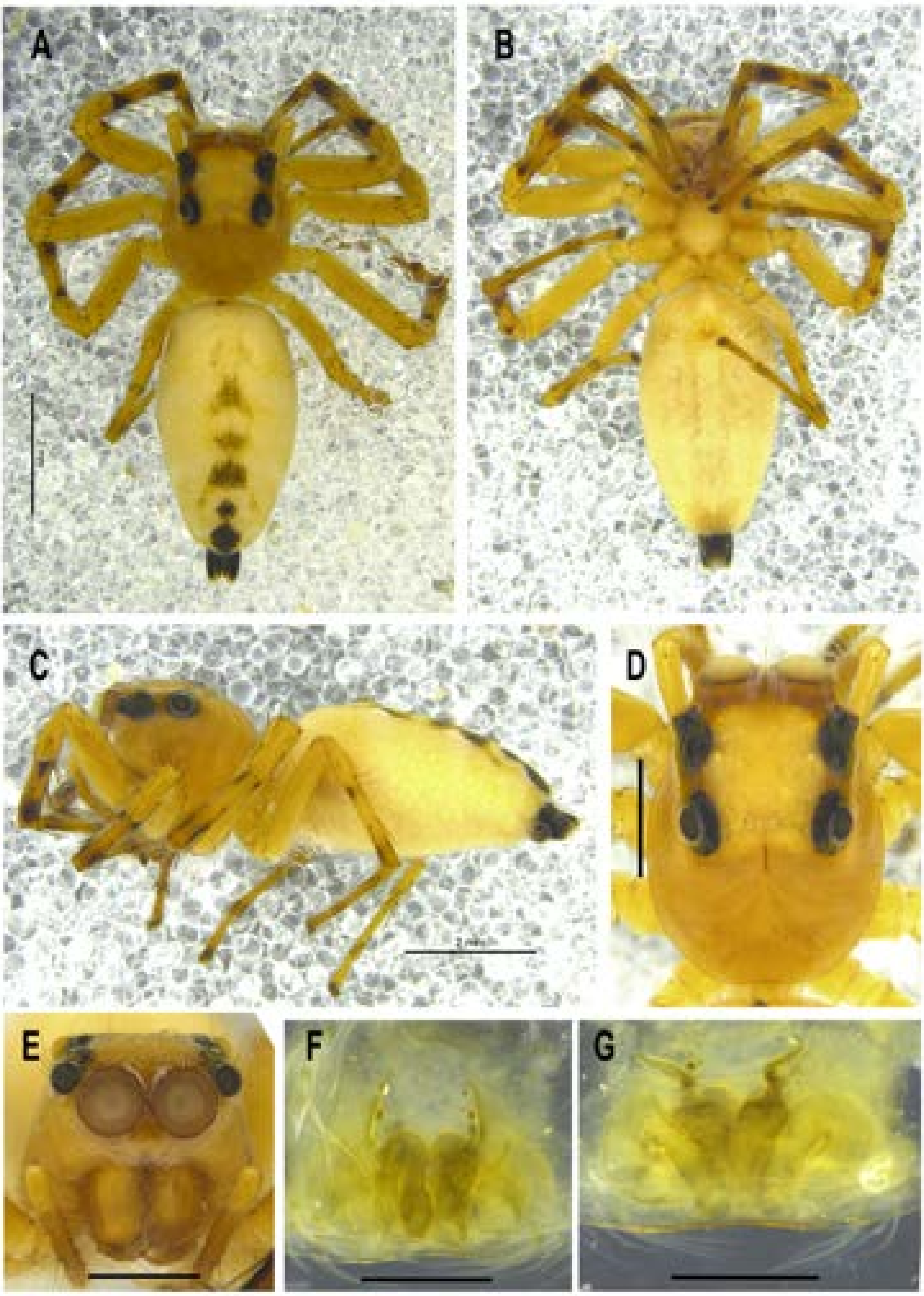

Figure 3.27: Female paratype of *Epeus triangulopalpis* sp. nov. **A**, general appearance, dorsal view. **B**, same, ventral view. **C**, same, lateral view. **D**, Carapace, dorsal view. **E**, same, frontal view. **F**, epigyne, ventral view. **G**, vulva, dorsal view. Scale bars. **A–C**, 2 mm. **D–E**, 1 mm. **F–G**, 0.1 mm.

Carapace pale yellow-brown, covered with colourless setae; head pale, with white mottling, adorned with lustrous white scales. Eye field covered with red-orange scales, starting from dorsolateral AMEs to some extend behind PLEs, flanked by a band of white scales laterally, posteriorly with a thin transverse band of greenish yellow scales bend anteriorly, AME rims dark brown, encircled by predominantly white setae and red orange setae in the region between AMEs and ALEs and below AMEs, the area behind ALEs black, PME situated almost on the edge of the black area, the region around PLEs black, thin band of white scales surrounds ALEs and PLEs on lateral sides. Clypeus covered with white scales in the middle, the mid-lower margin with long white setae, with two vertical black markings continuous with those of chelicerae, covered with black scales, the area beneath AMEs covered with reddish orange scales. Sternum sub-pentagonal, pale yellow-brown, covered with colourless setae. Endites and labium yellowish red-brown, endites with black margins. Chelicerae slender and vertical, yellow-brown with black vertical markings; promargin with two teeth and retromargin with one tooth. Legs long and slender, banded with white and red-orange scales, coxae and most of the femora pale yellow-brown, apical regions of femora yellow-brown, tibiae, metatarsi and tarsi of legs I, II & III yellow-brown and that of leg IV paler than the rest, legs covered with colourless and black setae, femora I–III with black longitudinal bands on their prolateral sides, such band is absent from femur IV, distal half of prolateral sides of femora I & II covered with reddish orange and white scales, proximal and distal parts of tibiae and metatarsi I–III darker, covered with black setae and red-orange scales. Tibia I & II with three pairs of ventral spines and metatarsi I & II with two pairs of ventral spines. Abdomen cylindrical, yellow-brown, dorsum adorned with greenish yellow and black scales, covered with long setae, margins with four pairs of white spots made of white scales, the space between the markings black, also covered with dark scales; the posterior midline with three indistinct black patches; venter pale yellow-brown, with longitudinal black mottling. Anterior lateral spinnerets and posterior lateral spinnerets black, the rest of the spinnerets yellow-brown and covered with white scales.

Palp as shown in Figs 3.26 E–F, 3.28A–B. palp pale yellow, except for yellowish brown cymbium; retrolateral tibial apophysis long and comma-like, apically bent anteriad, its tip pointed retro-laterad; cymbial apophysis triangular, projecting laterad; the posterior part of tegulum elevated, with a pooly visible tongue-like flap and drawn back ventro-retrolaterad over the tibia; embolus filiform, originates at eight o'clock and extends to the distal end of cymbium.

FEMALE paratype (Figs 3.27A–G, 3.28C–D). Measurements. Body length: 6.4. Carapace: 2.2 long, 2.7 wide, 1.4 height. Abdomen; 4.2 long, 1.6 wide, 1.5 height. Clypeus: 0.6 height. Chelicerae: 1.8 long. Eyes diameters: AME 0.58. ALE 0.27. PME 0.10. PLE 0.2. Eye interdistances: AME–AME 0.14. AME–ALE 0.22. PME–PLE 0.27. PME–PME 1.4. AME–PME 0.61.

Carapace yellow-orange, covered with colourless setae, head light yellow-orange. Eye field covered with red-orange scales, starting from dorsolateral AMEs to some extend behind PLEs, it is flanked by white scales on the lateral sides, AME borders reddish brown, encircled by white setae except on the dorsolateral and lower AME–AME giving it an eyebrow-like appearance; the area around ALEs black, PMEs situated almost on the edge of the black area, the region around PLEs black, thin band of white scales surrounds ALEs and PLEs on the lateral sides; the posterior part of the head with an indistinct transverse band of white scales. Clypeus covered with white setae, its upper-mid region adorned with red orange scales and long setae. Sternum yellow orange, sub-pentagonal. Labium red-orange, endites light red-orange. Chelicerae yellow-orange. Femora and patellae of legs I–IV yellow-orange, femora I & II with a prolateral black spot on their distal ends, tibiae, metatarsi and tarsi of legs I–III yellow-brown and that of leg IV light yellow-brown, white scales present on tibiae, metatarsi & tarsi I–III, basal and the apical parts of tibiae and metatarsi I & II lateral black spots, black spots present only on tibiae III & IV and is absent from the retrolateral side of the basal tibia. Tibiae I & II with three pairs of ventral spines and metatarsi I & II with two pairs of ventral spines. Palpal femur and patella yellow-orange, the remaining segments yellow-brown. Abdomen oblong, pale yellow, posteriorly with two distinct and three indistinct black markings, marginally with four pairs of white markings made of white scales, yellow scales are present in the region around the black markings and between the white markings. Spinnerets long and black, anterior lateral and posterior lateral spinnerets with white scales.

Epigyne and spermathecae as shown in Figs 3.27F, G. The sclerotised rim of the epigynal opening in the anterior half of the epigyne; no epigynal pockets; insemination duct large, forming a large loop laterally, posteriorly entering and forming an elongated loop and finally entering the receptacles posteriorly.

Habitus of live specimens: (Figs 3.25A–D) Live specimens of both sexes are very colourful, having a yellowish green colour. The eye field laterally bordered by red-orange bands, which are flanked by white scales on their sides, and with a white trianglular patch on the clypeus; the upper and lower regions of the eyes

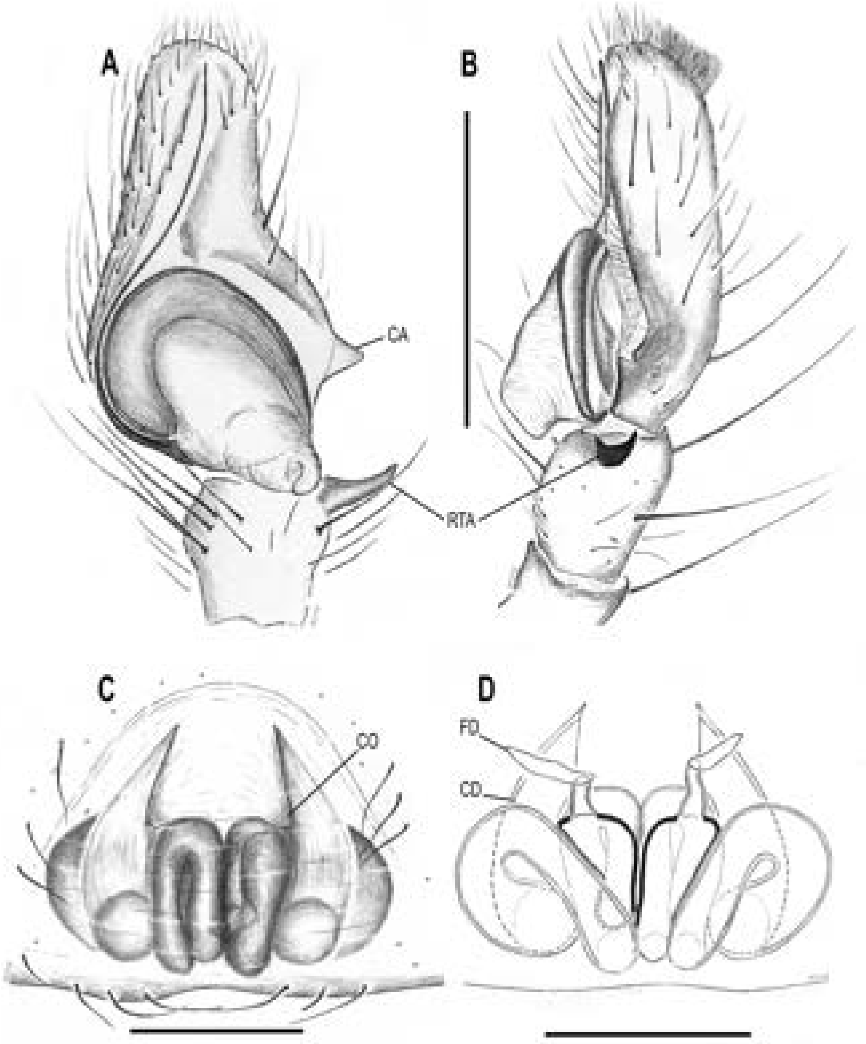

Figure 3.28: Copulatory organs of *Epeus triangulopalpis* sp. nov. Holotype male (**A–B**) and paratype female (**C–D**). **A**, male palp, ventral view. **B**, same, retrolateral view. **C**, epigyne, ventral view. **D**, vulva, dorsal view. Scale bars. **A–B**, 0.5 mm. **C–D**, 0.1 mm.

with white scales. All legs with alternative dark red-orange and white bands, the prolateral side of all femora with a black patch. Abdomen with four pairs of prominent white spots. Cymbium of the male palp dark red-orange, with long white hairs anteriorly. All femora and patellae in the female yellowish green, tibiae to tarsi with alternative pale black and white bands. Abdomen possesses five pairs of white patches and four black patches in its posterior half.

Distribution: India: Kerala (Parambikulam, Pathiramanal Island, Irinjalakuda and Wayanad)(Fig. 3.29).

Habitat: *E. triangulopalpis* sp. nov. were collected from foliages of shrubs ands trees.

Natural history: *E. triangulopalpis* sp. nov. were tolerant to human disturbances and commonly occur in various habitats around the wetlands. They construct silken retreats on the surface of leaves covered with sheets of silk.

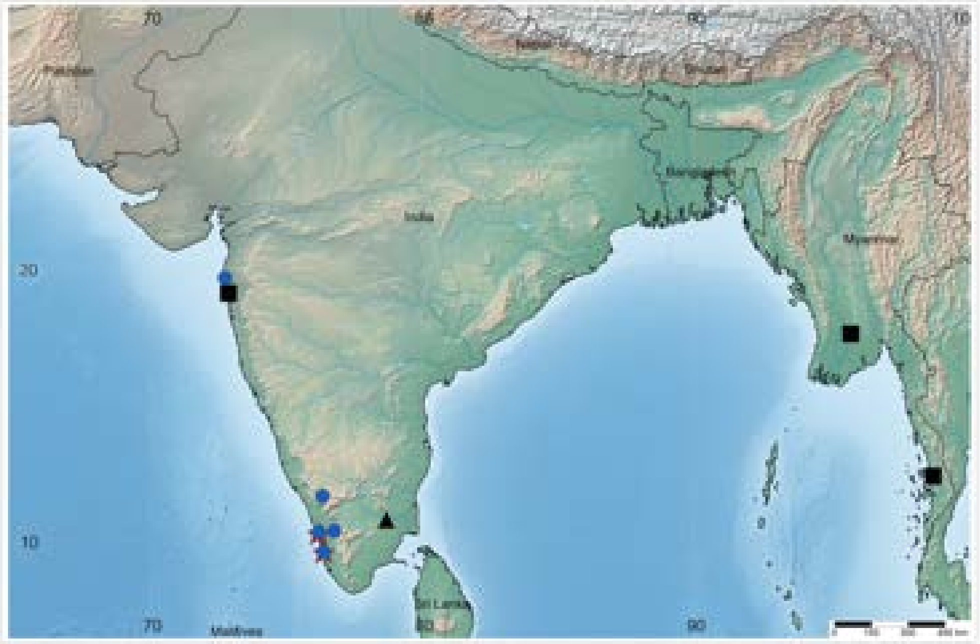

Figure 3.29: Distribution map of *Epeus triangulopalpis* sp. nov. (circle) and all the *Piranthus* species. star—*P. planolancis* sp. nov.; triangle—*P. casteti* Simon, 1900; square—*P. decorus* Thorell, 1895.

Other species sampled:

***Epeus* sp. 1**

3.3.26.11 *EPOCILLA* Thorell, 1887

Epocilla is a less species-rich genus which is distributed in the Oriental region and introduced in Hawaii (World Spider Catalog, 2021). The genus currently comprises 12 nominal species, with 4 species known from India (World Spider Catalog, 2021).

Diagnosis: *Epocilla* species can be distinguished by the following combination of characters: long body with robust legs; males strongly built, with longitudinal orange streaks; male palp with a double RTA, consisting of a flat rounded projection, dorsal and prolateral to which is a more normal, pointed apophysis. In some species, presence of a distinct integumental bump in the ocular area in both males and females, in front of the fovea and between the PLE (Ali et al., 2018).

Type species: *Epocilla praetextata* Thorell, 1887

Species sampled from the Muriyad Kol Wetland.

Epocilla aurantiaca (Simon, 1885)
Fig. 3.A.9B

Opistoncus aurantiacus Simon, 1885: 30 (♀).

Epocilla aurantiaca Simon, 1901a: 555.

(For complete list of references, see World Spider Catalog, 2021)

3.3.26.12 *HYLLUS* C. L. Koch, 1846

Hyllus is a moderately species-rich genus widely distributed in the Oriental and Ethiopian regions (World Spider Catalog, 2021). The genus currently comprises 64 nominal species globally, with 5 species known from India (World Spider Catalog, 2021).

Diagnosis: *Hyllus* species can be distinguished by the following combination of characters: medium to large sized spiders often have horns formed of tufts of long bristles located at the posterior median eyes; cephalothorax broad and rounded and legs with densely covered hairs; epigyne with two pockets near to the epigastric furrow and palp generally with long embolus (Barrion & Litsinger, 1995).

Type species: *Hyllus giganteus* C. L. Koch, 1846

Species sampled from the Muriyad Kol Wetland.

Hyllus semicupreus Simon, 1885
Figs 3.A.9C, 3.A.9D and 3.A.17G

Hyllus semicupreus Simon, 1885: 4, 29, pl. 10, Fig. 1 (♂♀).

Phidippus indicus Tikader, 1974: 122, Figs 5–9 (♂♀).

Hyllus semicupreus Prószyński, 1990: 177.

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *H. semicupreus* were found in foliages and tree trunks in all habitats of the region.

Natural history: *H. semicupreus* or heavy bodied jumper as they are commonly called, are one of the most abundant jumping spiders in the region.

Figure 3.30: Holotype male of *Hyllus kerala* sp. nov. **A**, general appearance, dorsal view. **B**, same, ventral view. **C**, left palp, prolateral view. **D**, same, ventral view. **E**, same, prolateral view. Scale bars. **A–B**, 1 mm. **C–E**, 0.2 mm.

***Hyllus kerala* sp. nov.**

(Figs 3.30A–E)

Types: Holotype ♂(CATE, 8404B) from India, Kerala, Thrissur, Thazhekkad, Edamana padam (10°19´44.9″N 76°16´00.2″E), 7 m a.s.l., from foliage by hand, 08-05-2019, K. S. Nafin. **Paratype.** ♂(CATE, 8404) from the Wayanad Wildlife Sanctuary (11°38´09.7″N, 76°18´39.3″E), Sulthan Bathery Range, Kallumukku, Wayanad District, Kerala, India, 889 m a.s.l., 9.04.2017, P.P. Sudhin & K.S. Nafin.

Etymology: The specific name is a noun in apposition taken from the name of the state where the type locality is situated.

Diagnosis: The male of *Hyllus kerala* sp. nov., is closely similar to *H. manu* Caleb, Christudhas, et al., 2014, but differ from it in the following combination of characters: RTA broad and triangular (basally broad with pointed tip in *H. manu*); tegulum without posterior protrusion (with posterior protrusion in *H. manu*); embolus moderately long, originated prolaterally with distal tip directed at 1 o' clock position (In *H. manu* embolus long, originated ventrally with distal tip directed at 2 o' clock position (cf. Figs 3.30C–E with Figs 7–8 in Caleb, Christudhas, et al., 2014).

Description: MALE (Holotype, Figs 3.30A–E). Measurements: body length 6.36. Carapace length 2.48, width (at the middle) 2.42. Abdomen length 3.54, width (at the middle) 1.85. Eye diameters: AME 0.56, ALE 0.25, PME 0.06, PLE 0.25. Eye interdistances: AME–ALE 0.03, PME–PME 2.10, ALE–ALE 2.11, PME–PLE 0.08, PLE–PLE 2.36, ALE–PME 0.07. Carapace large, slightly wider than long, almost spherical with hairs and setae; carapace dorsally with a patch of black hairs narrowing to the posterior, laterally with patch of white hairs extend from the anterior lateral eyes to meet at the posterior (Fig. 3.30A); ocular area wider than long covered with black setae; AME largest, PME smallest; clypeus strongly covered with white hairs; chelicerae black, robust clothed with hairs; sternum oval clothed with hairs uniformly (Fig. 3.30B). Leg's stout, short, strongly covered with hairs. Abdomen small, posteriorly narrowing clothed with hairs; lateral sides black, medially with a broad white longitudinal band extend from anterior to posterior (Fig. 3.30A). Spinnerets small, covered with black hairs. Palp as shown in Figs 3.30A–C. Palp short, densely covered with hairs; cymbium pale yellowish, broadly triangular with hairs and setae; tegulum round; embolus moderately long, originated prolaterally with distal tip directed at 1 o´clock position; RTA broad and triangular.

Distribution. India: Kerala (Thrissur and Wayanad).

3.3.26.13 *INDOMARENGO* Benjamin, 2004

Indomarengo is a less species-rich genus distributed in the Oriental region (World Spider Catalog, 2021). The genus currently comprises 5 nominal species globally with only one species reported from India (World Spider Catalog, 2021).

Diagnosis: *Indomarengo* species can be distinguished from other Ballinae genera by the S-shaped path of the sperm duct (except for *Leikung* and *Afromarengo*); presence of a prosomal protuberance (except for *Sadies, Leikung* and *Afromarengo*); distinguished from *Leikung* by the presence of tooth on anterior epigynal border, raised PLE, eight spines on tibia I and pits with sensory setae (Benjamin, 2004).

Type species: *Indomarengo sarawakensis* Benjamin, 2004

Species sampled from the Muriyad Kol Wetland.

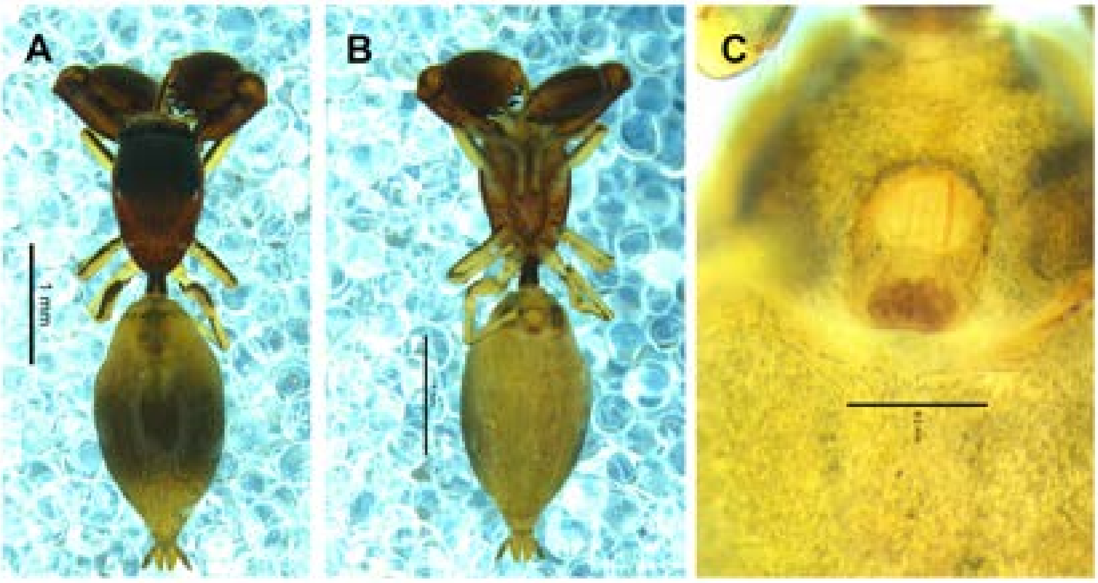

Figure 3.31: Female of *Indomarengo chavarapater*. **A**, general appearance, dorsal view. **B**, same, ventral view. **C**, epigyne, ventral view. Scale bars. **A–B**, 1 mm. **C**, 0.2 mm.

Indomarengo chavarapater Malamel, Prajapati, Sudhikumar & Sebastian, 2019

Fig. 3.31

Indomarengo chavarapater Malamel, Prajapati, et al., 2019: 428, Figs 1–26 (♂♀).

Habitat: *I. chavarapater* found from foliages in banana plantations and uncultivated plots.

3.3.26.14 *INDOPADILLA* Caleb & Sankaran, 2019

The tribe Baviini Simon, 1901 currently includes five genera: *Bavia* Simon, 1877, *Stagetilus* Simon, 1885, *Padillothorax* Simon, 1901, *Piranthus* Thorell, 1895 and *Bavirecta* Kanesharatnam & Benjamin, 2018 (Kanesharatnam & Benjamin, 2018; Maddison, 2015; Prószyński, 2018a; Prószyński, 2017). The south-east Asian salticid genus *Padillothorax* Simon, 1901, which was also included in Simon's 'Bavieae' Prószyński, 2018b; Simon, 1901b, was previously considered a junior synonym of *Stagetilus* Simon, 1885 Prószyński, 1987a but was recently revalidated Prószyński, 2017; Prószyński, 2018b; this is why this genus is also included in the Baviini. While examining unidentified Salticid specimens collected over a century ago, in 1916, by F.H. Gravely from the Eastern Himalayas in Darjeeling district, West Bengal State of India, an undescribed species was recognized. It closely resembles *Bavia insularis* Malamel, Sankaran, and Sebastian, 2015 described from South India. Superficially, both these species are similar to the baviines in general body shape, with a flattened and broad carapace, elongated and tubular abdomen and enlarged first pair of legs Kanesharatnam and Benjamin, 2018; Maddison, 2015. However, these species have a distinct conformation of copulatory organs that does not correspond to any of the previously described genera. To accommodate these two species, as well as *Bavia thorelli* Simon, 1901 from Indonesia, a new genus was erected, which seems to be close to *Padillothorax*. Additionally, a new combination for the baviine species *Piranthus casteti* Simon, 1900 was proposed, because it shares a striking resemblance of its copulatory organs to the recently described genus*Bavirecta*. Following this revision, the genus currently has 14 nominal species globally and 3 of them known from India (World Spider Catalog, 2021).

Diagnosis: *Indopadilla* Caleb & Sankaran, 2019 in Caleb, Sankaran, Nafin, and Acharya, 2019 is closely related to the members of the tribe Baviini in having a similar body shape, with a flattened oval carapace, elongated, tubular abdomen and the robust first pair of legs. The males, however, can be readily distinguished from other baviines by the following combination of characters: comparatively longer and slender embolus ; RTA medium sized and stout, tegulum with a proximal lobe protruding retrolaterally, without black blotches unlike Bavirecta, and without prolateral lobe of bulbus unlike Bavia and *Bavirecta*. The females are similar to those of *Padillothorax*, but can be distinguished by the relatively shorter and uniform insemination ducts unlike the unusual membraneous and broad ducts in the distal portion followed by a narrower and straight proximal portion in *Padillothorax*. The thin, long accessory glands originate near the distal portion of the insemination ducts and directed posteriorly, whereas in *Padillothorax* they are situated midway and directed laterally, opposing each other. The spermathecae is tubular and simple, whereas in *Padillothorax* they are sub-divided or multi-chambered.

Type species: *Indopadilla darjeeling* Caleb & Sankaran, in Caleb, Sankaran, Nafin, and Acharya, 2019.

Description: Carapace oval and flat dorsally. Abdomen elongate, tubular and narrowing posteriorly. Dorsum with light yellow or brown (*I. darjeeling*) or black to greyish (*I. insularis*), dorso-lateral margins with either continuous or discontinuous longitudinal white patches. The first pair of legs robust, longer and darker than the remaining legs. Tibia I with six thick ventral spines in three pairs, metatarsi I with four ventral spines. Embolus long and tapering gently toward the tip, without membranous margin, tegulum with broad posterior lobe protruding retrolaterally; RTA thick, with broad base and narrow at the tip. Epigyne with a posterior medial blind pocket, the copulatory openings present at the anterior portion of rounded or oval epigynal 'windows', insemination ducts accompanied with thin, long accessory glands and small spermathecae (Figs 3.32 to 3.34; Figures 1–18 in Caleb, Sankaran, et al., 2019).

Composition: *Indopadilla darjeeling* Caleb & Sankaran, in Caleb, Sankaran, et al., 2019, *I. insularis* (Malamel, Sankaran et Sebastian, 2015) comb.nov. and *I. thorelli* (Simon, 1901) comb.nov.

Species sampled from the Muriyad Kol Wetland.

Indopadilla insularis **(Malamel, Sankaran & Sebastian, 2015) comb. nov.**

Figs 3.A.8B, 3.A.8C and 3.33 to 3.35

Bavia insularis Malamel, Sankaran, and Sebastian, 2015: 597, Figs 1–2, 4–20 (♂♀); the type series in ADSH, examined.

Types: Holotype ♂(ADSH856501) from India, Kerala, Alappuzha, Pathiramanal Island (9°37´07.11″N, 76°23´04.95″E), 0 m a.s.l., 27.03.2015, M.S. Pradeep & M.J. Jobi. PARATYPES: INDIA: 3 ♂, 6 ♀(ADSH856502), together with the holotype.

Material examined: INDIA: 1 ♂, 2 ♀(CATE), Kerala, Ernakulam, Aluva, Aluva Manalpuram (10°07´21.1″N 76°21´07.4″E), 2 m a.s.l., 20.09.2015, K.S. Nafin; 3 ♂, 2 ♀(CATE), Kerala, Thrissur, Nedumpal, Konthipulam (10°23´20.2″N 76°14´31.7″E) 0 m a.s.l., 11.10.2016, K.S. Nafin; 1 ♀(CATE), Irinjalakuda, Thrissur, Christ College (10°21´27.3″N 76°12´47.5″E), 30 m a.s.l., 26.07.2015, K.S. Nafin & P.P. Sudhin.

Remarks: The species was originally described and placed in *Bavia* by

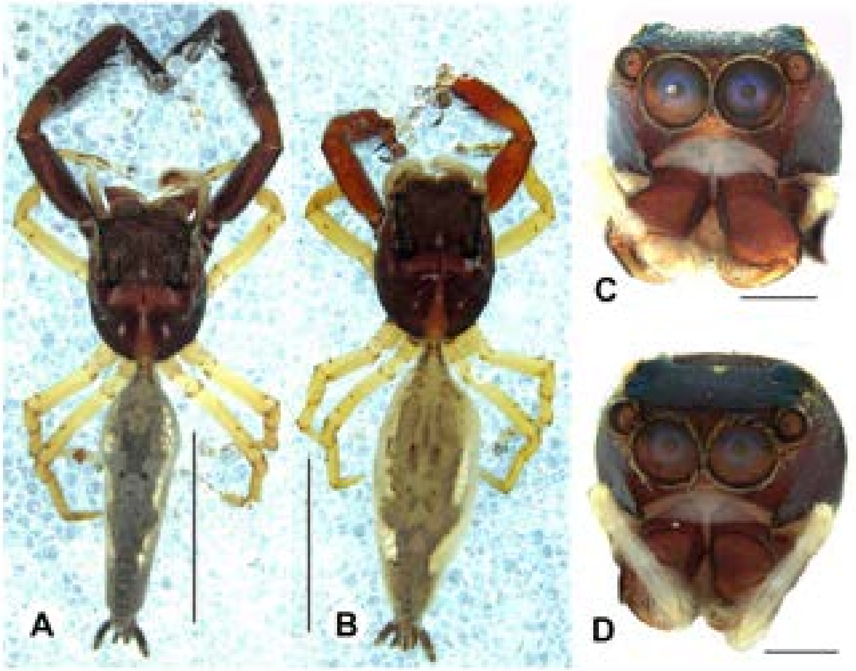

Figure 3.32: *Indopadilla insularis*, habitus, male (**A, C**) and female (**B, D**). **A**–**B**, habitus, dorsal view. **C**–**D**, frontal view. Scale bars. **A**–**B**, 5 mm. **C**–**D**, 1 mm.

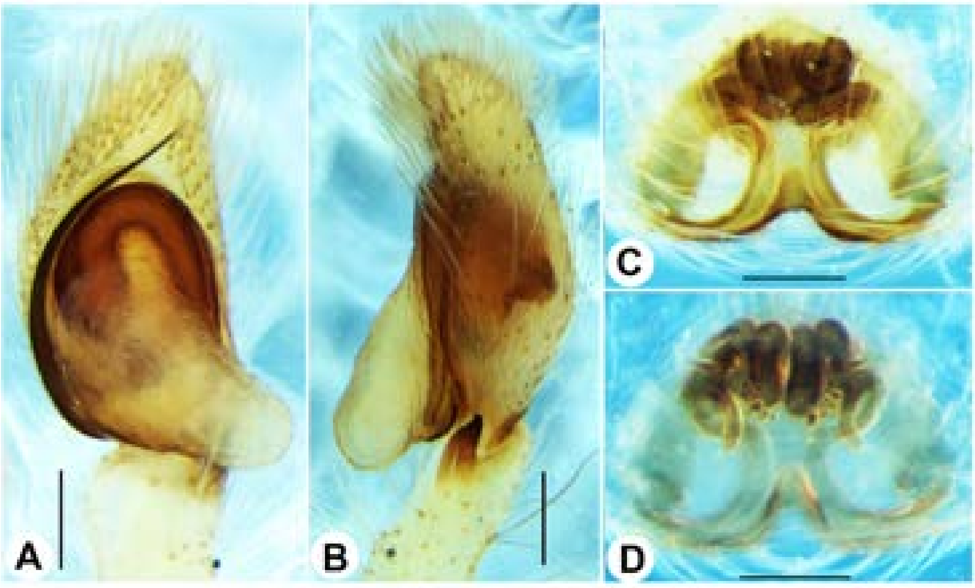

Figure 3.33: *Indopadilla insularis*, male and female genitalia. **A**, male left palp, ventral view. **B**, same, retrolateral view. **C**, epigyne, ventral view. **D**, vulva, dorsal view. Scale bars. **A**–**B**, 0.25 mm. **C**–**D**, 0.2 mm.

Malamel, Sankaran, and Sebastian, 2015, who also indicated that the genus was in need of revision, since many of its species were unrelated to the generotype

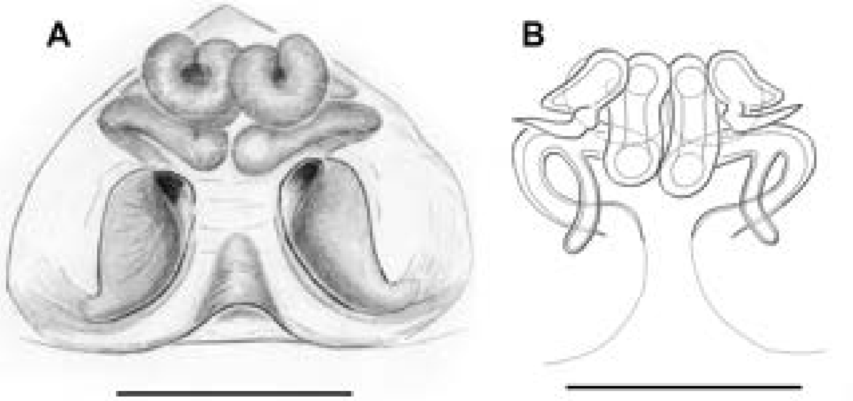

Figure 3.34: Female genitalia of *Indopadilla insularis*. **A**, epigyne. **B**, vulva. Scale bars. **A–B**, 0.2 mm.

Figure 3.35: Distribution map of *Indopadilla darjeeling* and *Indopadilla insularis* in India. *I. insularis* comb. nov. (circles) and *I. darjeeling* (square).

(see also Prószyński and Deeleman-Reinhold, 2013; Żabka, 1988). This species is very close to its congener from Darjeeling, but differs significantly in details of the copulatory organs (see 'Diagnosis' above). The copulatory opening is present in the anterior region of the epigynal 'window', similar to that of *I. darjeeling*, but the duct course is different (it was incorrectly interpreted by Malamel, Sankaran, and Sebastian, 2015; cf. Fig. 20).

Habitat: *Indopadilla insularis* found among the foliages of understorey in most of the habitats in the study area, except paddy fields and grasslands. They are particularly easy to spot in banana plantations, where they are seen foraging on the surfaces of banana leaves.

Natural history: *Indopadilla insularis* are on of the most abundant species of jumping spiders found among the foliages. They create silken retreats on leaves where they rests during night hours.

Other species studied.

Indopadilla darjeeling Caleb & Sankaran, in Caleb, Sankaran, Nafin, and Acharya, 2019

Distribution. India (West Bengal).

Indopadilla thorelli (Simon, 1901) **comb.nov.**

Bavia thorelli Simon, 1901a: 461, Fig. 532 (♂); the holotype ♂is not re-examind. *Bavia thorelli*: Simon, 1902: 24 (♂); Żabka, 1988: 440, Figs 52–55 (♂); the latter author re-examined and illustrated the holotype.

Remarks: The species was originally described by Simon, 1901a from Minahassa (=Minahasa), Indonesia. Żabka, 1988, who erroneously provided the locality for this species as Sri Lanka, redescribed the holotype ♂and remarked that its generic placement is "doubtful and should be treated as temporary". Based on the similar palpal morphology with *I. darjeeling* and *I. insularis* and the resemblance of the abdominal colour pattern with *I. insularis*, it is safe to transfer this species name to the newly erected genus.

Bavirecta casteti (Simon, 1900) **comb.nov.**

Remarks: The species was first described by Simon in 1900 from South India. Based on the re-examination of the type deposited in MNHN, Paris, the female copulatory organs of this species were illustrated by Prószyński, 1987b.

The spermathecae differ considerably from those of the generotype of *Piranthus* — *P. decorus* Thorell, 1895 (cf. Figs in Prószyński, 1987a: 87 with Figs 2F, 3B in Caleb and Sanap, 2017) — but are rather similar to those of *Bavirecta flavopuncta* Kanesharatnam and Benjamin, 2018, the generotype of Bavirecta, in having the simple copulatory openings, the relatively shorter, wider and sclerotized insemination ducts and the compact spermathecae. However, it can be distinguished from *B. flavopuncta* by the elongate, almost slit-like, laterally directed copulatory openings (rounded and anteriorly directed in *B. flavopuncta*), the bean-shaped spermathecae (pear-shaped in *B. flavopuncta*), and the fertilization ducts which arise from the anterior region of the spermathecae (from mid-lateral walls in *B. flavopuncta*) (cf. Figs 2C, D in Kanesharatnam and Benjamin, 2018).

3.3.26.15 *MARENGO* Peckham & Peckham, 1892

Marengo is a less species-rich genus distributed in the Oriental region (World Spider Catalog, 2021). The genus currently comprises 9 nominal species globally with 4 species reported from India (World Spider Catalog, 2021).

Diagnosis: *Marengo* species can be distinguished by the following combination of characters: ant-like genera, first leg enlarged, massive; clypeus backwards sloping; male palp with simple tibial apophysis and coiled embolus on the distal part of tegulum; Epigyne copulatory opening indistinct and sometimes with lightly sclerotised depressions; seminal duts long, convoluted or tangled, spermathecae with spicules (Wanless, 1978).

Type species: *Marengo crassipes* Peckham & Peckham, 1892

Species sampled from the Muriyad Kol Wetland.

Marengo sachintendulkar Malamel, Prajapati, Sudhikumar & Sebastian, 2019
Fig. 3.A.9E

Marengo sachintendulkar Malamel, Prajapati, et al., 2019: 430, Figs 27–49 (♂♀).

Habitat: *M. sachintendulkar* found from foliages of shrubs in banana plantations, grasslands and bordering paddy fields.

3.3.26.16 ***MARIPANTHUS*** **Maddison, 2020**

Maripanthus is a less species-rich genus distributed in the Oriental region (World Spider Catalog, 2021). The genus currently comprises 6 nominal species globally with 2 species reported from India (World Spider Catalog, 2021).

Diagnosis: *Maripanthus* species can be distinguished by the following combination of characters: Epigynal atria long and gaping, anteriorly located; embolus long and beginning on the basal side of tegulum; retromarginal cheliceral teeth close together, forming a single short ridge; male endite with sharp corner (Maddison et al., 2020).

Type species: *Maripanthus draconis* Maddison, 2020

Species sampled from the Muriyad Kol Wetland.

Maripanthus **sp.**

3.3.26.17 ***MENEMERUS*** **(Hahn, 1829)**

Menemerus is a moderately species-rich genus with a cosmopolitan distribution (World Spider Catalog, 2021). The genus currently comprises 65 nominal species globally with 6 species reported from India (World Spider Catalog, 2021).

Diagnosis: *Menemerus* species can be distinguished by the following combination of characters: body flattened, strongly hairy; carapace in most species with white lateral margin; copulatory organs with the presence of very long tegular furrow and characteristic tegular protuberance in the male; epigyne with sclerotized openings and distinctive accessory glands (Wesołowska, 1999).

Type species: *Menemerus semilimbatus* Peckham & Peckham, 1892

Species sampled from the Muriyad Kol Wetland.

Menemerus bivittatus (Dufour, 1831)

Salticus bivittatus Dufour, 1831: 369, pl. 11, Fig. 5 (♀).
Menemerus bivittatus Peckham and Peckham, 1886: 292.
(For complete list of references, see World Spider Catalog, 2021)

Habitat: *M. bivittatus* found on walls of buildings and tree trunks.

3.3.26.18 *MYRMAPLATA* Prószyński, 2016

Myrmaplata is a less species-rich genus distributed in Oriental region (World Spider Catalog, 2021). The genus currently comprises 5 nominal species globally with a single species reported from India (World Spider Catalog, 2021).

Diagnosis: *Myrmaplata* species can be distinguished from *Myrmarachne* by the following combination of characters: absence of transversal detour, terminated at the anterior end by discrete, round or oval small chamber, with internal spines; copulatory ducts make large membranous coils, connecting slit-like, almost indiscernible, copulatory openings pressed to median septum of epigyne, with proximal ends of spermathecae, near posterior rim of epigyne (Prószyński, 2016).

Type species: *Myrmaplata plataleoides* (O. Pickard-Cambridge, 1869)

Species sampled from the Muriyad Kol Wetland.

Myrmaplata plataleoides (Pickard-Cambridge, 1869)
Figs 3.A.9F and 3.A.9G

Salticus plataleoides Pickard-Cambridge, 1869b: 68, pl. 6, Figs 61–65 (♂).

Myrmarachne plataleoides Simon, 1901a: 499, Figs 586, 590–592 (♂); Prószyński, 2018a: 165, Fig. 22F (♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *M. plataleoides* found among the foliages in all habitats.

Natural history: *M. plataleoides*, commonly called Red Weaver-ant mimicking jumper, is a batesian mimic of the weaver ant (*Oecophylla smaragdina*) which is common in the region. The are sexually dimorphic, male chelicerae are protruded and elongated compared to the females. Retreat consists of webbing on the leaf surface.

3.3.26.19 *MYRMARACHNE* MacLeay, 1839

Myrmarachne is a moderately species-rich genus distributed in Oriental, Neotropical, Australian, Ethiopian, Palearctic and Neotropical regions (World Spider Catalog, 2021). The genus currently comprises 186 nominal species globally with 23 species known from India (World Spider Catalog, 2021).

Diagnosis: *Myrmarachne* species can be distinguished by the following combination of characters: loop-like detour in the anterior third of pipe-like spermathecae; male palps with corkscrew-like, short tibial apophysis with flange, and by additional thin loop of sperm duct (Prószyński, 2016).

Type species: *Myrmarachne melanocephala* MacLeay, 1839.

Species sampled from the Muriyad Kol Wetland.

Myrmarachne melanocephala MacLeay, 1839
Fig. 3.A.9H

Myrmarachne melanocephala MacLeay, 1839: 11, pl. 1, Fig. 4 (♂).
(For complete list of references, see World Spider Catalog, 2021)

Habitat: *M. melanocephala* found among the foliages in all habitats.

Natural history: *M. melanocephala* is a widely occuring species in the region, supposed to be a bayesian mimic of the ant species *Tetraponera rufonigra.* It was observed to be living in close proximity to the ants in areas where the ant species has been found. The spider's morphology and colour closely resemble that of the ant.

3.3.26.20 *PHAEACIUS* Simon, 1900

Phaeacius is a less species-rich genus distributed in Oriental region (World Spider Catalog, 2021). The genus currently comprises 14 nominal species globally with 2 species known from India (World Spider Catalog, 2021).

Diagnosis: *Phaeacius* species can be distinguished by the following combination of characters: Male palpal tibia with massive RTA, ventral apophysis and sometimes an intermediate apophysis; cymbium with small basal protuberances, embolus robust, long and curved, primary conductor lacking; epigyne opening paired (Wanless, 1981).

Type species: *Phaeacius fimbriatus* Simon, 1900

Species sampled from the Muriyad Kol Wetland.

Phaeacius lancearius (Thorell, 1895)
Fig. 3.A.10A

Cocalus lancearius Thorell, 1895: 357 (♂).

Phaeacius lancearius Wanless, 1981: 205, Figs 1, 2A–F, 5A, C–F (♂); Phaeacius lancearius

Malamel, 2018: 115, Figs 2E–F, 6G–I (♂).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *P. lancearius* found on tree trunks in wooded areas of the wetland.

3.3.26.21 *PHINTELLA* Strand, 1906

Phintella is a moderately species-rich genus distributed in Oriental, Palearctic and Australian regions (World Spider Catalog, 2021). The genus currently comprises 63 nominal species globally with 11 species known from India (World Spider Catalog, 2021).

Diagnosis: *Phintella* species can be distinguished by the following combination of characters: Abdomen with transverse light and dark streaks, with metallic lustre and the presence of scale-like setae; epigyne is not visibly sclerotised, and the spermatheca has curved copulatory ducts (Żabka, 1985).

Type species: *Phintella typica* Strand, 1906

Species sampled from the Muriyad Kol Wetland.

Phintella vittata (C. L. Koch, 1846)
Fig. 3.A.10B

Plexippus vittatus Koch, 1846: 125, Fig. 1185.

Phintella vittata Żabka, 1985: 429, f. 435-441, 453.

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *P. vittata* were found in the foliages in most of the habitats in the study area.

3.3.26.22 *PHINTELLOIDES* Kanesharatnam & Benjamin, 2019

Phintelloides is a moderately species-rich genus distributed in Oriental region (World Spider Catalog, 2021). The genus currently comprises 10 nominal species globally, with 5 species known from India (World Spider Catalog, 2021).

Diagnosis: *Phintelloides* species can be distinguished by the following combination of characters: clypeus with white tuft of hairs, white diamond-shaped mark behind PLE and pale white band on the anterior eye field, abdomen with black median band bordered by two lateral bands; males with presence of lamellar process, comparably longer embolus; copulatory ducts in females with duck-neck-shaped diverging curves. This genus is closer to *Proszynskia* in appearance than to *Phintella* and *Chrysilla* (Kanesharatnam & Benjamin, 2019).

Type species: *Phintelloides jesudasi* (Caleb & Mathai, 2014)

Species sampled from the Muriyad Kol Wetland.

Phintelloides jesudasi (Caleb & Mathai, 2014)
Fig. 3.A.10C

Chrysilla jesudasi Caleb, Christudhas, et al., 2014: 63, Figs 1–14 (♂♀).

Phintelloides jesudasi Kanesharatnam and Benjamin, 2019: 41, Figs 3, 6E–H, 17A–E, 18A–D; Caleb, 2010: 15739, Figs 17E–G, 29B (♂♀).

Habitat: *P. jesudasi* were found in the foliages in riparian habitat.

3.3.26.23 *PIRANTHUS* Thorell, 1895

Piranthus is a less species-rich genus distributed in the Indian subcontinent and South-east Asia (World Spider Catalog, 2021). For more than a century after Thorell, 1895 described the jumping spider genus *Piranthus*, it was known from only the single female and two juveniles of *P. decorus* he described from Myanmar, apart from a species misplaced in the genus (Caleb, Sankaran, et al., 2019). Recently, *P. decorus* was discovered in Mumbai, India (Caleb & Sanap, 2017) and redescribed. Caleb & Sanap provided photographs of a living male, but did not have the specimen to describe. Here, a second new species of *Piranthus* is described from Kerala, *P. planolancis*. The first description of a male *Piranthus*, that of *P. planolancis* sp. nov is provided, and images and illustrations of the genitalia are given. Following this research, Maddison et al., 2020 added 4 new species of *Piranthus* from Malaysia and Singapore, making it a total of 6 nominal species in the genus, with two species known from India (World Spider Catalog, 2021).

Diagnosis: Carapace surface rugose, with a coarse reticulate sculpturing throughout. Carapace flat with ocular area and frontal part of thorax on a plane, and fovea well back of PLE. Legs are robust, especially the first pair. Embolus begins at prolateral basal corner of bulb; epigyne with central septum. Tip of abdomen black (Maddison et al., 2020).

Type species: *Piranthus decorus* Thorell, 1895

Species sampled from the Muriyad Kol Wetland.

Piranthus planolancis sp. nov.

(Figs 3.36A–C, 3.37A–K, 3.38A–B, 3.39A–E, 3.29)

Figure 3.36: Live images of *Piranthus planolancis* sp. nov. **A**, Female, Vellangallur. **B**, female, Mysuru. **C**, Male, Mysuru. Photos **B–C** used with permission from Wayne P. Maddison. Scale bars. **A–C**, 1 mm.

Table 3.8: *Piranthus planolancis* sp. nov. Measurements of legs and palp

Male						
	Leg segments	**I**	**II**	**III**	**IV**	**Palp**
	Femur	1.63	1.21	0.98	1.24	0.71
	Patella	0.85	0.69	0.49	0.6	0.27
	Tibia	1.22	0.78	0.39	0.88	0.21
	Metatarsus	0.76	0.54	0.63	0.87	–
	Tarsus	0.57	0.5	0.43	0.51	0.53
	Total	5.03	3.72	2,92	4.1	1.72
Female						
	Leg segments	**I**	**II**	**III**	**IV**	**Palp**
	Femur	1.5	1.3	1.3	1.6	–
	Patella	0.9	0.7	0.55	0.6	–
	Tibia	1	1.9	0.7	1	–
	Metatarsus	0.6	0.6	0.7	1.1	–
	Tarsus	0.5	0.5	0.6	0.4	–
	Total	4.5	4	3.8	4.7	–

Types: Holotype ♀(ADSH 8744003A) from India, Kerala, Pathiramanal Island (9°37´07.11˝N, 76°23´04.95˝E), 4 m. a.s.l., from foliage by hands, 16.08.2015, M.J.

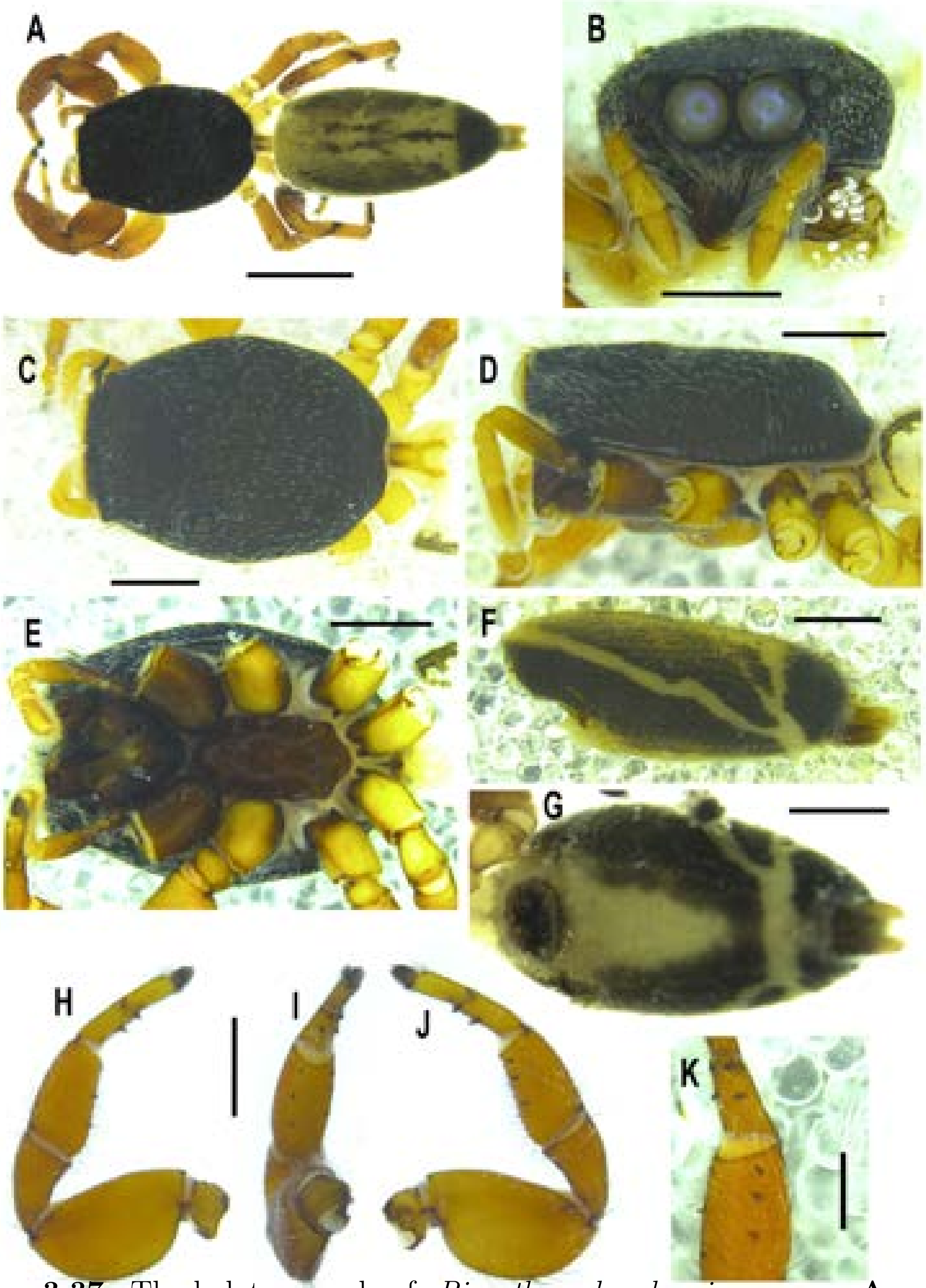

Figure 3.37: The holotype male of *Piranthus planolancis* sp. nov. **A**, general appearance, dorsal view. **B**, carapace, frontal view. **C**, same, dorsal view. **D**, same, lateral view. **E**, same, ventral view. **F**, abdomen, lateral view. **G**, same, ventral view. **H**, left leg I, prolateral view. **I**, same, ventral view. **J**, same, retrolateral view. **K**, same, close-up of ventral spines. Scale bars. **A**, 2 mm **B–J**, 1 mm. **K**, 0.5 mm.

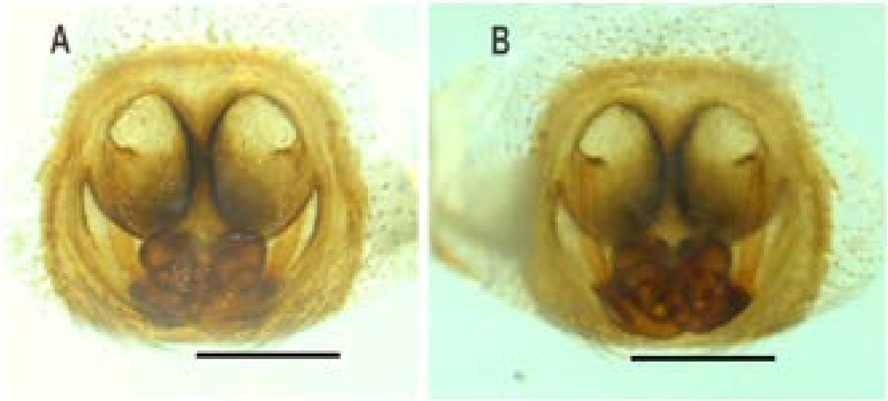

Figure 3.38: Images of female genitalia of *Piranthus planolancis* sp. nov. **A**, Epigyne, ventral view. **B**, vulva, dorsal view. Scale bars. **A–B**, 0.25 mm.

Jobi & M.S. Pradeep. **Paratype**: INDIA: 1 ♀(CATE 8705A), 1♂(CATE 8705B), Kerala, Thrissur, Vellangallur (10°18´24.4″N, 76°12´16.1″E), 10 m a.s.l., 12.2017, Varun Das Manakkatt & K.S. Nafin.

Other material: Karnataka: south of Mysuru, farm, 12.223°N 76.627°E, 710 m a.s.l, 1 ♂(specimen NCBS-BN246 = AS19.5970) and 1 ♀(specimen NCBS-BN247 = AS19.5940) collected 4 July 2019 by Marathe,Maddison,Abhijith & Sumukha, collecting code WPM#19-107; 1 ♀(specimen NCBS-BN248) collected 4 July 2019 by Abhijith A.P.C.

Etymology: The specific epithet derives from the Latin words *plano* (= flat) and *lancis* (= plate) and refers to the plain posterior median plate of the epigyne.

Diagnosis: The new species is strikingly similar to *P. decorus*, but can be easily distinguished from it by the following characters: the posterior plate of the epigyne without the epigynal pocket (present in *P. decorus*); the major axis of the epigynal oval groves parallel to each (major axis at approximately a 45 degrees angle anteriorly in *P. decorus*); insemination ducts highly convoluted and larger (smaller and markedly less convoluted in *P. decorus*) (cf. Figs 3.38A–B, 3.39D–E with Figs 2E, F & 3A, B in Caleb and Sanap, 2017).

The male palp is unlike others described in the Baviini (Maddison, 2015) in two aspects: the long embolus (longer than in most baviines) arises on the prolateral proximal corner of the bulb, proceeding proximally from its base before curling and turning distally, and the retrolateral tibial apophysis is an especially long blade (Figs 3.39A–C).

Comparison of the male with that of *P. decorus* is made difficult by the fact that the latter is known only from photographs of a living specimen (Caleb &

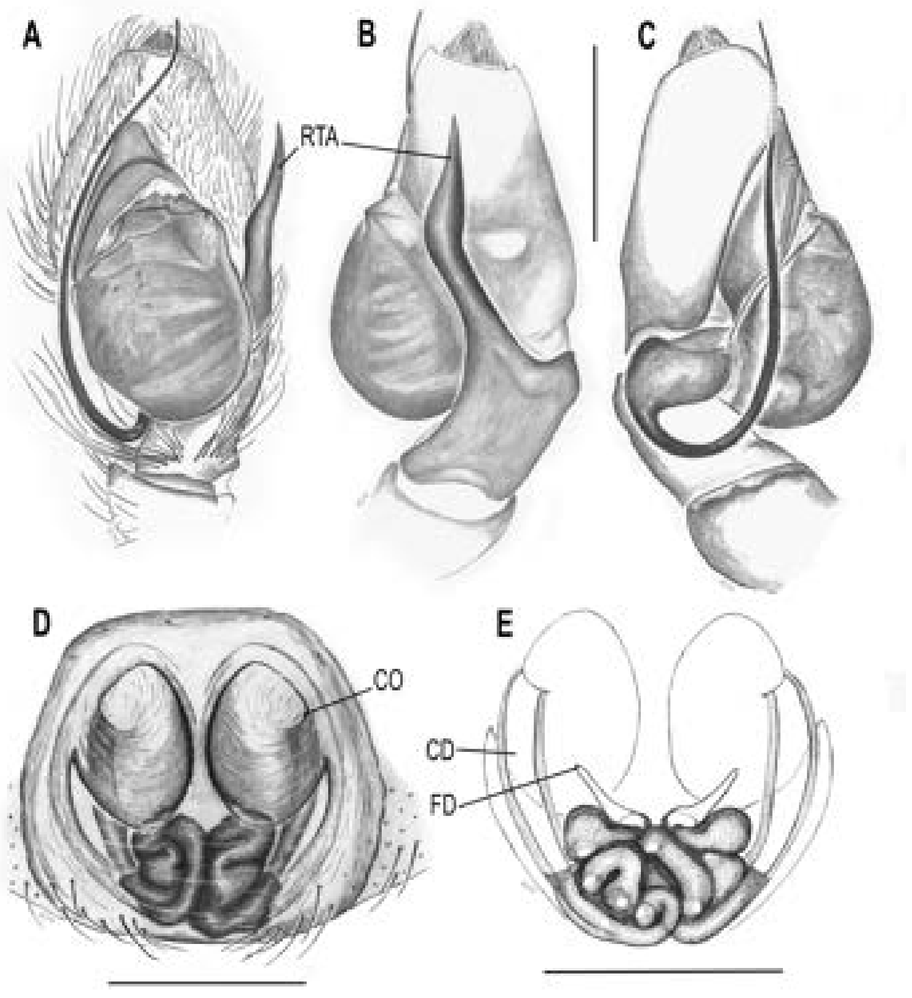

Figure 3.39: The male palp and female genitalia of *Piranthus planolancis* sp. nov. Paratype male (**A–C**) and holotype female (**D–E**). **A**, left palp, ventral view. **B**, same, retrolateral view. **C**, same, prolateral view. **D**, epigyne, ventral view. **E**, vulva, dorsal view. Scale bars. **A–C**, 0.5 mm. **D–E**, 0.25 mm.

Sanap, 2017). One distinguishing feature may be in the colours of the first leg — the first leg is nearly solid black in *P. planolancis* males (Figure 10), but has pale areas on the patella, metatarsus and tarsus in *P. decorus* (Caleb and Sanap, 2017 Figs 5b, c). The females also differ in the first leg, with the first tibia much darker than the patella in *P. decorus* (Caleb and Sanap, 2017 fig. 4c), but both pale in *P. planolancis* Fig. 3.36B. Females of the two species are quite similar in overall appearance, but their epigynes are distinct (Malamel et al., 2019) in what we interpret to be the RTA coupling pockets: small and medial in *P. decorus*, large and lateral in *P. planolancis*, giving the appearance of a broad ”smile” (Fig. 3.39D). The copulatory openings are narrow curved slits covered by raised flaps in the

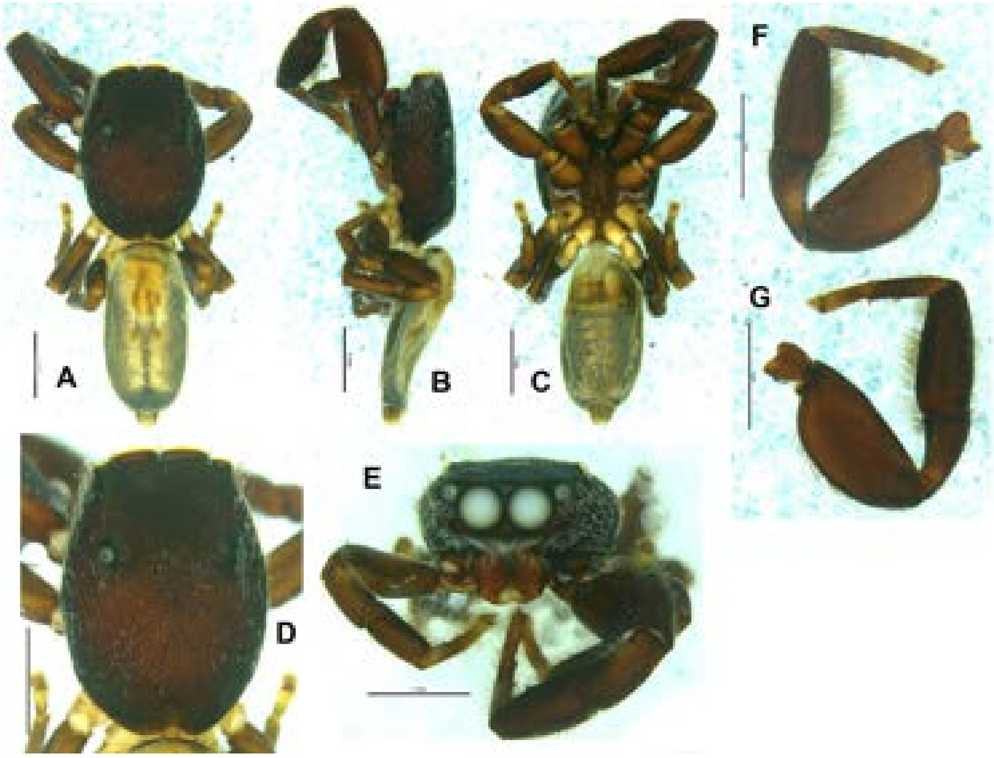

Figure 3.40: Male of *Piranthus planolancis* sp. nov. **A**, general appearance, dorsal view. **B**, same, lateral view. **C**, same, ventral view. **D**, carapace, dorsal view. **E**, same, frontal view. **F**, left leg I, prolateral view. **G**, same, retrolateral view. Scale bars. **A–G**, 1 mm.

epigyne in *P. planolancis*, but in *P. decorus* the openings are broader, not covered by flaps, at the bottom of deep atria (Caleb and Sanap, 2017 fig. 2e). In *P. planolancis* the atria, which are depressed compared to the raised medial septum, are deepest medially, near the septum, not at the openings.

While the male palp of *P. decorus* remains undescribed, a prediction can be made as to its likely features. The RTA would be expected to be smaller than that of *P. planolancis*, given the small size and medial location of the coupling pocket of *P. decorus*. The embolus might be about as long as that of *P. planolancis*, given the similar copulatory ducts.

Description: FEMALE (Holotype; Figs 3.37A–K, 3.38A–B, 3.39D–E). Measurements. Body length: 9.5. Carapace: 5.6 long, 3.7 wide, 0.8 height. Abdomen: 3.9 long, 2.3 wide, 1.2 height. Clypeus: 0.2 height. Chelicerae: 1.4 long. Eyes diameters: AME 0.71. ALE 0.32. PME 0.10. PLE 0.23. Eye interdistances: AME–AME 0.71. AME–ALE 1.2. PME–PLE 1.69. PME–PME 1.92.

Carapace black, rugose, covered with setae and scattered white scales, widest in the middle, top flat, posteriorly abruptly sloping, the posterior border curved inwardly. Eye field wider than long; AMEs and ALEs surrounded by setae, PMEs minute, located one third the distance from ALEs and PLEs, ALEs slightly bigger than PLEs, the inner margin of PLE slightly elevated. Clypeus short, covered with setae and lower margin with long white setae. Sternum reddish brown, longer than wide. Endites and labium dark brown. Chelicerae pluridentate, promargin with three teeth and retromargin with 6–8 teeth. Legs robust, legs I enlarged, with massive flattened, deep orange femora (Figs 31–34), other legs yellowish orange, femora II and III flattened, a gap between coxae II and III, coxae III and IV with a basal notch, tibiae I and metatarsi I with three and two pairs of very short, stout ventral spines respectively, tibia II ventrally with a tiny stout spine and metatarsus II with two pairs of short stout spines. Abdomen long and cylindrical, covered with long dark setae and black and cream scales, two pairs of sigillae present; dorsum creamy, with a tuning fork-like dark marking along the longitudinal midline, flanked by lateral black mottling, the posterior fifth black; sides mostly black, with a prominent diagonal creamy band from antero-dorsal to posteroventral parts of the abdomen; three fourth of the venter creamy, tapering towards the posterior part, which has a wide transverse creamy band. Epigyne and spermathecae as shown in Figs 35–38; highly sclerotised, copulatory openings situated antero-laterally in the prominent oval grooves occupying almost a half of the anterior part of the epigyne, separated by a thin median septum; the posterior plate of the epigyne flat, slightly sloping anteriorly, bordered with a sclerotised rim forming a pocket at postero-lateral side of the anterior groves; insemination ducts long, entering the highly convoluted spermathecal canals posteriorly, oval receptacles are located anteriorly; fertilisation ducts are situated anteriorly.

MALE (CATE 8705B, Fig. 3.36C, 3.39A–C). Measurements for male CATE 8705B from Kerala: body length 5.49, carapace length 2.67, width (at the middle) 1.94, height at middle 1.16. Abdomen length 2.79, width (at the middle) 1.30. Eye diameters: AME 0.44, ALE 0.18, PME 0.06, PLE 0.17. Eye interdistances: AME–AME 0.05, AME–ALE 0.07, PME–PME 1.12, ALE–ALE 0.93, PME–PLE 0.53, PLE–PLE 1.17, ALE–PME 0.12. Clypeus height 0.08. Length of chelicera 0.58. Measurement of palp and legs: palp 1.72 [0.71, 0.27, 0.21, 0.53], I 5.03 [1.63, 0.85, 1.22, 0.76, 0.57], II 3.72 [1.21, 0.69, 0.78, 0.54, 0.50], III 2.92 [0.98, 0.49, 0.39, 0.63, 0.43], IV 4.10 [1.24, 0.60, 0.88, 0.87, 0.51]. Leg formula: 1423. Male NCBS-BN246 from Karnataka: Carapace length 3.05; abdomen length 2.9.

Carapace flat and broad, widest not along ventral margin but at height of

AMEs (Fig. 3.40E). Ocular area and anteriormost two-thirds of thorax on the same plane, with thorax falling abruptly in last third (Fig. 3.40B). Carapace surface with coarse reticulate sculpturing except around eyes. Colour black to dark brown, with scattered white to cream coloured setae, which are more concentrated on sides and densely packed on lower margin of clypeus (Fig. 3.40E). Chelicerae: small, dark brown to black, with cream-coloured setae basally. Plurident, with at least 5 small closely adjacent retromarginal teeth, and at least 2 promarginal teeth. Palp (Figs 3.39A–C): black to dark brown with a few scattered white setae. Embolus long, beginning as a small bulb at the proximal prolateral corner of bulb, narrowing abruptly as it proceeds proximally then loops toward the ventral and then distally, running along the prolateral side of the bulb. RTA a long slightly curved blade that reaches approximately as far distally as the tegulum. Legs: most segments black to dark brown, posterior legs slightly paler with dark orange patches. First leg somewhat thicker than others, with ventral macrosetae of tibia and metatarsus very short, just nubbins. Ventral macrosetae 6 on first tibia (3 pro-, 3 retro-lateral) and 4 on first metatarsus (2 pro-, 2 retro-lateral). Abdomen (Fig. 3.40A): medium brown, dusted with cream to orange scales especially basally and laterally, darkest just in front of anal tubercle and along midline.

Distribution: India: Kerala (Pathiramanal Island and Vellangallur), Karnataka (Mysuru) (Fig. 3.29).

Natural history: The holotype female was found in foliage. Specimens were hand collected from understory branches of trees in an agricultural plot. Specimens in Karnataka were found in trees near a farmhouse, one male in a large suspended dried leaf, one female collected by shaking understory branches.

3.3.26.24 *PLEXIPPUS* C. L. Koch, 1846

Plexippus is a less species-rich genus distributed in Oriental, Palearctic, Ethiopian, Neotropical, Nearctic, Australian and Oceanian regions (World Spider Catalog, 2021). The genus currently comprises 46 nominal species globally, with 6 species known from India (World Spider Catalog, 2021).

Diagnosis: *Plexippus* species can be distinguished by the following combination of characters: Carapace nearly twice as long as it is wide, truncate at the back, and curved upwards towards the front row of eyes; abdomen oval, widest in the middle; male palpal organ thick, sclerotised, and dark brown, with almost rectangular bulbus and a sharply pointed, slightly curved embolus; tibial apophysis sharp, short, broad, and inwardly curved; Tibia with long hair tuft; epigyne with a transverse base and a median upward canal.

Type species: *Plexippus ligo* C. L. Koch, 1846

Species sampled from the Muriyad Kol Wetland.

Plexippus paykulli (Audouin, 1826)

Figs 3.A.10D and 3.A.10E

Attus paykullii Audouin, 1826: 409, pl. 7, Fig. 22 (♂).

Plexippus paykulli Peckham and Peckham, 1886: 296.

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *P. paykulli* were found on tree trunks and inside buildings.

Natural history: *Plexippus paykulli* or pantropical jumping spider is one of the most commonly encountered spiders in the world, especially in human habitats. Retreats usually consists of silken case made inside cracks on the walls or under leaves in the natural habitats. They exhibit sexual dimorphism.

Plexippus petersi (Karsch, 1878)

Euophrys petersii Karsch, 1878: 332, pl. 2, Fig. 7 (♂).

Plexippus petersi Simon, 1903: 728.

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Plexippus petersi* were found on vegetation and inside buildings.

Natural history: *Plexippus petersi* or tropical fly catcher, is commonly found inside human dwellings and is considered as potentila pest control agent, due to its skill in hunting down mosquitoes, flies and other invertebrates. They are also common in agricultural landscapes.

3.3.26.25 *PORTIA* Karsch, 1878

Portia is a less species-rich genus distributed in Oriental, Palearctic, Ethiopian and Australian regions (World Spider Catalog, 2021). The genus currently comprises 17 nominal species globally, with 4 species known from India (World Spider Catalog, 2021).

Diagnosis: *Portia* species can be distinguished by the following combination of characters: Legs in both sexes delicate and long, frequently with a scopula on the ventral surface of femora, patellae and tibiae; male palpal embolus usually long, tibia with numerous big apophyses, dorsal surface of cymbium frequently a distinct cymbial flange; epigyne weakly sclerotized, densely covered with hairs, spermathecae oval (Żabka, 1985).

Type species: *Portia schultzi* Karsch, 1878

Species sampled from the Muriyad Kol Wetland.

Portia fimbriata (Doleschall, 1859)
Figs 3.A.10F and 3.A.11G

Salticus fimbriatus Doleschall, 1859: 22, pl. 5, Fig. 8 (♂♀).

Portia fimbriata Wanless, 1978: 99, f. 7A-G, 8A-F, pl. 3a-f, 4c-f, 5c-d, f (♂♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Portia fimbriata* were collected from all habitats except grasslands and paddy fields.

Natural history: *Portia fimbriata* uses cryptic stalking to hunt down prey, mainly spiders including salticids. They employ ingenious ways to hunt other web building spiders, they were observed to pluck on the web from a safe distance with numerous range of signals to lure the prey to them.

3.3.26.26 *PTOCASIUS* Simon, 1885

Ptocasius is a moderately species-rich genus distributed in Oriental region (World Spider Catalog, 2021). The genus currently comprises 52 nominal species globally, with one species known from India (World Spider Catalog, 2021).

Diagnosis: *Ptocasius* species can be distinguished by the following combination of characters: Body is not elongate, abdominal pattern with chevrons or transverse dark and light stripes, cymbium wide, neither with apophysis nor with strong bristles; some species have cymbial bump; tegulum either round or elongate; embolus and tibial apophysis similar to members of *Epeus*, *Telamonia* and *Plexippoides* (Patoleta et al., 2020).

Type species: *Ptocasius weyersi* Simon, 1885.

Species sampled from the Muriyad Kol Wetland.

***Ptocasius* sp.**

3.3.26.27 *RHENE* Thorell, 1869

Rhene is a moderately species-rich genus distributed in Oriental, Palearctic, Ethiopian and Australian regions (World Spider Catalog, 2021). The genus currently comprises 64 nominal species globally, with 16 species known from India (World Spider Catalog, 2021). Members of the genus move slowly in general.

Diagnosis: *Rhene* species can be distinguished by the following combination of characters: Carapace is longer than wide, roughly square, and highly flattened, with small inconspicuous eyes; small abdomen with a broad base and a blunt tip; legs are small, with first pairs having broad and flat tibiae; palpal organ with a swollen bulbus and a short-curved conductor.

Type species: *Rhene flavigera* (C. L. Koch, 1846)

Species sampled from the Muriyad Kol Wetland.

Rhene flavigera (C. L. Koch, 1846)
Figs 3.A.10G and 3.A.10H

Rhene flavigera Prószyński, 1984b: 119–121 (♂♀); Peng, 2020: 388, Figs 282a–h (♀).
(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Rhene flavigera* were collected from vegetation in uncultivated, mixed crops and riparian areas.

3.3.26.28 *SILER* Simon, 1889

Siler is a less species-rich genus distributed in Oriental and Palearctic regions (World Spider Catalog, 2021). The genus currently comprises 11 nominal species globally, with only one species known from India (World Spider Catalog, 2021).

Diagnosis: *Siler* species can be distinguished by the following combination of characters: Body covered with numerous scale-like setae, abdomen with transverse multicoloured streaks; palpal organ with a long spatular tibial apophysis and an elongate bulbus; epigyne oval, with strongly sclerotized spermathecae; copulatory ducts vary in length or sometimes completely reduced (Żabka, 1985).

Type species: *Siler cupreus* Simon, 1889

Species sampled from the Muriyad Kol Wetland.

Siler semiglaucus (C. L. Koch, 1846)

Figs 3.A.11A and 3.A.11B

Cyllobelus semiglaucus Simon, 1901a: 549, Fig. 664 (♂); Reimoser, 1925: 91 (♀).

Siler semiglaucus: 137.

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *S. semiglaucus* were collected from shrubs and short trees in the riparian, uncultivated and mixed crop plots.

3.3.26.29 ***STENAELURILLUS*** Simon, 1886

Stenaelurillus is a moderately species-rich genus distributed in Oriental, Ethiopia and Australian regions (World Spider Catalog, 2021). The genus currently comprises 50 nominal species globally, with 10 species known from India (World Spider Catalog, 2021). They are ground-dwelling jumping spiders.

Diagnosis: *Stenaelurillus* species can be distinguished all other Aelurillines by the following combination of characters: Spinnerets longest and conspicuous; tarsal claws with well-developed and numerous teeth; cymbial pocket least developed, embolic division is situated openly, in a shallow cavity at the top of the bulbus; true tegulum heavily sclerotized sclerite hidden behind the Salticid radix; body coloration bright consisting of numerous stripes and paired/singular spots (Logunov & Azarkina, 2018).

Type species: *Stenaelurillus nigricaudus* Simon, 1886

Species sampled from the Muriyad Kol Wetland.

Stenaelurillus albus (C. L. Koch, 1846)

Fig. 3.A.11C

Stenaelurillus albus Sebastian, Sankaran, et al., 2015: 65, Figs 1A–B, 2A–G, 3A–C, 7A, 8A–I, 9A–F (♂♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *S. albus* were collected from ground surfaces bordering paddy fields and grasslands.

3.3.26.30 *STERTINIUS* Simon, 1890

Stertinius is a less species-rich genus distributed in Oriental and Palearctic regions (World Spider Catalog, 2021). The genus currently comprises 14 nominal species globally (World Spider Catalog, 2021).

Diagnosis: *Stertinius* is closer to *Uroballus* , but can be distinguished by the position of PMEs, which is markedly closer to the ALEs (it is half way between the ALEs and PLEs in *Uroballus*); presence of conspicuous and sclerotized sigillae in Stertinius (absent from *Uroballus* (Logunov, 2018)).

Type species: *Stertinius dentichelis* Simon, 1890

Species sampled from the Muriyad Kol Wetland.

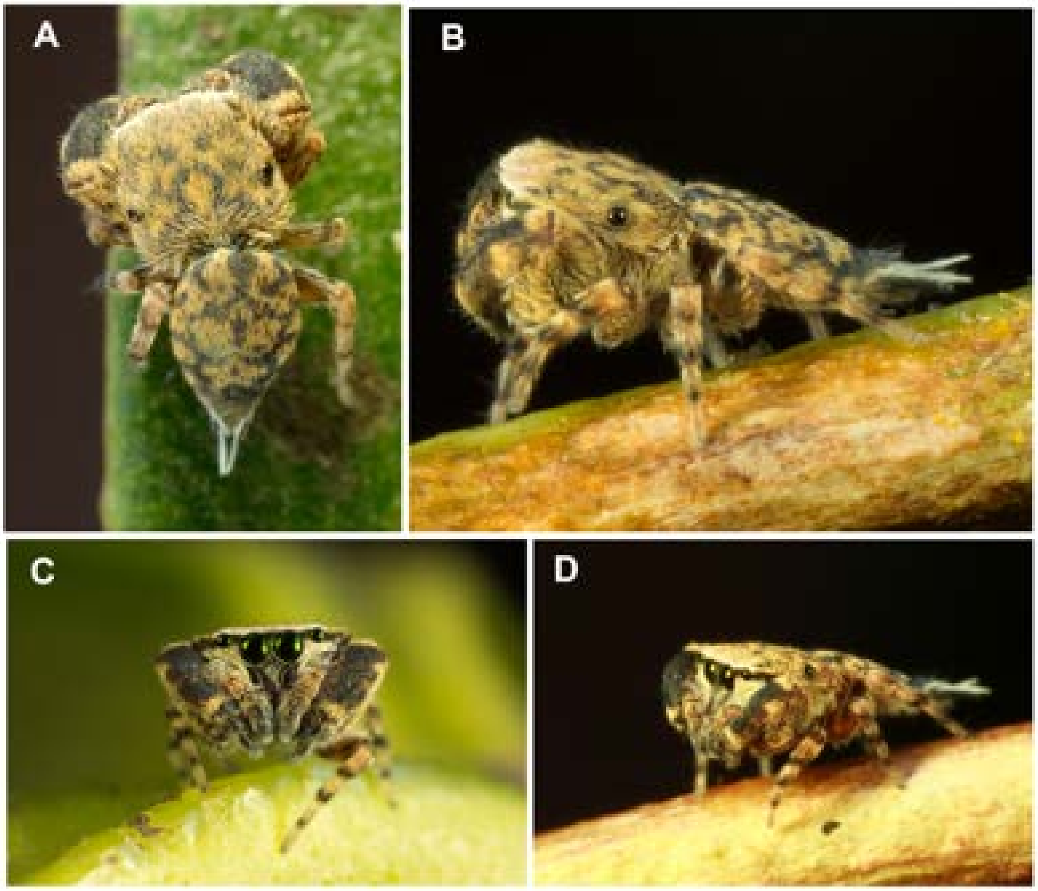

Figure 3.41: Live images of *Stertinius aluva* sp. nov. **A**, Male, dorsal view. **B**, same, lateral view. **C**, same, frontal view. **D**, same, frontolateral view.

Stertinius aluva sp. nov.

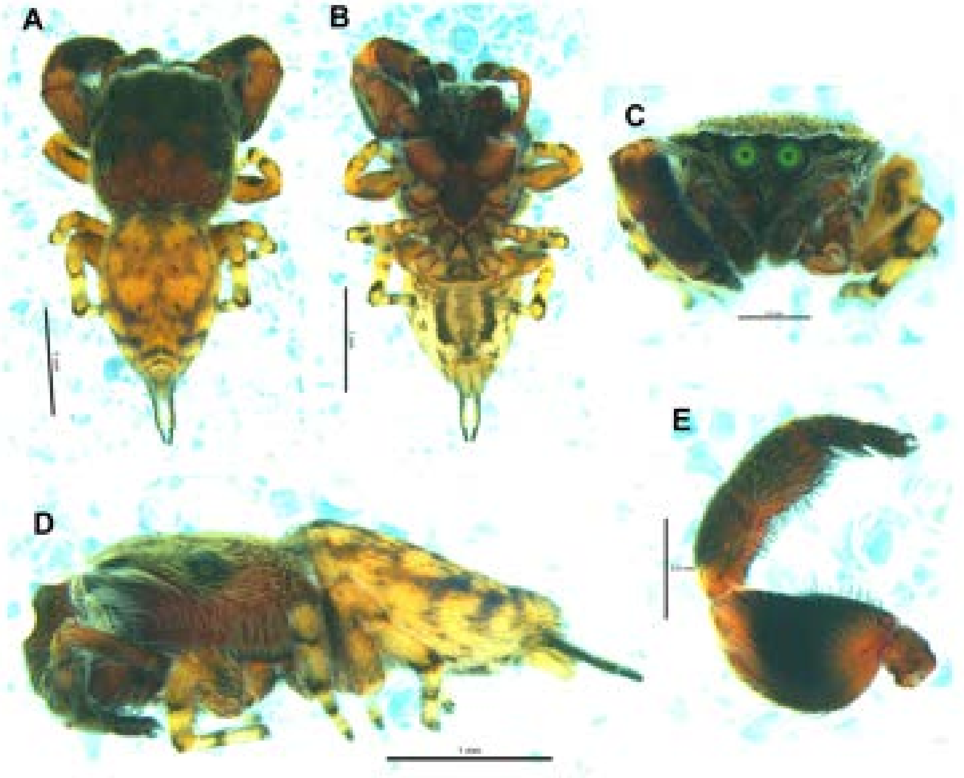

Figure 3.42: Holotype male of *Stertinius aluva* sp. nov. **A**, general appearance, dorsal view. **B**, same, ventral view. **C**, same, frontal view. **D**, same, lateral view. **E**, left leg I, prolateral view. Scale bars. **A–B,D**, 1 mm. **C, E**, 0.5 mm.

(Figs 3.41 to 3.44)

Type: Holotype ♂(CATE 8715A), India, Kerala, Aluva, Elookkara (10°5´46.13″N, 76°19´57.33″E), 8 m a.s.l., 21.08.2019, K. S. Nafin. Paratype: 3 ♀(CATE 8715B), same data as holotype.

Other material: 2 ♂(CATE 8715D), same data as holotype; 1 ♀(CATE 8715C), Kerala, Thrissur, Thottippal (10°24´39.80″”N, 76°13´56.60″E), 4 m a.s.l., 3.03.2017, K. S. Nafin.

Etymology: The specific epithet is a noun in apposition derived from the name of the type locality.

Diagnosis: Females of *S. aluva* sp. nov. is closer to *S. borneensis* Logunov, 2018, but can be distinguished from the latter by the short and less prominent epigynal pocket which is posteriorly placed (prominent and placed midially in *S. borneensis*); anterior spermathecae round (oval in *S. borneensis*) (cf. Figs 3.44 with Figs 2–3 in Logunov, 2018). Males can be distinguished from properly described congeners by the short and thick embolus.

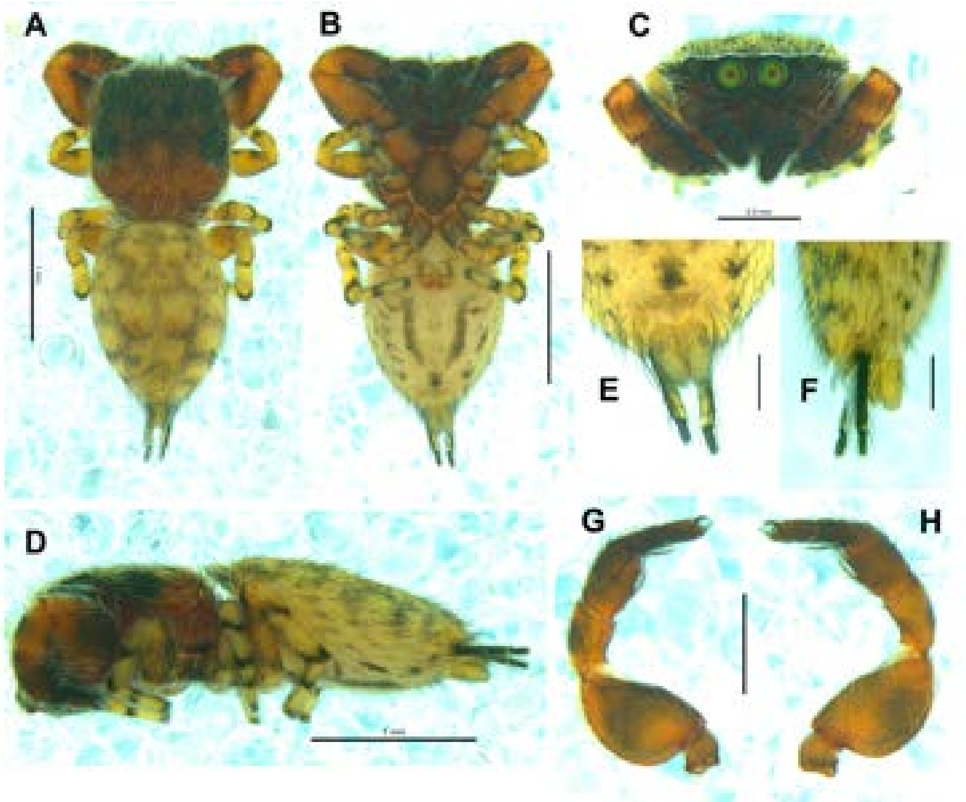

Figure 3.43: Paratype female of *Stertinius aluva* sp. nov. **A**, general appearance, dorsal view. **B**, same, ventral view. **C**, same, frontal view. **D**, same, lateral view. **E**, spinnerets, ventral view. **F**, same, lateral view. **G**, left leg I, prolateral view. **H**, left leg I, rettolateral view. Scale bars. **A–B,D**, 1 mm. **C, E–H**, 0.5 mm.

Description: MALE (Holotype; Figs 3.41, 3.42, 3.44A–B). Measurements. Carapace 1.33 long, 1.37 wide and 0.95 high at PLE. Chelicera length 0.37. Abdomen 2.16 long, 1.16 wide. Eyes diameters: AME 0.29. ALE 0.12. PME 0.10. PLE 0.14. Eye interdistances: AME–ALE 0.07. PME–PLE 0.44. PME–PME 1.13. Leg formula: 1423

Carapace russet, surface leathery, covered with fawn setae and few black setae, dense white fringe above the eyes of the first row; black around eyes, clypeus with long white setae, lateral sides with brush of white and black long setae, middle with three feathery seate bent upright; fovea poorly visible. Sternum, endites, labium and chelicerae russet, with dark mottling. Abdomen fawn, lateral sides and posterior end pale, with dark reticulate pattern patches and stripes, three pairs of large, sclerotized sigillae; venter pale yellow, with three longitudinal dark stripes. Spinnerets long, one thrid length of abdomen, dorsal pair light yellow, with longitudinal black strip laterally.

Legs I robust and thickest, dark red orange and black, swollen femora with

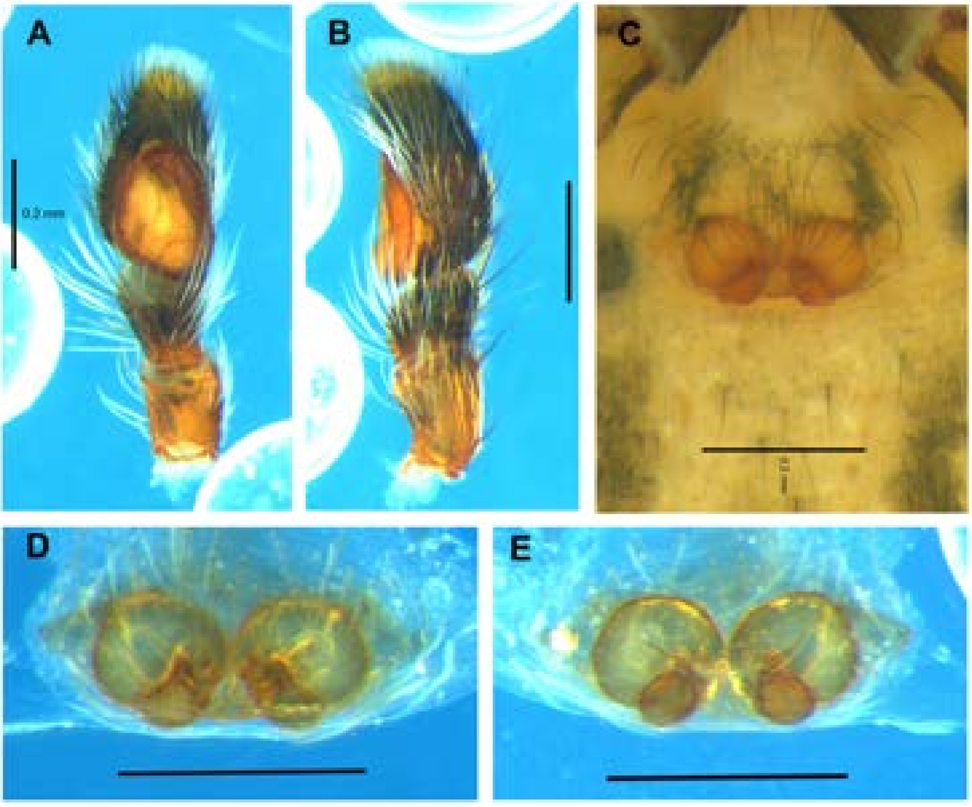

Figure 3.44: Male and female genitalia of *Stertinius aluva* sp. nov. **A**, male left palp, ventral view. **B**, same, retrolateral view. **C**, intact epigyne, ventral view. **D**, epigyne, ventral view. **E**, vulva, dorsal view. Scale bars. **A–E**, 0.2 mm.

long white setae; patella and tibia with bluish iridescent scales dorsally. Legs II–IV fawn to yellowish and banded with dark rings on segment joints. Palps (Figs 3.44A–B). Orange-red, patella tibia and cymbium with bluish iridescent scales dorsally, femora covered with long white seate; embolus short, tip bend, RTA pointed.

FEMALE (Paratype; Figs 3.43, 3.44C–E). Measurements. Carapace 1.20 long, 1.03 wide and 0.70 high at PLE. Chelicera length 0.26. Abdomen 1.78 long, 1.02 wide. Eyes diameters: AME 0.25. ALE 0.11. PME 0.33. PLE 0.94. Eye interdistances: AME–ALE 0.05. PME–PLE 0.27. PME–PME 0.77. Leg formula: 4123

In all details like male except the following: Carapace less darker than males, leg I red-orange, less thicker than males, covered in pale yellow and dark setae, leg II–IV light yellow-brown. Abdomen pale yellow brown, sigillae visible, but less sclerotised, venter with two longitudinal stripes. Epigyne (Figs 3.44C–E). Copulatory opening posteriorly situated; anterior spermathecae round, posterior

Table 3.9: *Stertinius aluva* sp. nov. Measurements of legs and palp

Male	Leg segments	I	II	III	IV	Palp
	Femur	0.85	0.59	0.54	0.69	0.53
	Patella	0.46	0.31	0.25	0.37	0.22
	Tibia	0.57	0.32	0.27	0.41	0.14
	Metatarsus	0.24	0.25	0.28	0.33	–
	Tarsus	0.29	0.27	0.33	0.32	0.36
	Total	2.41	1.74	1.61	2.12	1.25
Female	**Leg segments**	**I**	**II**	**III**	**IV**	**Palp**
	Femur	0.67	0.48	0.44	0.63	–
	Patella	0.29	0.21	0.15	0.31	–
	Tibia	0.31	0.24	0.20	0.35	–
	Metatarsus	0.15	0.18	0.18	0.26	–
	Tarsus	0.24	0.24	0.22	0.27	–
	Total	1.66	1.35	1.19	1.82	–

spermathecae small; fertilisation duct anterolatrally oriented; epigynal pocket small, extending short of mid spermathecae.

Habitat: *S. aluva* sp. nov. were collected from undisturbed thickly vegetated uncultivated plots.

Natural history: The spiders were collected from dried stems and leaves of climber plants hanging from short trees and shrubs, collected by beating method.

Distribution: India: Kerala (Ernakulam and Thrissur districts).

Remarks: First report of the genus from India.

3.3.26.31 *TAMIGALESUS* Żabka, 1988

Tamigalesus is a less species-rich genus distributed in the Oriental region, specifically in the Indian subcontinent (World Spider Catalog, 2021). The genus currently comprises 2 nominal species globally, with a single species known from India (World Spider Catalog, 2021). They are small ground dwellers and are found in great numbers in their habitats.

Diagnosis: *Tamigalesus* species can be distinguished from other salticids by the following combination of characters: Carapace larger than abdomen; male palpal bulb with much elongated proximal bulbus with three terminal mounds; two apophyses on patella and epigynum with pocket near epigastric furrow, lenticular structures adjoining copulatory ducts and spermathecae (Kanesharatnam &

Benjamin, 2020; Żabka, 1988).

Type species: *Tamigalesus munnaricus* Żabka, 1988

Species sampled from the Muriyad Kol Wetland.

Tamigalesus munnaricus Żabka, 1988

(Fig. 3.45)

Tamigalesus munnaricus Żabka, 1988: 468, Figs 129–133 (♂♀); Samson and Sebastian, 2013: 1037, pl. Ia–h (♂); Prószyński, 2017: 129, Fig. 56R (♂♀); Kanesharatnam and Benjamin, 2020: 13, Figs 8A–D, 9A–E, 10A–E, 11A–B, 12A–B (♂♀).

Habitat: *T. munnaricus* were found in all habitats except grasslands and paddy fields.

Natural history: *T. munnaricus* were collected from the ground, they are especially abundant when litter layer is thicker.

***Tamigalesus noorae* sp. nov.**

(Fig. 3.46)

Type: Holotype ♂(CATE 8718A), India, Kerala, Thrissur, Thazhekad (10°19’48.81”N, 76°16’43.32”E), 6 m a.s.l., 15.02.2016, K. S. Nafin. Paratype: ♂(CATE 8718B), same data as holotype.

Etymology: The specific name is a patronym in honour of my mother Noorjahan K. A.

Diagnosis: *Tamigalesus noorae* can be distinguished from *Tamigalesus malabaricus* sp. nov. and *T. munnaricus* by the following characteristics: male palpal embolus shorter and less curved (it is comparatively curved and longer in *T. munnaricus*, shorter and less bend in *Tamigalesus malabaricus*sp. nov.); Tegular mound shape different and presence of a constriction dorsally at the neck(cf. Figs 3.45D–F, 3.48E–G, 3.46B–D); apical lobe of tegulum short (it is longer in *Tamigalesus malabaricus* sp. nov. and *T. munnaricus*); tegulum comparatively wider (it is slightly truncate distally in *Tamigalesus malabaricus* sp. nov.)(cf. Figs 3.45D–F, 3.48E–G, 3.46B–D).

Description: MALE (Figs 3.46A–D). Measurements. Carapace 1.90 long, 1.22 wide and 0.95 high at PLE. Chelicera length 0.44. Abdomen 1.62 long, 0.81

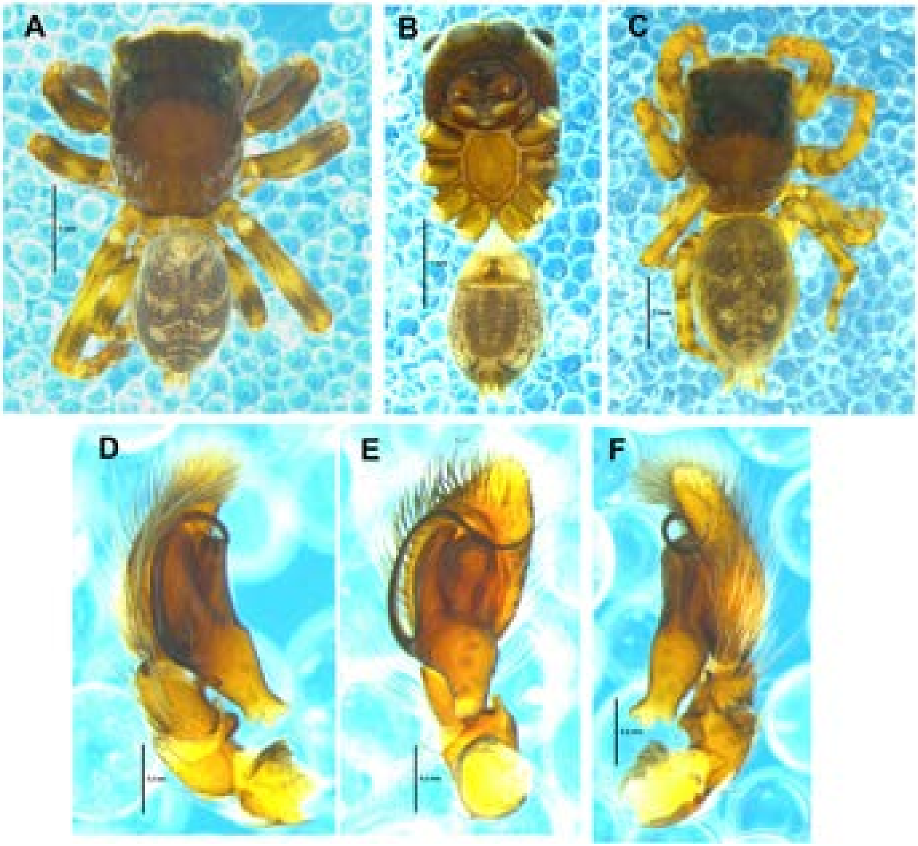

Figure 3.45: Habitus and male palp of *Tamigalesus munnaricus*. Male (**A–B, D–F**) and female (**C**). **A**, general appearance, dorsal view. **B**, same, ventral view. **C**, general appearance, dorsal view. **D**, male left palp, prolateral view. **E**, same, ventral view. **F**, same, retrolateral view. Scale bars. **A–C**, 1 mm **D–F**, 0.2 mm.

wide. Eyes diameters: AME 0.28. ALE 0.19. PME 0.06. PLE 0.25. Carapace elevated, pale yellow and white setae on the ocular region and laterally, ocular surface dark, covered in white setae towards the mid-thorax; chelicerae reddish brown. Fovea short and distinct; sternum reddish brown. All legs yellow-brown, with black bands near segment joints. Abdomen oval, grey with dark mottling, four pairs of pale-yellow spots on dorsum, distinct pattern of light and dark colour on the dorsum, venter grey. Palp (Figs 3.46B–D). Embolus shorter and less curved, tegular mound without distinct lobe and presence of a constriction dorsally at the neck;apical lobe of tegulum extending just above the level of tegulum distally and wider; tegulum comparatively wider distally, RTA stout, short with a pointed tip.

FEMALE (Figs 3.48E–G). In all details like male except the following: Carapce covered in pale yellow setae, ocular area without white setae. All legs yellow, with dark bands in the joints of the articles. Epigyne (not separated) with short pocket, copulatory opening small (Fig. 3.46G).

Natural history: The spiders were collected from the ground by hand.

Distribution: India: Kerala (Thrissur).

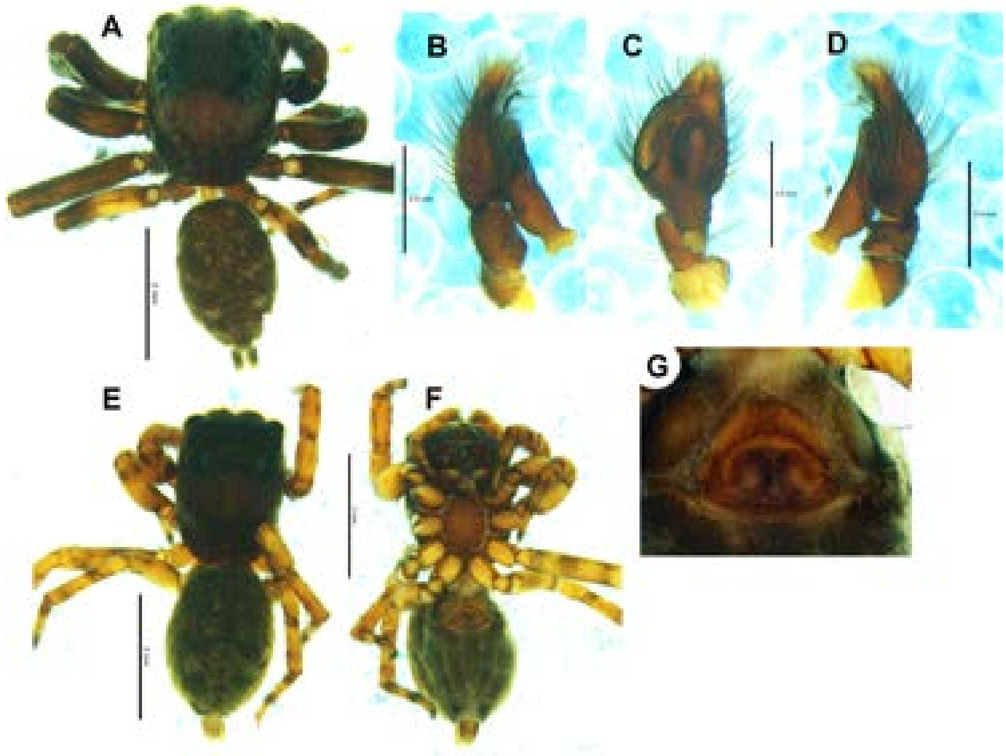

Figure 3.46: Holotype male and paratype female of *Tamigalesus noorae* sp. nov. Male (**A–D**) and female (**D–F**). **A, E**, general appearance, dorsal view. **B**, left palp, prolateral view. **C**, same, ventral view. **D**, same, retrolateral view. **F**, general appearance, ventral view. **G**, epigyne. Scale bars. **A, E, F**, 2 mm. **B–D**, 0.5 mm.

Tamigalesus malabaricus sp. nov.
(Figs 3.47 and 3.48)

Type: Holotype ♂(CATE 8717A), India, Kerala, Thrissur, Muriyad (10°24´39.80″N, 76°13´56.60″E), 4 m a.s.l., 4.06.2015, K. S. Nafin. Paratype: 1 ♂(CATE 8717B), same data as holotype.

Other material: 3♂(ADSH975662), India: Kerala: Parambikulam Tiger Reserve: Karimala (10°22´00.26″N, 76°44´33.64″E), 1422 m a.s.l., 14.08.2015, Jimmy Paul & K. S. Nafin.

Etymology: The specific name refers to the Malabar coast of India where the type locality is located.

Diagnosis: See diagnosis for *Tamigalesus noorae* sp. nov.

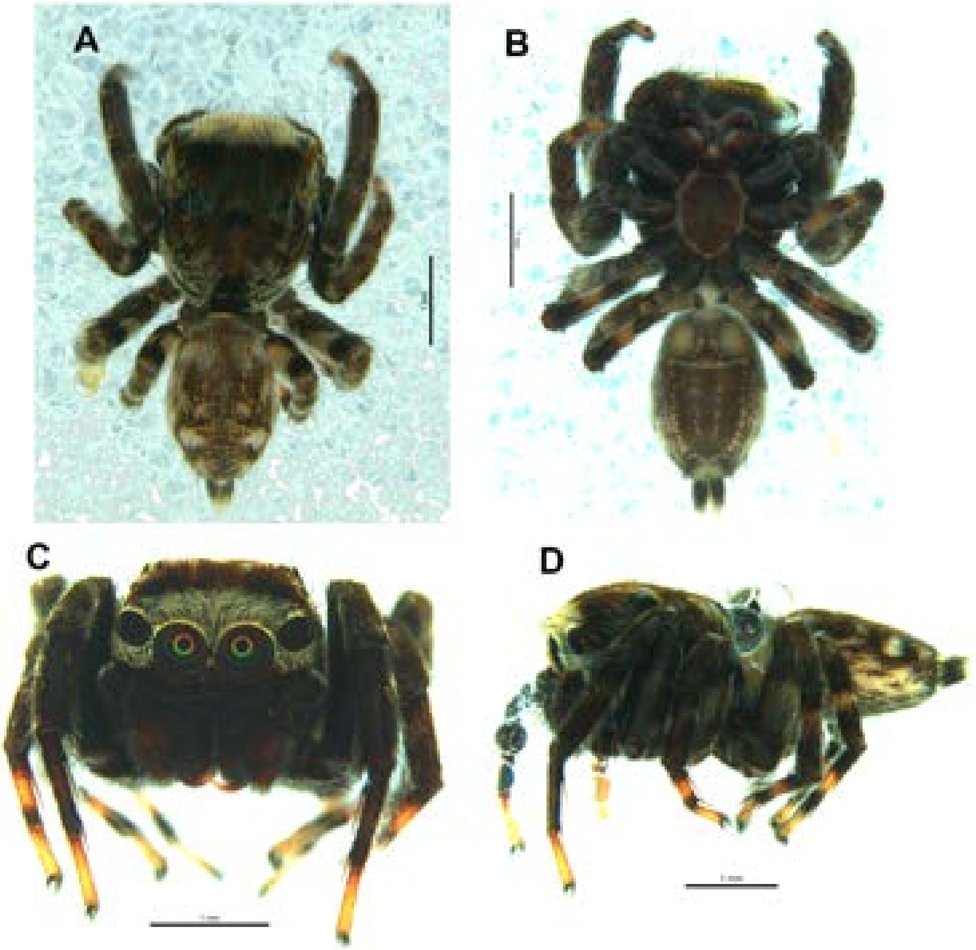

Figure 3.47: Holotype male of *Tamigalesus malabaricus* sp. nov. **A**, general appearance, dorsal view. **B**, same, ventral view. **C**, carapace, frontal view. **D**, general appearance, lateral view. Scale bars. **A–D**, 1 mm.

Description: MALE (Figs 3.47A–D, 3.48A–B, E–G). Measurements. Carapace 1.870 long, 1.32 wide and 0.92 high at PLE. Chelicera length 0.33. Abdomen 1.55 long, 0.81 wide. Eyes diameters: AME 0.22. ALE 0.15. PME 0.07. PLE 0.27. Carapace covered with pale white, red-brown and white setae, ocular region covered with thick band of pale white setae; chelicerae reddish brown. Fovea not visible; sternum reddish brown. All legs dark red-brown, except all tarsi and metatarsi II–IV, femur thickly covered with white, red-brown setae, with banded appearance; coxae dark brown.

Abdomen oval, orange-brown, covered with pale fawn, and dark setae, white spots formed of white seate on the dorsum and lateral sides; venter brown with two longitudinal dotted stripes medially. Palp (Figs 3.48E–G). Embolus shorter and less curved, tegular mound with two distinct lobe; apical lobe of tegulum shorter

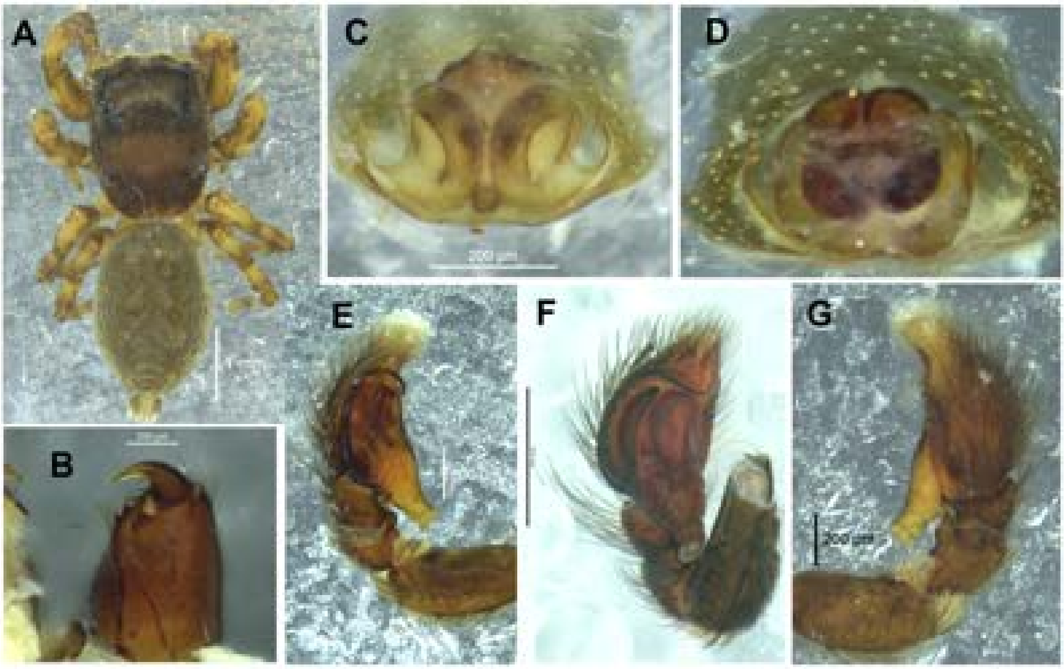

Figure 3.48: Paratype female and genitalia of *Tamigalesus malabaricus* sp. nov. **A**, paratype female, dorsal view. **B**, same, chelicerae. **C**, epigyne, ventral view. **D**, vulva, dorsal view. **E**, male left palp, prolateral view. **F**, same, ventral view. **G**, same, retrolateral view. Scale bars. **A**, 1 mm. **B–E, G**, 0.2 mm. **F**, 0.5 mm.

than the main tegulum; RTA short with a pointed tip.

FEMALE (Figs 3.48A–D). Measurements. Carapace 1.98 long, 1.43 wide and 0.89 high at PLE. Chelicera length 0.27. Abdomen 1.90 long, 0.90 wide. Eyes diameters: AME 0.19. ALE 0.14. PME 0.07. PLE 0.25. In all details like male except the following: Carapace covered in fawn setae, ocular area without band of white setae, it is dark instead. All legs yellow, with dark brown bands. Abdomen brown to grey, covered in pale yellow setae. Epigyne (Figs 3.48C–D). Epigyne with short pocket, copulatory opening large, spermathecae round and large, fertilisation duct originating posteriorly and oriented laterally.

Natural history: The spiders were collected from the ground by hand.

Distribution: India: Kerala (Thrissur and Palakkad).

3.3.26.32 *TELAMONIA* Thorell, 1887

Telamonia is a less species-rich genus distributed in the Oriental and Ethiopian regions (World Spider Catalog, 2021). The genus currently comprises 41 nominal species globally, with 3 species known from India (World Spider Catalog, 2021).

Diagnosis: *Telamonia* species can be distinguished from *Epeus*, *Phintella* and others by the following characters: Presence of short thick bristles on the lateral edges of the cymbium of the male pedipalp. Epigyne usually dome-shaped, with a pair of dark orifices separated by a pair of ducts medially (Barrion & Litsinger, 1995).

Type species: *Telamonia festiva* Thorell, 1887

Species sampled from the Muriyad Kol Wetland.

Telamonia dimidiata (Simon, 1899)
Figs 3.A.11D and 3.A.11E

Viciria dimidiata Simon, 1899: 118 (♂).

Phidippus pateli Tikader, 1974: 124, Figs 10–11 (♀).

Telamonia dimidiata Prószyński, 1984b: 428, Figs 29–32 (♂♀, T from *Viciria*).

Telamonia dimidiata Prószyński, 1992: 207 (Synonymy of *Phidippus pateli*).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *T. dimidiata* was found in the foliages in all the habitats in the study area, except paddy fields and grass lands.

Natural history: *T. dimidiata*, commonly called two-striped jumping spider, are medium-sized spiders commonly spotted in home gardens and agricultural plots. The females are pale yellow with white cephalic region, while the males are darker, with white markings. Adult males are larger compared to the females.

3.3.26.33 *THIANIA* Thorell, 1887

Thiania is a less species-rich genus distributed in the Oriental region and introduced to Nearctic region (World Spider Catalog, 2021). The genus currently comprises 23 nominal species globally, with one species known from India (World Spider Catalog, 2021).

Diagnosis: *Thiania* species can be distinguished by the following characters: Broad flattened carapace and slender abdomen; palpal organ thick, apophysis big, laterally hooked; lateral surface of bulb with seminal reservoir, base of embolus strongly sclerotized plate, frequently with a conductor; epigyne big, two depressions divided by a median ridge, copulatory openings slit-like. vulva with distinct accessory glands, spermathecae oval or pear-shaped (Żabka, 1985).

Type species: *Thiania pulcherrima* C. L. Koch, 1846

Species sampled from the Muriyad Kol Wetland.

Thiania bhamoensis Thorell, 1887
Fig. 3.A.11F

Euophrys chiriatapuensis Tikader and Malhotra, 1981: 101, Figs 183–184 (♀).

Thiania bhamoensis Sen, Dhali, et al., 2015: 37, Figs 112–116, pl. 13 (♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *T. bhamoensis* was found in the foliages in uncultivated and riparian areas.

Natural history: *T. bhamoensis* are covered in irridisent scales and endowed with a beautiful pattern on their body. They are found foraging on the surfaces of leaves.

3.3.27 FAMILY SCYTODIDAE Blackwall,1864

SPITTING SPIDERS

Family Scytodidae represents small to medium sized araneomorphs, ecribellate, haplogyne, three clawed, six-eyed , with pantropical distribution (Jocqué & Dippenaar-Schoeman, 2006). Commonly known as spitting spiders, they are wandering spiders found in varied habitats. Some species are synanthropic. Members of the family overpower their prey by spurting glue onto them, hence the name spitting spiders. Females carry the egg sac in chelicerae. The family currently has 245 species in 5 genera globally, and 12 of them are known from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following characters: Carapace domed towards the thorax, fovea absent; eyes small, in widely spaced diads, contigious in each pair; chelicerae basally fused, very short fangs; metatarsi longer than tarsi; abdomen broad, oval; colulus large, ointed, anterior spinnerets contigious; epigyne simple, with clasping holes behind the epigastric fold; male palpal bulb large or small, lacks basal haematodocha, embolus basally slender (Jocqué & Dippenaar-Schoeman, 2006).

Type genus: *Scytodes* Latreille, 1804

3.3.27.1 *SCYTODES* Latreille, 1804

Scytodes is a specious genus with a cosmopolitan distribution (World Spider Catalog, 2021). The genus currently comprises 225 nominal species globally, with 10 species known from India (World Spider Catalog, 2021).

Diagnosis: *Scytodes* species can be distinguished the following characters: Carapace without fovea or thoracic impressions, hump posteriorly; eyes whitish to light colored, arranged in three widely spaced diads; abdomen is ovoid to subglobular; spinnerets small and preceded by a projecting slightly conical colulus; epigynum absent, represented by oblique sclerotized pits Barrion and Litsinger, 1995.

Type species: *Scytodes thoracica* (Latreille, 1802)

Species sampled from the Muriyad Kol Wetland.

Scytodes fusca Walckenaer, 1837
Fig. 3.A.11H

Scytodes fusca Walckenaer, 1837: 272 (♂♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Scytodes fusca* were found in cracks on barks and inside buildings.

Natural history: *Scytodes fusca* are nocturnal and rests inside their retreat inside cracks or openings on the walls of buildings. The spiders comes out and waits immediately outside the retreat for ambushing unsuspecting prey such as ants, insects and other invertebrates.

Scytodes thoracica (Latreille, 1802)
Fig. 3.A.12A

Scytodes thoracica Audouin, 1826: 378, pl. 5, Fig. 1 (♀); Walckenaer, 1837: 270 (♂♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Scytodes thoracica* were found on the surface of soil in habitats surrounding the wetlands.

3.3.28 FAMILY SICARIIDAE Keyserling, 1880

VIOLIN SPIDERS

Family Sicariidae represents medium sized to large araneomorphs, ecribellate, haplogyne, thwo clawed, six eyed, distributed in Neotropics, temperate and tropical regions of Old World (Jocqué & Dippenaar-Schoeman, 2006). They are commonly known as violin spiders, and they are known for their necrotic bites. Family comprises of both wandering and ground-welling species. The venom of these spiders are highly haemolytic and dermonecrotic, species like *Loxosceles reclusa* or brown recluse spider are considered medically significant for their venom in North America. Loxoscelism is the only proven necrotic arachnidism found in humans, is a condition occassionally produced by recluse spider (*Loxosceles*) bites (Swanson & Vetter, 2006). The family currently represents 169 species in 3 genera globally, and only one is known from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following characters: Carapace flat, longer than wide, conspicuous, deep fovea (*Loxosceles*); chelicerae joined basally, semi-chelate, without condyle, with stridulatory file; legs with many serrated bristles borne on a onychium, clothed in sickle-shaped setae, long and slender in *Loxosceles*; abdomen depressed, clothed with sickle-shaped setae (*Sicarius*) or barbed spine-like setae (*Loxosceles*); colulus conspicuous and pointed; epigyne with a single broad opening in *Loxosceles*, paired vulva; male palpal bulb small, embolar base conical, conductor absent (Jocqué & Dippenaar-Schoeman, 2006).

Type genus: *Sicarius* Walckenaer, 1847.

3.3.28.1 *LOXOSCELES* Heineken & Lowe, 1832

Loxosceles is a moderately species-rich genus with a cosmopolitan distribution (World Spider Catalog, 2021). The genus currently comprises 140 nominal species globally and one cosmopolitan species,*Loxosceles rufescens* (Dufour, 1820), is found in India (World Spider Catalog, 2021).

Diagnosis: *Loxosceles* species can be distinguished by the following combination of characters: Eyes six, forming transverse row, in three diads; epigyne haplogyne with single opening; palp with simple bulb lacking hematodocha, bearing thin embolus and lacking conductory or accessory elements (Gertsch & Ennik, 1983).

Type species: *Loxosceles citigrada* Heineken & Lowe, 1832

Loxosceles rufescens (Dufour, 1820)

Fig. 3.A.12B

Loxosceles citigrada Heineken & Lowe, in Lowe, 1832: 322, pl. 48, Figs 1–14 (♂♀).

Loxosceles rufescens Bösenberg and Strand, 1906: 113, pl. 6, Fig. 69, pl. 16, Fig. 450 (♂♀); Caleb, 2020: 15743, Figs 21A–H, 29N (♂♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *L. rufescens* were collected from shady areas inside buildings.

Natural history: *L. rufescens* or the mediterranean recluse spider is nocturnal and usually set out at night to capture prey. Bites can cause necrosis and widespread sytemic damage, referred to as loxoscelism.

3.3.29 FAMILY SPARASSIDAE Bertkau,1872

HUNTSMAN SPIDERS

Family Sparassidae represents medium-sized to very large araneomorph spiders,ecribellate, entelegyne, two clawed, eight-eyed, with cosmopolitan distribution (Jocqué & Dippenaar-Schoeman, 2006). They are commonly known as huntsman spiders, and are nocturnal, wandering spiders that are found on plants, soil surface or in caves. Huntsman spider known for their speed and their mode of hunting got them the name. They utilize their venom to immobilize prey and are also known to inflict unpleasant defensive bites on humans. The family currently has 1253 species in 89 genera globally, and 84 of them are known from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following characters: Carapace broadly oval, as long as wide, eye region narrow, fovea present, dense covering os setae; eyes in two rows; chelicerae free, both rows with teeth; legs laterigrade, trochanteres notched, dense claw tufts, distal metatarsi with soft trilobate membrane; abdomen oval or round; colulus absent; epigyne conspicuous and sclerotized, male palp provided with strong tibial apophysis, tegulum with conductor (Jocqué & Dippenaar-Schoeman, 2006).

Type genus: *Micrommata* Latreille , 1804

3.3.29.1 *HETEROPODA* Latreille, 1804

Heteropoda is a specious genus mostly distributed in the Oriental and Australian regions, and a few species in the Neotropical and Palearctic regions (World Spider Catalog, 2021). The genus currently comprises 189 nominal species globally, with 23 species known from India (World Spider Catalog, 2021).

Diagnosis: *Heteropoda* can be distinguished from other Heteropodinae by the following characters: Males possess sheath-like conductor and the filiform embolus, RTA arises distally at the male palpal tibia; females copulatory ducts wound at least one spiral; spermathecae consist of internal wound ducts (Jäger, 2020).

Type species: *Heteropoda venatoria* (Linnaeus, 1767)

Species sampled from the Muriyad Kol Wetland.

Heteropoda venatoria (Linnaeus, 1767)
Fig. 3.A.12C

Heteropoda venatoria Bösenberg and Strand, 1906: 273, pl. 6, Fig. 64, pl. 16, Fig. 453 (♂♀). (For complete list of references, see World Spider Catalog, 2021)

Habitat: *H. venatoria* are present in all habitats of the study area.

Natural history: Adult females of *H. venatoria* are larger than the males. They are very commonly sighted in human inhabitations and wooded areas. They are commonly known as giant crab spider, or cane spider.

Other species sampled:
***Heteropoda* sp. 1**

3.3.29.2 *OLIOS* Walckenaer, 1837

Olios is a specious genus with a widespread distribution(World Spider Catalog, 2021). The genus currently comprises 177 nominal species globally, with 21 species known from India (World Spider Catalog, 2021).

Diagnosis: *Olios* species can be distinguished from other Sparassinae by the following characters: Males with tegular apophysis, membranous conductor without specific shape, simple, distally arising RTA; females epigyne simple with median septum usually visible only in posterior half close to epigastric furrow, vulva with copulatory openings situated medially, first winding laterad and a widened part (Jäger, 2020).

Type species: *Olios argelasius* (Walckenaer, 1806).

Species sampled from the Muriyad Kol Wetland.

Olios milleti (Pocock, 1901)
Fig. 3.A.12D

Sparassus milleti Pocock, 1901: 494 (♂).

Olios milleti Gravely, 1931: 244, Figs 5G, 6F (♂♀). Sethi and Tikader, 1988: 35, Figs 163-168 (♂♀). (For complete list of references, see World Spider Catalog, 2021)

Habitat: *Olios milleti* were found in the foliages in the wooded areas.

Natural history: *Olios milleti* are nocturnal and are usually found foraging on the branches of trees in gardens, plantations and other naturally wooded areas. Their larger size mean their bites are painful. Retreats made out of bend leaves edges with silken covering and they rest inside with legs held close together.

3.3.29.3 *PANDERCETES* L. Koch, 1875

Pandercetes is a less species-rich genus distributed in the Oriental and Australian regions (World Spider Catalog, 2021). The genus currently comprises 17 nominal species globally, with a single species known from India (World Spider Catalog, 2021). Most species live on tree barks and known for their camouflage and resemble *Hersilia* spp. (Hersiliidae) from their habit and behaviour.

Diagnosis: *Pandercetes* species can be distinguished by the following characters: Head region with eyes in both sexes is elevated; males palp with irregular distal coils of the embolus and a membranous conductor, females vulva with screw-like copulatory ducts (Jäger, 2002).

Type species: *Pandercetes gracilis* L. Koch, 1875.

Species sampled from the Muriyad Kol Wetland.

***Pandercetes* sp.**

3.3.29.4 *THELCTICOPIS* Karsch, 1884

Thelcticopis is a less species-rich genus mostly distributed in the Oriental region, and some species in the Ethiopian, Oceanian and Palearctic regions (World Spider Catalog, 2021). The genus currently comprises 50 nominal species globally, with 10 species known from India (World Spider Catalog, 2021).

Diagnosis: *Thelcticopis* species can be distinguished by the following combination of characters: carapace longer than wide and convex laterally; posterior eye row procurved, lateral eyes close to one another; anterior medians larger than the laterals; MOQ narrower in front than behind; retromargins of chelicerae with five or six small teeth each; spinnerets supported on a membranous stalk, strengthened by a hairy chitin (Barrion & Litsinger, 1995).

Type species: *Thelcticopis severa* (L. Koch, 1875)

Species sampled from the Muriyad Kol Wetland.

Thelcticopis moolampilliensis Sunil Jose & Sebastian, 2007
Fig. 3.A.12E

Thelcticopis moolampilliensis Sunil Jose and Sebastian, 2007: 42, Figs 1A–E (♀).

Habitat: *T. moolampilliensis* were found in the foliages of trees and shrubs.

3.3.30 FAMILY TETRAGNATHIDAE Menge, 1866

WATER ORB WEAVERS

Family Tetragnathidae represents small to very large, araneomorph, ecribellate, entelegyne or secondary haplogyne, three-clawed, eight-eyed spiders with cosmopolitan distribution (Jocqué & Dippenaar-Schoeman, 2006). They are commonly known as water orb weavers and most of them build webs in grassy or bushy areas near water (Barrion & Litsinger, 1995). The family currently has 978 species in 48 genera globally (World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following characters: Carapace longer than wide, chelicerae with with rows of large teeth and strong projecting spurs; comparatively simple male genitalia, with large paracymbium and often with cymbial processes, conductor and apically coiled embolus;

median apophysis absent.

Type genus: *Tetragnatha* Latreille, 1804.

3.3.30.1 *GLENOGNATHA* Simon, 1887

Glenognatha is a moderately species-rich tetragnathid genus having a broad distribution range, with records in Nearctic, Neotropic, Afrotropic, Indo-Malaya, Oceania and Paleartic regions (Cabra-García & Brescovit, 2016). The genus currently has 34 nominal species and only one species is known from India (World Spider Catalog, 2021).

Diagnosis: *Glenognatha* species can be distinguished from other tetragnathids by the following combination of characters: Carapace longer than wide, sternum as wide as long and prolonged between coxae in some species, labium trapezoidal, wider than long, and rebordered, cheliceral boss well developed, legs without spines (except in *G. hirsutissima*), abdomen oval to spherical, epigyne slit-shaped with sclerotized edges, internal genitalia is haplogyne with the following structures: a membranous chamber, a large uterus externus and a pair of copulatory ducts leading to the spermathecae (Cabra-García & Brescovit, 2016). Males of *Glenognatha* are similar to that of *Pachygnatha* by having a conductor with a retrolateral apophysis, but can be distinguished by the presence of the following: paracymbium with the distal portion oriented in opposite direction to the cymbium, folded retrolateral apophysis on the conductor lamina and the embolus with a medial groove in its basal portion (Cabra-García & Brescovit, 2016).

Type species: *Glenognatha emertoni* Simon, 1887

Species sampled from the Muriyad Kol Wetland.

Glenognatha dentata (Zhu & Wen, 1978)

Fig. 3.A.12F

Dyschiriognatha dentata Zhu and Wen, 1978: 16, Figs 1–9 (♂♀); Hu, 1984: 133, Figs 135.1–8 (♂♀); Chen and Gao, 1990: 74, Figs 93a–e (♂♀);Okuma, 1991: 15, fig. 1, 2A–F, 3A (♂); Okuma, Kamal, et al., 1993: 31, Figs 28A–C (♂).

Dyschiriognatha hawigtenera Barrion and Litsinger, 1995: 490, Figs 300a–e, 301a–g (♂♀); Song et al., 1999: 213, Figs 119 O–R (♂); Zhu, Song, and Zhang, 2003: 204, Figs 111A–K, 112A–G, pl. VIIA–D (♂♀); Tanikawa, 2007: 103, Figs 364–365, 812–814 (♂♀); Tanikawa, 2009: 412, Figs 49–51 (♂); Cabra-García, Hormiga, et al., 2014: 1029, Figs 1E, 2C, F, 5D, 7C (♀).

Glenognatha dentata Cabra-García and Brescovit, 2016: 53, Figs 38A–H, 39A–F, 40A–H, 41A–G, 42A–H, 43A–J, 44A–F

Habitat: Paddy fields and grasslands.

Natural history: *G. dentata* is commonly seen in the lower section of the paddy plant. The spider finds refuge in between stems of the paddy and builds web among the tillers of the adjacent plants.

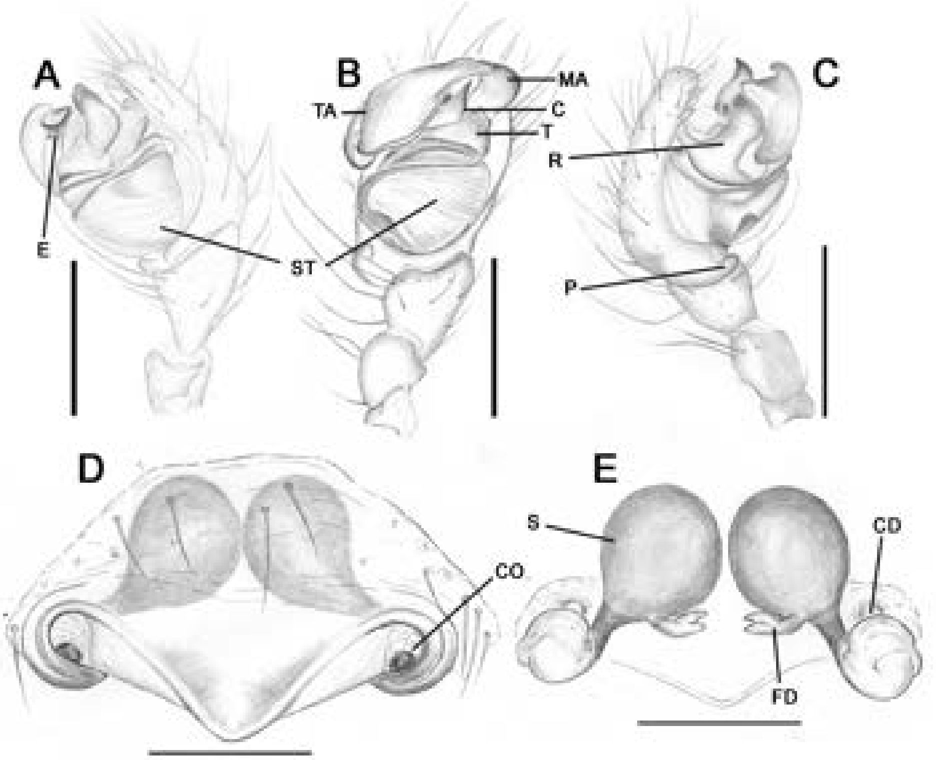

Figure 3.49: Male and female genitalia of *Guizygiella nadleri*. **A**, male left palp, prolateral view. **B**, same, ventral view. **C**, same, retrolateral view. **D**, Epigyne, ventral view. **E**, vulva, dorsal view. Abbreviations: C—conductor, CD—copulatory duct, CO—-copulatory opening, E—-embolus, FD—fertilization duct, H—hematodocha, MA—median apophysis, R—radix, TA—terminal apophysis, P—paracymbium, T—tegulum. Scale bars. **A–C**, 0.5 mm. **D–E**, 0.1 mm.

3.3.30.2 *GUIZYGIELLA* Zhu, Kim & Song, 1997

Genus *Guizygiella* is a less species-rich genus distributed in the South and South East Asia (World Spider Catalog, 2021). The genus is represented by 6 nominal species and 3 are currently known from India (World Spider Catalog, 2021).

Diagnosis: *Guizygiella* species can be distinguished from other tetragnathids by the following combination of characters: Eyes of anterior row about equally spaced, but PME–PME smaller than PME–PLE, median ocular area wider than long, wider in front than behind; chelicerae without lateral condyles, with four promarginal teeth and three retromarginal teeth; epigyne sclerotized, posterior half with quadrangular vestibulum. Male palpal tibia with two spines, embolus with a basal process, cymbium with a large process, very small paracymbium (Zhu, Kim, et al., 1997).

Type species: *Tetragnatha extensa* (Linnaeus, 1758)

Species sampled from the Muriyad Kol Wetland.

Guizygiella nadleri (Heimer, 1984)
Figs 3.A.12G and 3.A.12H

Zygiella nadleri Heimer, 1984b: 95, Figs 1–6; (♂♀)

Zygiella x-notata Feng, 1990: 102, Figs 77.1–2 (♀)

Zygiella melanocrania Yin, Wang, Xie, et al., 1990: 138, Figs 344–346 (♀)

Zygiella nadleri Zhu and Zhang, 1993: 40, Figs 28–31 (♂♀); Song et al., 1999: 229, Figs 130A–C (♂♀).

Guizygiella nadleri Zhu, Song, and Zhang, 2003: 48, Figs 19A–J, pl. IA–D; Yin, Peng, et al., 2012: 430, Figs 192a–f (♂♀).

Remarks: First report from India.

Habitat: *Guizygiella nadleri* can be seen on the vegetation associated with the wetlands.

Natural history: Colour variants were observed in the field, with the abdomen displaying white to reddish tinge colouration.

Distribution: India (New record), China, Laos and Vietnam (World Spider Catalog, 2021).

3.3.30.3 *LEUCAUGE* White, 1841

Leucauge is a species-rich genus with a pan-tropical distribution and a few occurrences in temperate regions (World Spider Catalog, 2021). The genus is represented by 171 nominal species globally and only 10 species are currently known from India (World Spider Catalog, 2021). Spins large vertical to almost horizontal webs in vegetation, in damp places such as marshes or rainforest. Several species of this genus spin webs both in the morning and during the day and occasionally re-use the frame and anchor lines (Sebastian & Peter, 2009).

Diagnosis: *Leucauge* species can be distinguished from other tetragnathids by the following combination of characters: Carapace truncate anteriorly, thoracic furrow deep and posteriorly directed, two parallel rows of feathered trichobothria on the IV femoral ectal surface; abdomen nearly twice as long as wide, epigastric plate without any furrow, spermathecae walls translucent and weakly sclerotized, fertilization ducts coiled around the copulatory ducts; palp equipped with flagelliform embolus with an elongated base, conductor apically projected, sperm duct with more than four switchbacks (Álvarez-Padilla & Hormiga, 2011).

Type species: *Leucauge venusta* (Walckenaer, 1841).

Species sampled from the Muriyad Kol Wetland.

Leucauge decorata Gravely, 1921

Fig. 3.A.13A

Tetragnatha decorata Blackwell, 1864: 44 (♀); Pickard-Cambridge, 1869a: 389, pl. 13, fig. 61–68 (♂♀).

Leucauge decorata Song et al., 1999: 216, fig. 121H–I, 122E–F, 130L–M (♂♀); Gajbe, 2007: 509, fig. 263–265 (♀); Sen, Dhali, et al., 2015: 102, fig. 595–600, pl. 21 (♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: Common in all wetland habitats.

Natural history: *Leucauge decorata* were observed in the bushes, lower branches of trees in the wetland and lining the paddy fields. Mating pairs were observed copulating on a more or less horizontal strand of web in the bushes.

3.3.30.4 *TETRAGNATHA* Latreille, 1804

Genus *Tetragnatha* is a species-rich genus with a widespread distribution with species found in tropical, temperate, and arctic climates, and is common in wetland ecosystems (Álvarez-Padilla, Dimitrov, et al., 2009; Barrion & Litsinger, 1995; World Spider Catalog, 2021). They are the most diverse in the tropics (Álvarez-Padilla, Dimitrov, et al., 2009).The genus is represented by 333 nominal species globally, but only 18 are currently known from India (World Spider Catalog, 2021). Many species construct orb webs usually in vegetation near or above water bodies.

Diagnosis: *Tetragnatha* species can be distinguished from other Tetragnathids by the following combination of characters: Body prominently long and narrow, several times longer than wide; carapace oval, widest near the middle, flattened above, with a conspicuous thoracic groove; eye rows either parallel or converge or diverge, but lateral eyes never contiguous, each eye surrounded by a black ring. Chelicerae well developed, especially in the males; margins of fang furrow provided with numerous teeth; in males a strong projecting clasping spur may or may not be bifid at its tip. Maxillae parallel, long and dilated at the distal ends. Abdomen at least twice as long wide, in females often swollen at base, often base is slightly bifid and overhangs cephalothorax. Epigynal slit posterior to lung slits in the procurved epigastric furrow, spinnerets usually terminal or almost so. Legs and palpi very long and thin, but proportion differs in various species.

Type species: *Tetragnatha extensa* (Linnaeus, 1758)

Species sampled from the Muriyad Kol Wetland.

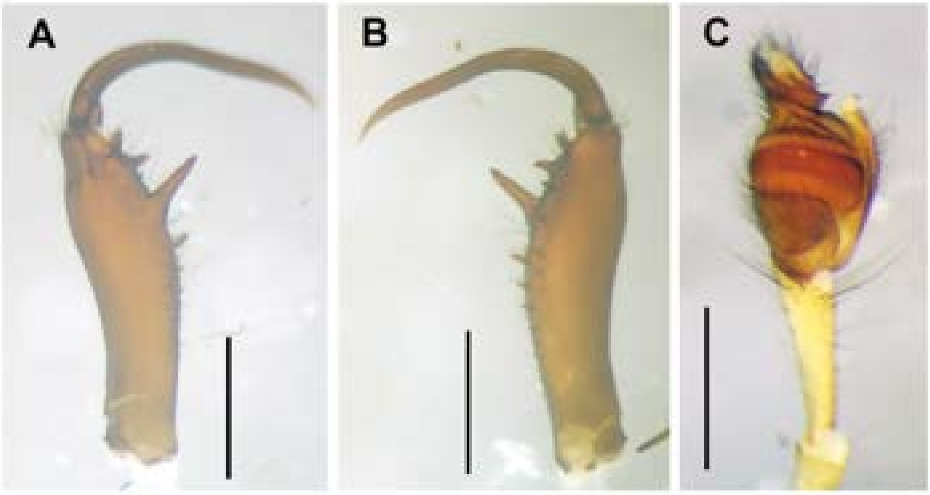

Figure 3.50: Male of *Tetragnatha ceylonica*. **A**, chelicerae, promargin. **B**, same, retromargin. **C**, left palp, ventral. Scale bars. **A**–**C**, 0.5 mm.

Tetragnatha cochinensis Gravely, 1921

Figs 3.51 to 3.53

Tetragnatha cochinensis Gravely, 1921a: 442, Figs 4a–b (♂♀, mistaken identity of sex)

Remarks: Gravely, 1921a described *T. cochinensis* based on type material collected from Parambikulam (Palani hills), and other collections from Coonoor

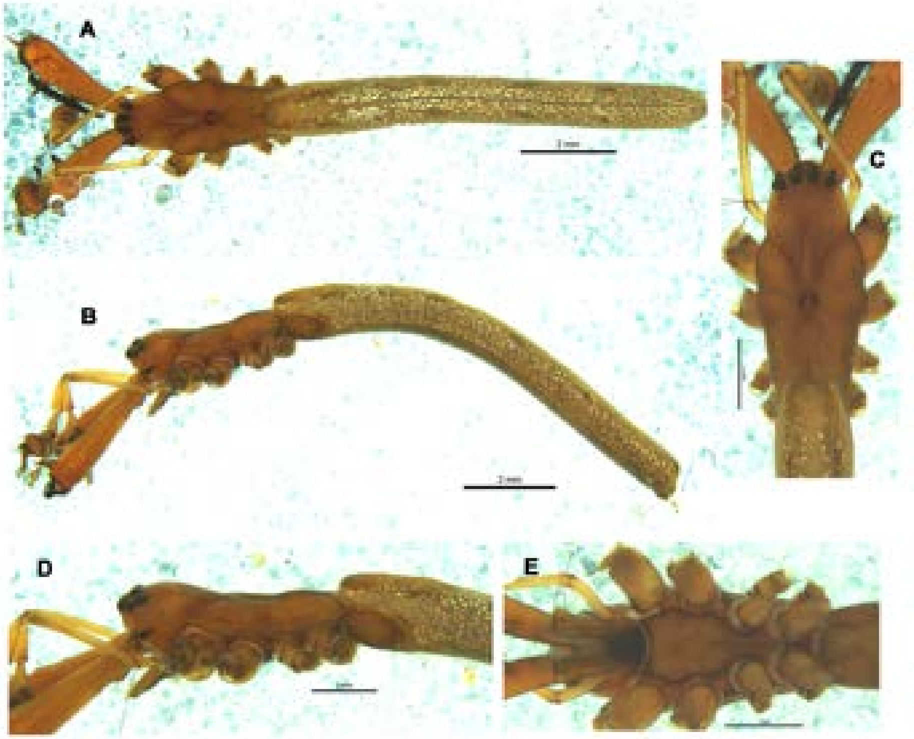

Figure 3.51: Male habitus of *Tetragnatha cochinensis.* **A**, general appearance, dorsal view. **B**, same, lateral view. **C**, carapace, dorsal. **D**, same, lateral view. **E**, sternum. Scale bars. **A**–**B**, 2 mm. **C–E**, 1 mm.

(Nilgiri hills), Thrissur and Ernakulam. New materials collected from Muriyad Kol wetlands, Parambikulam Tiger Reserve and Attapadi hills revealed that there is mismatch of sexes in the original description.

Types: Holotype male and female, deposited at Zoological Survey of India, Kolkatta, Not examined.

Material examined: 1 ♂, India: Kerala, Muriyad (10°24’39.80”N, 76°13’56.60”E), 1 m a.s.l., 13.4.15, K.S. Nafin; 1 ♂, 2 ♀♀, Parambikulam Tiger Reserve (10°23’54.36”N, 76°46’28.99”E), 700 m a.s.l, 15.9.14, K.S. Nafin, Jimmy Paul & P.P. Sudhin; 2 ♂♂, 2 ♀♀, Mukkali, Attapadi (11° 3’54.61”N, 76°32’15.02”E), 650 m a.s.l, 28.1.16, K.S. Nafin & P.P. Sudhin.

Redescription: MALE (Figs 3.51 and 3.52). Measurements. Carapace 3.35 long, 1.56 wide. Chelicera length 3.47. Abdomen 9.76 long, 1.03 wide. Eye interdistances: AME–AME 0.14 AME–ALE 0.19. PME–PLE 0.21. PME–PME 0.21. AER and PER almost equal in width, viewed from top both are recurved, parallel, ocular quadrangle is almost square, slightly wider posteriorly. Abdomen elongate, cylindrical, with five pairs of dark spots longitudinally. Chelicerae as in

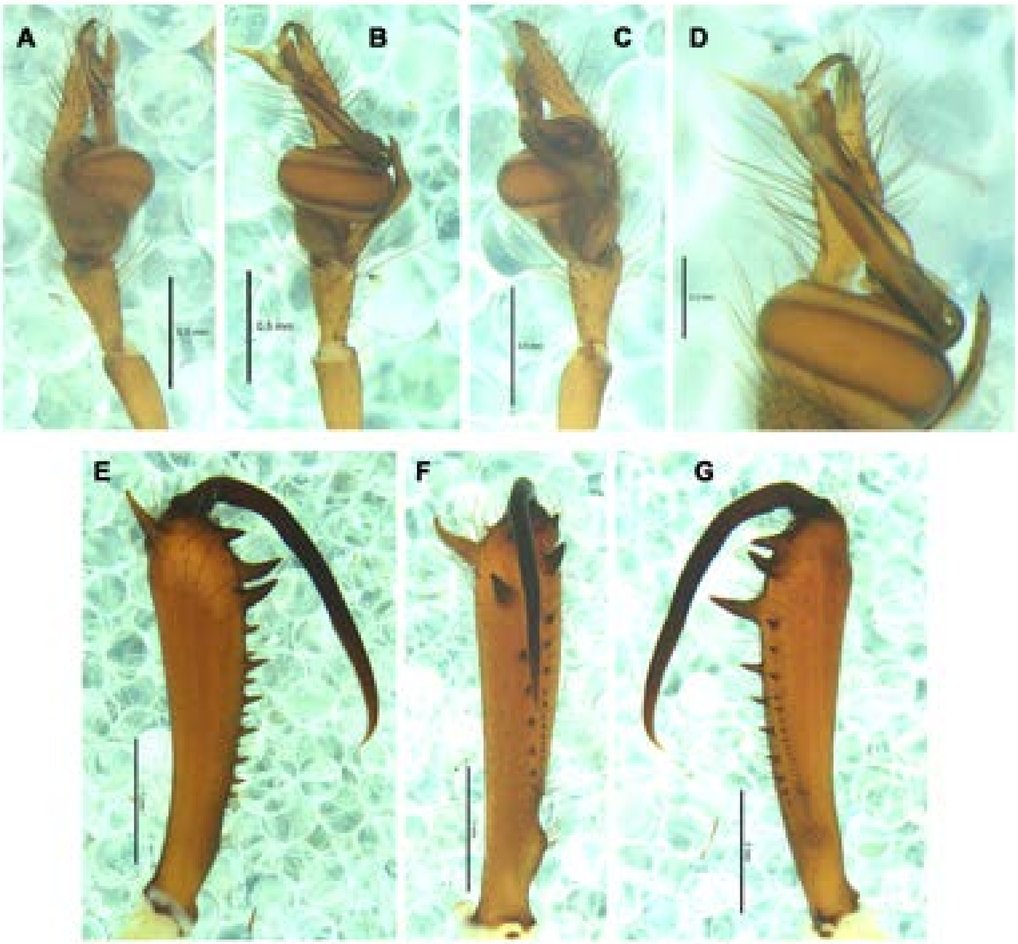

Figure 3.52: Male palp and chelicerae of *Tetragnatha cochinensis*. **A**, left palp, prolateral view. **B**, same, ventral view. **C**, same, retrolateral view. **D**, close up, ventral view. **E**, chelicerae, promargin. **F**, same, median view. **G**, same, retromargin. Scale bars. **A**–**B**, 0.5 mm. **C**, 0.2 mm. **E**–**G**, 1 mm.

Figs 3.52E–G (Terminology as per Castanheira et al., 2019). chelicerae as long as carpace, slender, long; male dorsal apophysis (a) bend, tip blunt; remaining teeth on the upper row (rsu) numbering 7 teeths, rsi greater than 10 teeths, elongated tooth on the upper row (T) present, pointed; t present; AXl present, small and close to fang base. Palp as in Figs 3.52A–D.

Description: FEMALE (Figs 3.53A–I). Measurements. Carapace 3.18 long, 1.63 wide. Chelicera length 3.09. Abdomen 10.57 long, 1.28 wide. Eye interdistances: AME–AME 0.13 AME–ALE 0.18. PME–PLE 0.19. PME–PME 0.19. In all details like male except the following: Abdomen wide and high anteriorly, dark spots present posteriorly. Chelicerae as in Figs 3.53F–I. CRu not prominent, CRl absent, Gu and Gl small, L2 away from Gl. Fang with basal and median cusps.

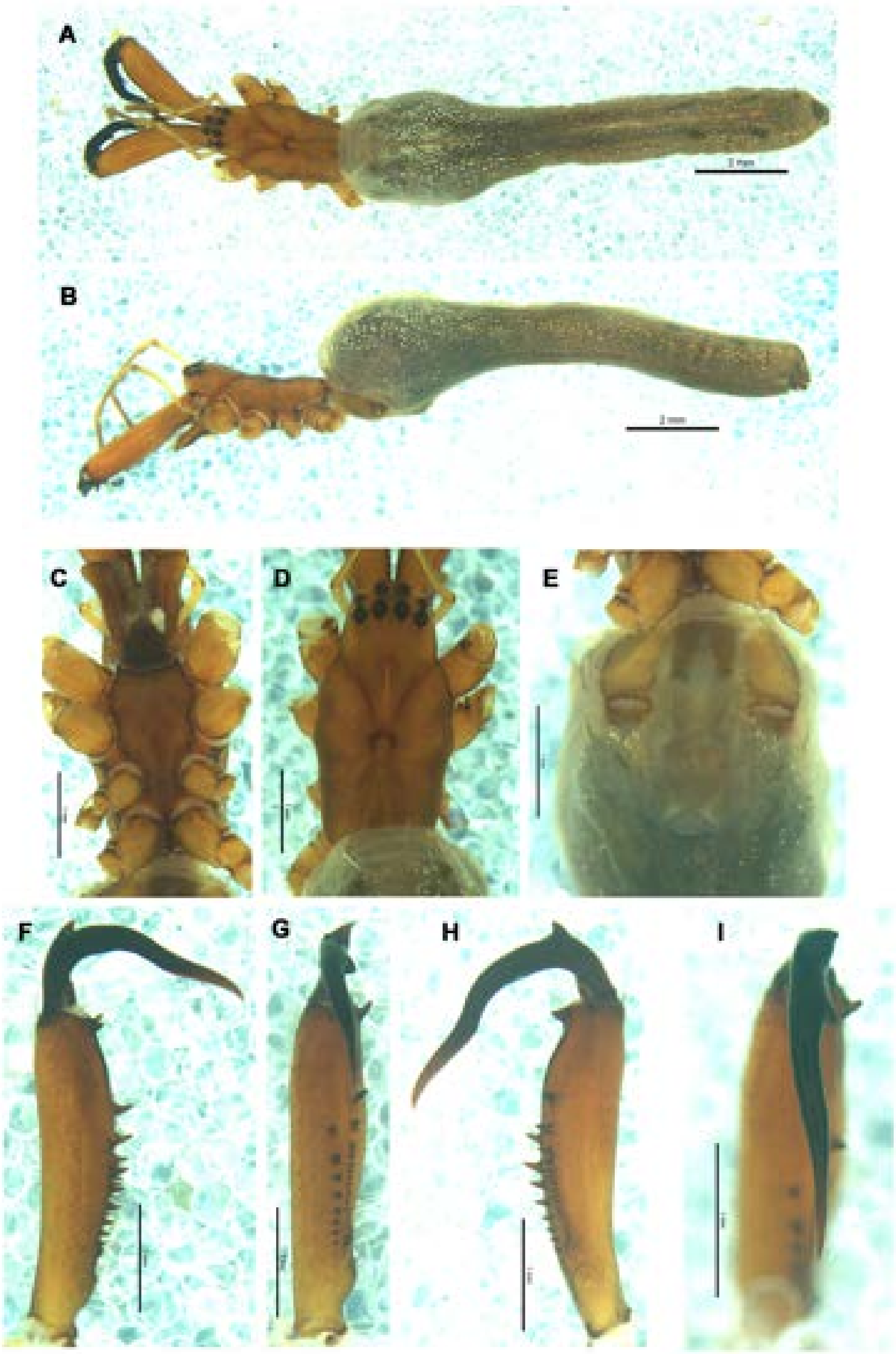

Figure 3.53: Female habitus and chelicerae of *Tetragnatha cochinensis*. **A**, general appearance, dorsal view. **B**, same, lateral view. **C**, sternum. **D**, carapace, dorsal view. **E**,epigastric area. **F**, chelicerae, promargin. **G**, same, median view. **H**, same, retromargin. **I**, same, focussed on fang. Scale bars. **A**–**B**, 2 mm. **C**–**I**, 1 mm.

Habitat: Riparian and water bodies close to paddy fields.

Natural history: *T. cochinensis* were collected from horizontal webs constructed over water bodies.

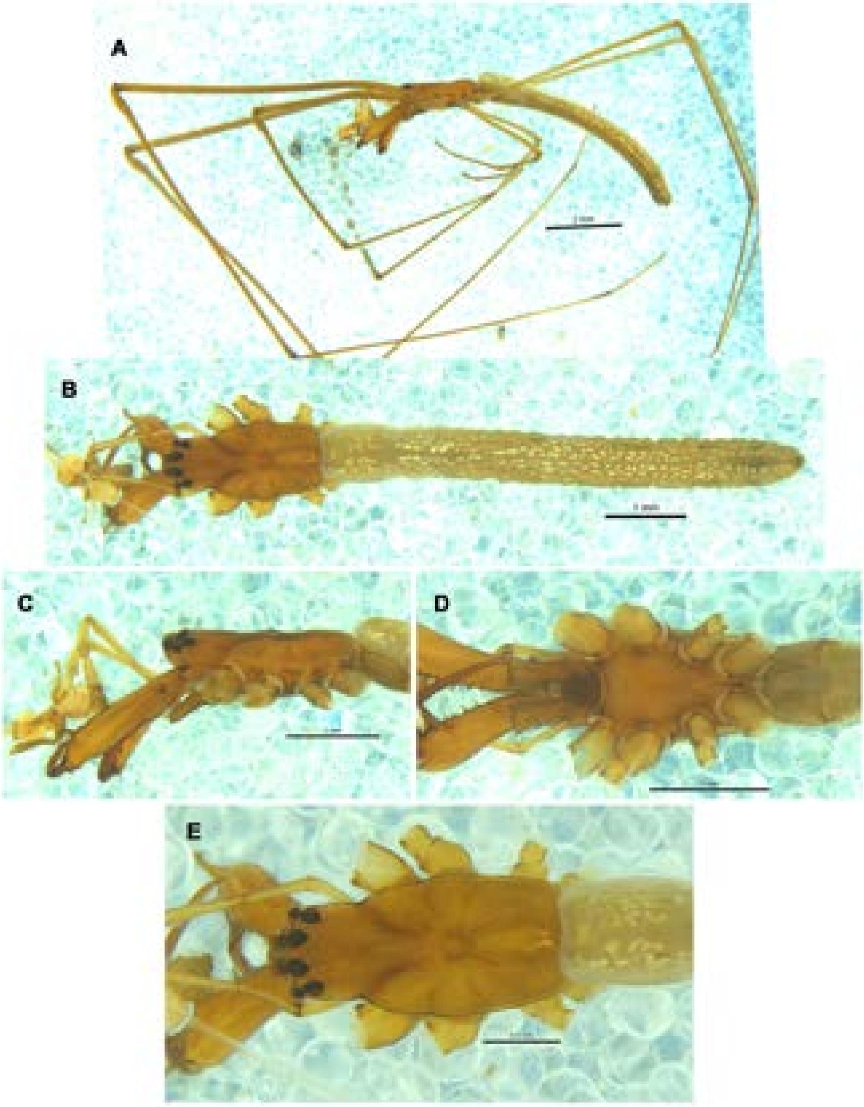

Figure 3.54: Male habitus of *Tetragnatha concordia* sp. nov. **A**, general appearance, lateral view. **B**, same, dorsal view. **C**, carapace, lateral view. **E**, same, dorsal view. **D**, sternum. Scale bars. **A**, 2 mm. **B**–**D**, 1 mm. **E**, 0.5 mm.

Tetragnatha concordia sp. nov.

(Figs 3.A.13E and 3.54 to 3.56)

Types: Holotype ♂(CATE), India, Kerala, Thrissur, Muriyad (10°2106.9N, 76°1506.2E), 2 m a.s.l., 5.7.2017, K. S. Nafin. Paratype: 3 ♂, 2 ♀, Parambikulam Tiger Reserve (10°23’54.36”N, 76°46’28.99”E), 700 m a.s.l, 15.9.14, K.S. Nafin, Jimmy Paul & P.P. Sudhin.

Etymology: The specific epithet is an adjective meaning ’unity’.

Diagnosis: *Tetragnatha concordia* sp. nov. can be eassily distinguished from *T. cochinensis* by the following features: Comparatively smaller spider, strongly recurved PER; in males anterior carapace almost parallel, sternum with no posterior constriction; chelicerae with prominent t.

Description: MALE (Holotype; Figs 3.54 and 3.56). Measurements. Carapace 2.08 long, .92 wide. Chelicera length 1.57. Abdomen 6.1 long, 0.73 wide. Eye interdistances: AME–AME 0.12 AME–ALE 0.15. PME–PLE 0.13. PME–PME 0.15. PER strongly recurved, anterior carapace parallel, fovea is a shallow depression. Abdomen elongated, slender. Cheliceral fang without basal and median cusps, Gu long, near to base of fang, t wide and prominent, T developed, Gl away from base, AXl absent, rsu with four teeth. Palp as in Figs 3.56D–F.

FEMALE (paratype; Figs 3.55). Measurements. Carapace 1.96 long, 0.98 wide. Chelicera length 1.49. Abdomen 6.33 long, 0.79 wide. Eye interdistances: AME–AME 0.14 AME–ALE 0.17. PME–PLE 0.16. PME–PME 0.22. In all details like male except the following: Abdomen with pairs of lateral spots dorsally, carapace not parallel anteriorly, sternum slightly constricted at coxae III. Chelicerae slender, L2 closer to Gl, five teeth in rsu, median cusp less developed.

Habitat: Riparian.

Natural history: *Tetragnatha concordia* sp. nov. were collected from horizontal webs constructed over water bodies.

Tetragnatha ceylonica O. Pickard-Cambridge, 1869
(Fig. 3.50)

Tetragnatha ceylonica Pickard-Cambridge, 1869a: 394, pl. 13, Figs 83–88 (♂♀); Gravely, 1921a: 427, 436, Fig. 1 (♂♀).Sen, Dhali, et al., 2015: 99, Figs 568–573, pl. 20 (♂); Basu and Raychaudhuri, 2016: 223, f. 31-35, 62-65 (♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Tetragnatha ceylonica* can be seen on the vegetation in wetlands close to streams and ponds.

Tetragnatha hasselti Thorell, 1890
(Fig. 3.57)

Tetragnatha hasselti Okuma, 1988b: 190, Figs 6A–K (♂♀); Basu and Raychaudhuri, 2016: 223, Figs 26–30, 58–61 (♀).

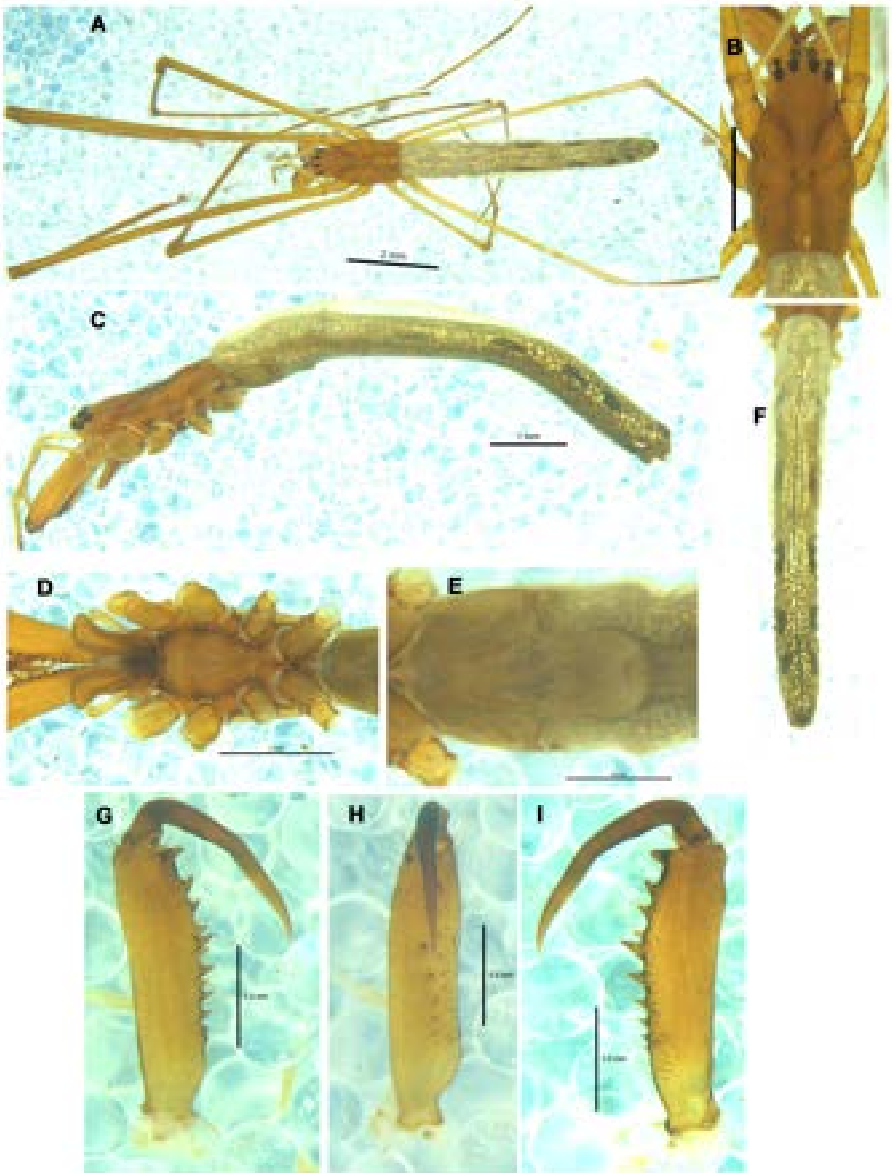

Figure 3.55: Female habitus of *Tetragnatha concordia* sp. nov. **A**, general appearance, dorsal view. **C**, same, lateral view. **B**, carapace, dorsal view. **D**, sternum. **E**, epigastric plate. **F**, abdomen, dorsal. **G**, chelicerae, promargin. **H**, same, median view. **I**, same, retromargin. Scale bars. **A**, 2 mm. **B**–**D**, 1 mm. **E**–**I**, 0.5 mm.

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *T. hasselti* were collected from vegetation close to waterbodies near paddy fields.

Tetragnatha keyserlingi Simon, 1890
(Figs 3.A.13G, 3.58 and 3.59)

Tetragnatha mandibulata Keyserling, 1865: 848, pl. 21, Figs 6–9 (♂♀); Koch, 1872: 194, pl. 17,

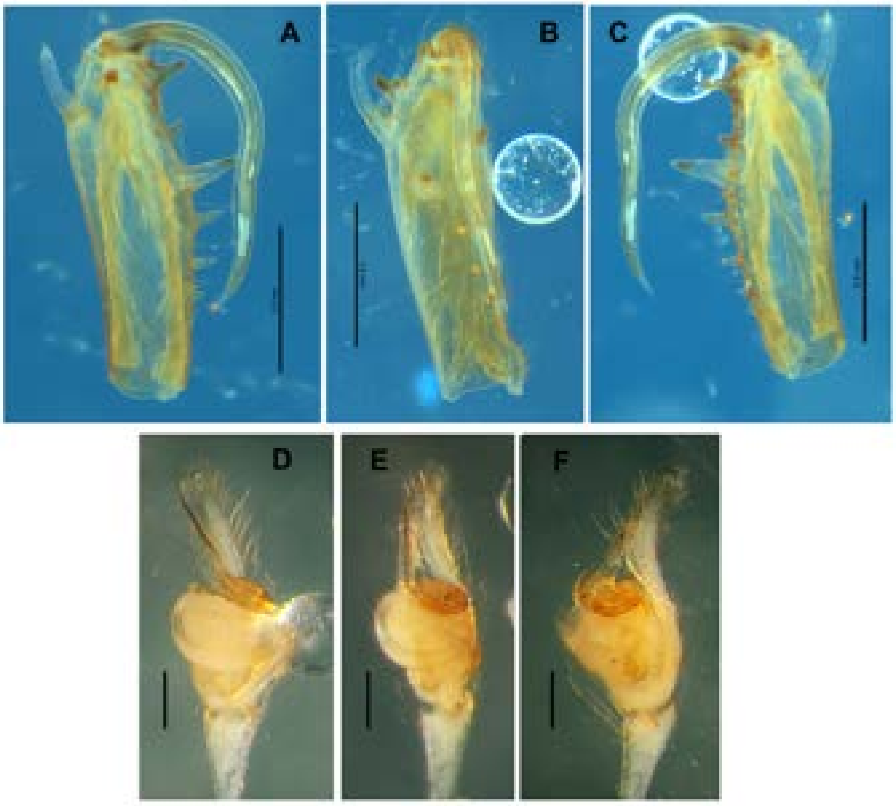

Figure 3.56: Male chelicerae and palp of *Tetragnatha concordia* sp. nov. **A**, chelicerae, promargin. **B**, same, median view. **C**, same, retromargin. **D**, left palp, prolateral view. **B**, same, ventral view. **C**, same, retrolateral view. Scale bars. **A–F**, 0.5 mm.

Figs 2–3 (♂♀)

Tetragnatha keyserlingi Simon, 1890: 134 (♂♀)

Tetragnatha maxillosa Okuma, Kamal, et al., 1993: 37, Figs 33A–G (♂♀); Barrion and Litsinger, 1995: 509, Figs 313a–f, 314a–i (♂♀); Basu and Raychaudhuri, 2016: 220, Figs 11–15, 45–48 (♀).

Tetragnatha keyserlingi Castanheira et al., 2019: 477, Figs 8A–J, 9A–I, 10A–F, 20C, 21H–I,L–M,O (♂♀).

(For complete list of references, see World Spider Catalog, 2021)

Tetragnatha mandibulata Walckenaer, 1841
(Figs 3.A.13D, 3.60 and 3.61)

Tetragnatha mandibulata Walckenaer, 1841: 211 (♂♀); Barrion and Litsinger, 1995: 516, Figs 317a–e, 318a–h (♂♀); Biswas and Raychaudhuri, 1996: 56, Figs 38–45 (♀); Zhu, Song, Zhang, and Gu, 2002: 81, Figs 5A–N (♂♀); Zhu, Song, and Zhang, 2003: 154, Figs 79A–G, 80A–G (♂♀); Tanikawa, 2007: 108, Figs 404–405, 870–873 (♂); Tanikawa, 2009: 419, Figs 112–115 (♂); Yin, Peng, et al., 2012: 458, Figs 208a–k, 3–13a (♂♀); Castanheira et al., 2019: 482, Figs 11A–K,

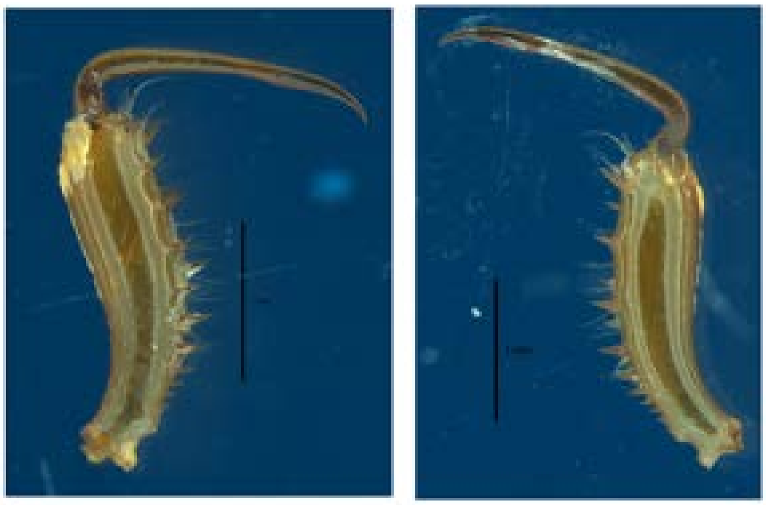

Figure 3.57: Female of *Tetragnatha hasselti.* **A**, chelicerae, promargin. **B**, same, retromargin. Scale bars. **A**–**B**, 1 mm.

12A–I, 13A–H, 20D, 21R–X.

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Tetragnatha mandibulata* is commonly found in the paddy fields, low level vegetation near to water bodies.

Natural history: Adults of *Tetragnatha mandibulata* were commonly observed in the upper portion of paddy plants during the morning and evening hours. They prefer night time to day. They erect more or less horizontal orb webs at the top strata of the paddy plants, and the spider sits upside down on the hub. The spider retreats to the hiding position below a leaf at a corner of the web when disturbed. They usually run further down into hinding on the stem of the paddy effortlessly blending with the plant.

Tetragnatha viridorufa Gravely, 1921

(Figs 3.A.13B, 3.62 and 3.63)

Tetragnatha viridorufa Gravely, 1921b: 411 (♂♀); Gravely, 1921a: 434, 445, Figs 6a–b (♂♀); Sunil Jose, Davis, et al., 2004: 182, Figs 1–19 (♂♀).

Habitat: *Tetragnatha viridorufa* is common in most wetland habitats including paddy fields.

Natural history: *Tetragnatha viridorufa* is most commonly encountered in trees lining wetlands. They are nocturnal and erect webs during sunset. The

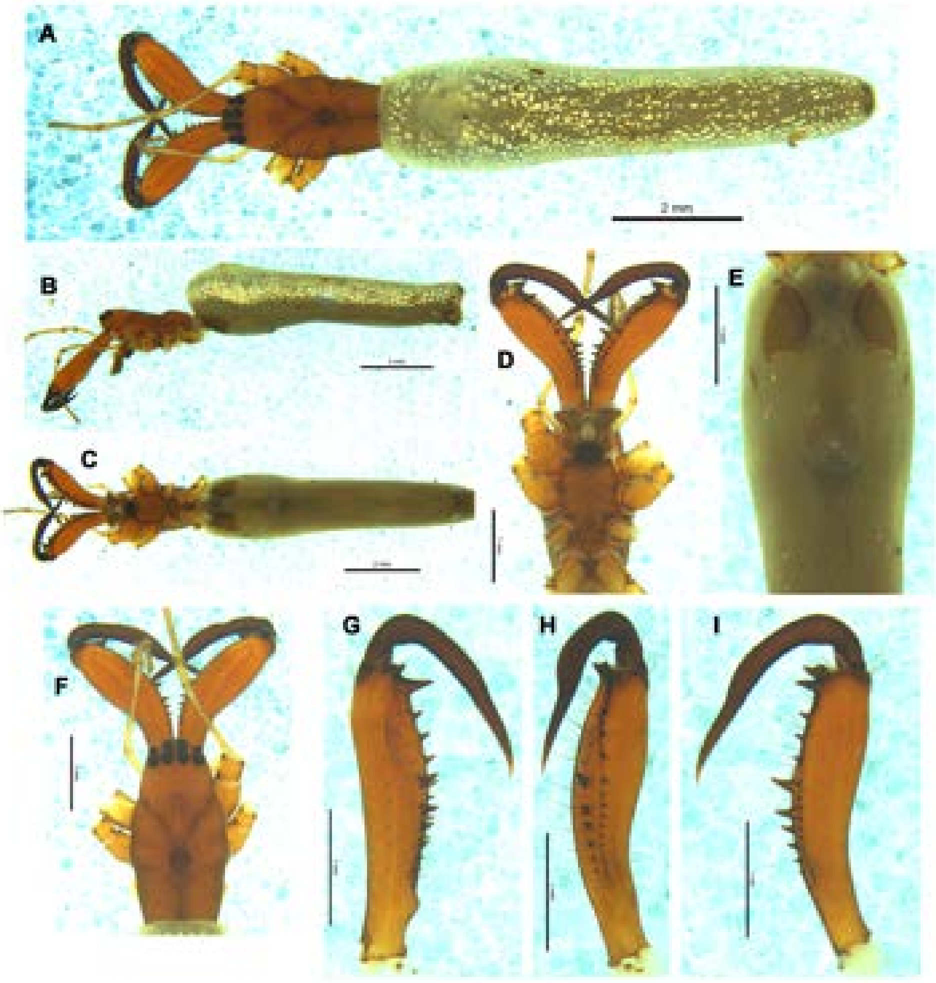

Figure 3.58: Female of *Tetragnatha keyserlingi.* **A**, general appearance, dorsal view. **B**, same, lateral view. **C**, same, ventral view. **D**, sternum. **E**, epigastric plate. **F**, carapace, dorsal view. **G**, chelicerae, promargin. **H**, same, median view. **I**, same, retromargin. Scale bars. **A**–**C**, 2 mm, **D**–**I**, 1 mm.

spiders occupy the centre of the web, which is usually at 45°angle. The adult mating pairs are found under the leaves of lower branches of the trees.

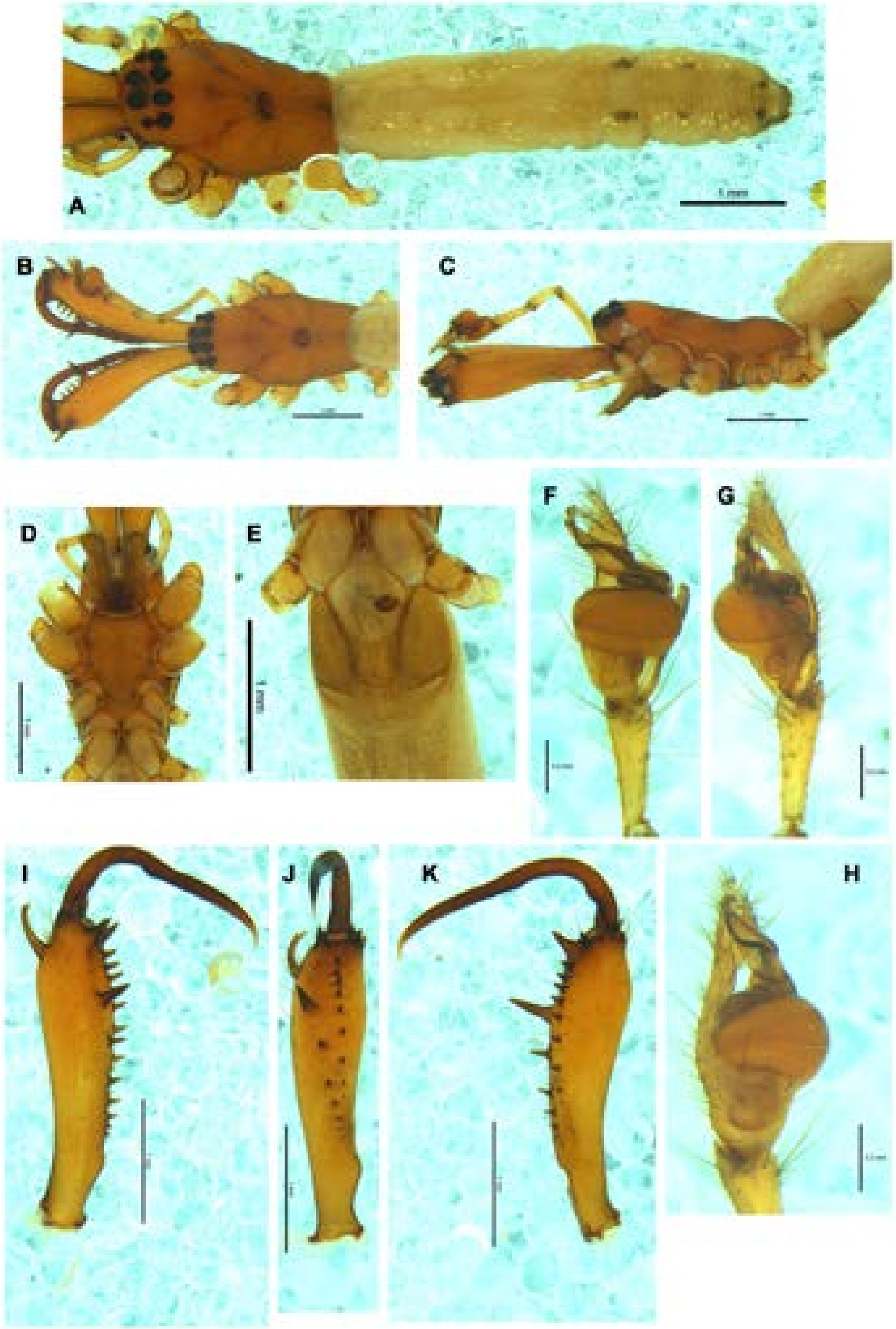

Figure 3.59: Male of *Tetragnatha keyserlingi*. **A**, general appearance, dorsal view. **B**, carapace, dorsal view. **C**, same, lateral view. **D**, sternum. **E**, epigastric plate. **F**, left palp, ventral view. **G**, same, retrolateral view. **H**, same, prolateral view. **I**, chelicerae, promargin. **J**, same, median view. **K**, same, retromargin. Scale bars. **A**–**E**,**I**–**K**, 1 mm, **F**–**H**, 0.5 mm.

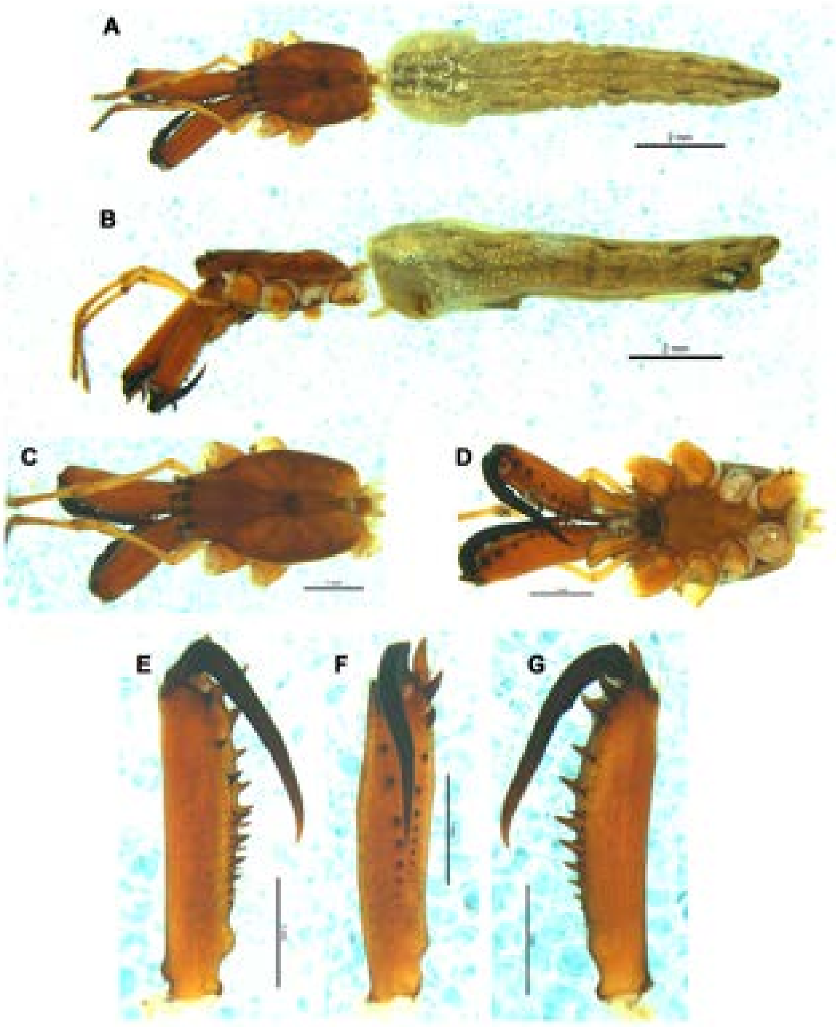

Figure 3.60: Female of *Tetragnatha mandibulata.* **A**, general appearance, dorsal view. **B**, same, lateral view. **C**, carapace, dorsal view. **D**, sternum. **E**, left chelicerae, promargin. **F**, Same, median view. **G**, same, retromargin. Scale bars. **A**–**B**: 2 mm, **C**–**G**: 1 mm.

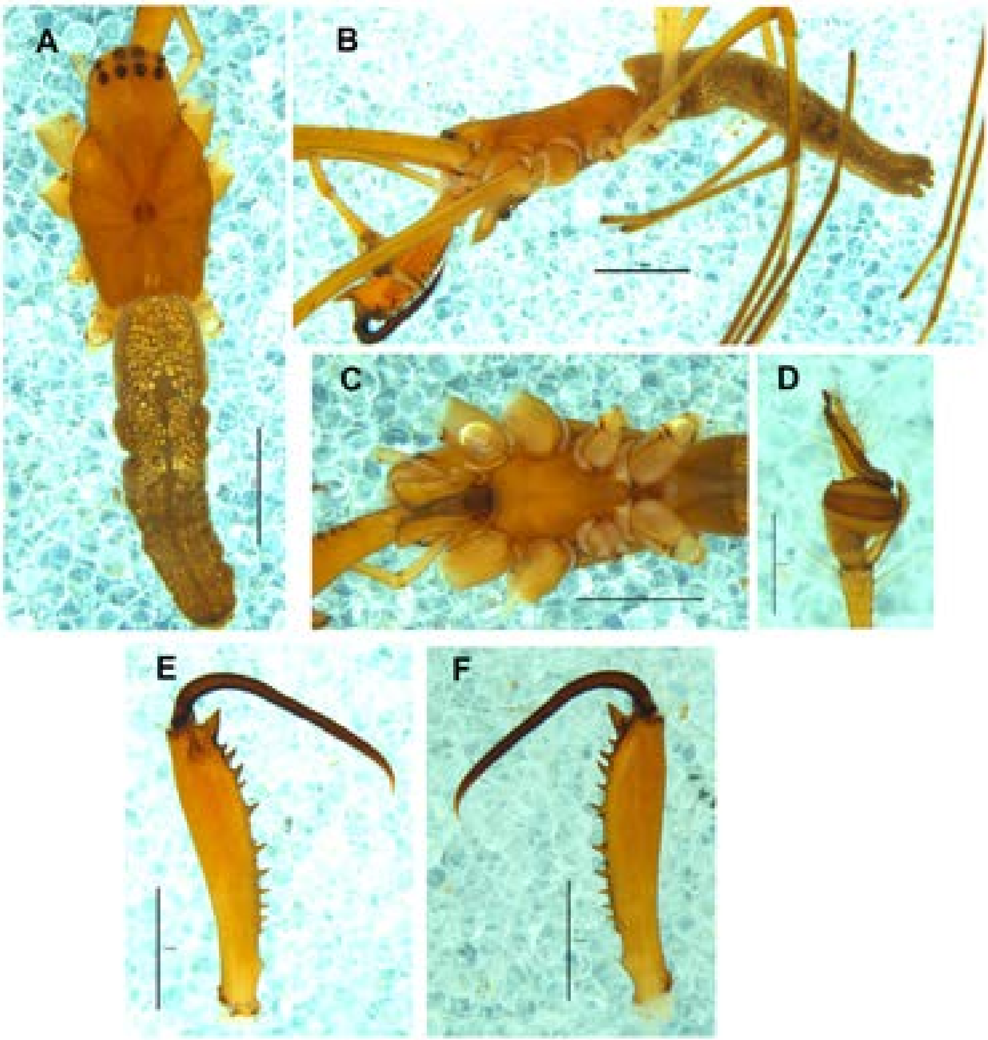

Figure 3.61: Male of *Tetragnatha mandibulata.* **A**, general appearance, dorsal view. **B**, same, lateral view. **C**, sternum. **D**, palp, ventral. **E**, left chelicerae, promargin. **F**, same, median view. Scale bars. **A–C, E, F**, 1 mm. **D**, 0.5 mm.

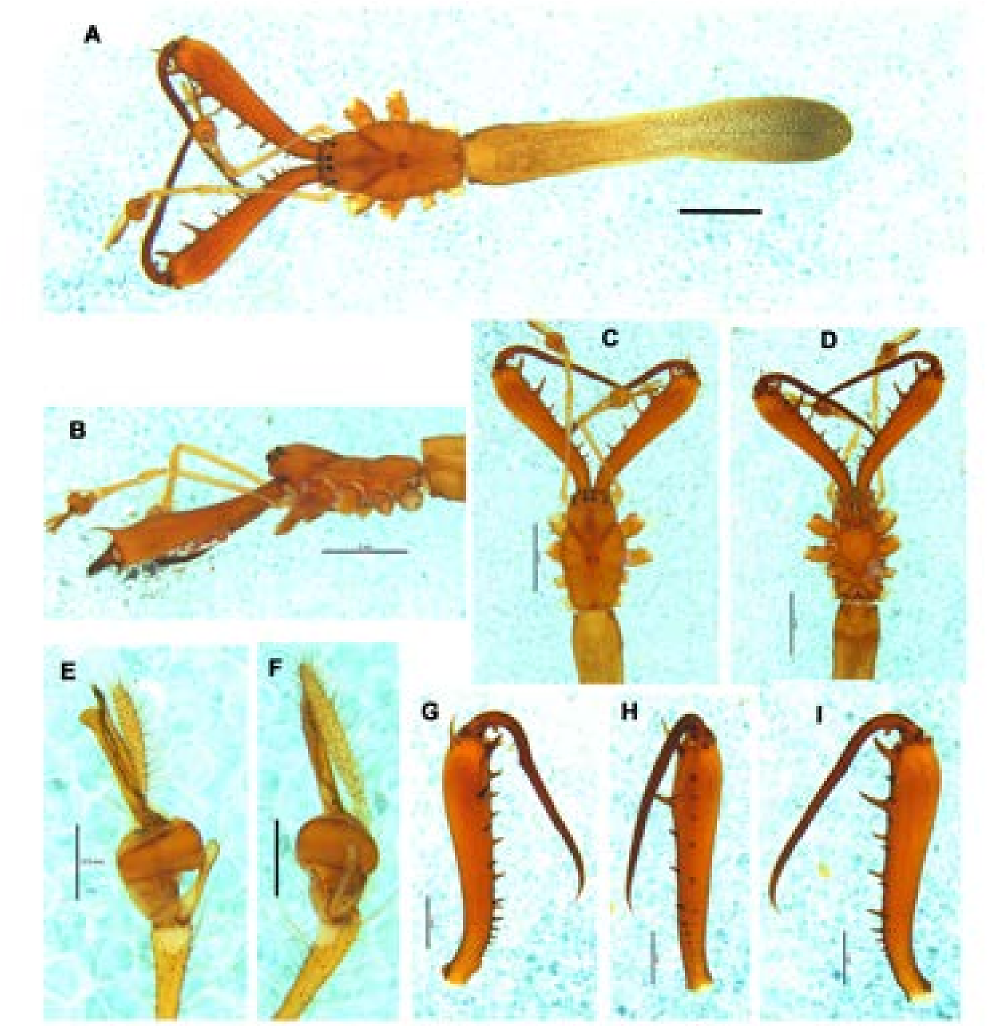

Figure 3.62: Male of *Tetragnatha viridorufa*. **A**, general appearance, dorsal view. **B**, carapace, lateral view. **C**, same, dorsal view. **D**, sternum. **E**, male palp, vetral view. **F**, same, retrolateral view. **G**, left chelicerae, promargin. **H**, same, median view. **I**, same, retromargin. Scale bars. **A**–**D**, 2 mm. **E**–**F**, 0.5 mm. **G**–**I**, 1 mm.

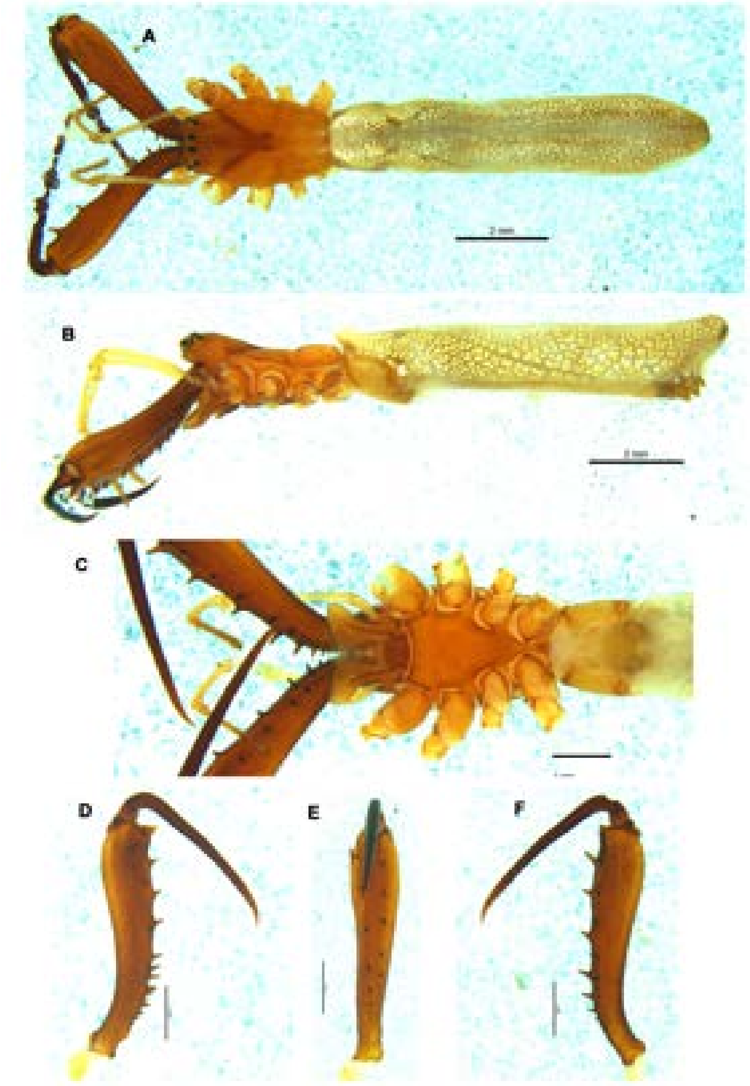

Figure 3.63: Female of *Tetragnatha viridorufa*. **A**, general appearance, dorsal view. **B**, same, lateral view. **C**, sternum and epigastric sclerite. **D**, left chelicerae, promargin. **E**, same, median view. **F**, same, retromargin. **Scale bars**. **A**–**B**, 2 mm. **C**–**F**, 1 mm.

Tetragnatha javana (Thorell, 1890)

(Figs 3.A.13C, 3.64 and 3.65)

Eucta javana Thorell, 1890a: 236 (♂); Thorell, 1895: 146 (♀).

Tetragnatha javana Okuma, 1988c: 169, Figs 2A–L (♂♀); Biswas and Raychaudhuri, 1996: 46, Figs 1–8 (♀); Zhu, Song, Zhang, and Gu, 2002: 81, Figs 4A–N (♂♀); Tanikawa, 2009: 414, Figs 62-65 (♂); Yin, Peng, et al., 2012;: 456, Figs 207a–g (♂♀); Sen, Dhali, et al., 2015: 99, Figs 563–567, pl. 20 (♀); Basu and Raychaudhuri, 2016: 218, Figs 1–5, 36–39 (♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Tetragnatha javana* is common in paddy fields, grass and shrubs in the wetlands.

Natural history: *Tetragnatha javana* builds horozontal orb webs and waits in the underside of web on the upper edge of the paddy fields. The elongated abdomen with pointed distal end conveniently camouflages the spider against the backdrop of the leaves of paddy plants or grass they hide on.

Tetragnatha squamata Karsch, 1879

(Figs 3.A.13H, 3.66 and 3.67)

Tetragnatha squamata Karsch, 1879a: 65, pl. 1, Figs 3 (♂♀); Barrion and Litsinger, 1994: 324, Figs 1704–1706, 1711–1712 (♂♀); Song et al., 1999: 223, Figs 126U, 128R–S, W (♂); Zhu, Song, Zhang, and Gu, 2002: 94, Figs 10A–N (♂♀); Zhu, Song, and Zhang, 2003: 183, Figs 97A–G, 98A–G (♂♀); Tanikawa, 2007: 108, Figs 396–398, 859–860 (♂); Kim, Kim, et al., 2008: 40, Figs 16, 25, 25.1–2 (♂♀); Tanikawa, 2009: 416, Figs 97–98 (♂); Zhu and Zhang, 2011: 187, Figs 131A–G, 132A–G (♂♀); Yin, Peng, et al., 2012: 465, Figs 212a–g, 3–18h–i (♂♀); Kim and Lee, 2013: 65, Figs 41A–D (♂♀); Baba and Tanikawa, 2015: 36, Fig. 5 (♂♀).
(For complete list of references, see World Spider Catalog, 2021)

Remarks: First report from India.

Habitat: *Tetragnatha squamata* can be seen on the branches of trees and shrubs in the wetlands and along the fringes of wetlands.

Natural history: *Tetragnatha squamata* are smaller sized Tetragnathids and erects orb webs in the lower branches of trees.

Distribution: India (New record), Russia (Far East), China, Korea, Taiwan and Japan (World Spider Catalog, 2021).

Tetragnatha nitens (Audouin, 1826)

(Figs 3.A.13F and 3.68)

Tetragnatha nitens Barrion and Litsinger, 1994: 324, Figs 1715–1717, 1742–1744 (♂♀); Barrion and Litsinger, 1995: 518, Figs 319a–f, 320a–i (♂♀); Tanikawa, 2007: 111, Figs 412–414, 881–884 (♂); Tanikawa, 2009: 419, Figs 123–126 (♂); Wunderlich, 2011: 210, Figs 16–29 (♂♀); Kim and Lee, 2013: 60, Figs 38A–E (♂♀); Najim, 2019: 11, Figs 2A–L, 3A–H (♂♀); Castanheira et al., 2019: 486, Figs 14A–J, 15A–L, 16A–F, 20E (♂♀).
(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Tetragnatha nitens* can be seen in paddy fields, shrubs and tall grass on embankments.

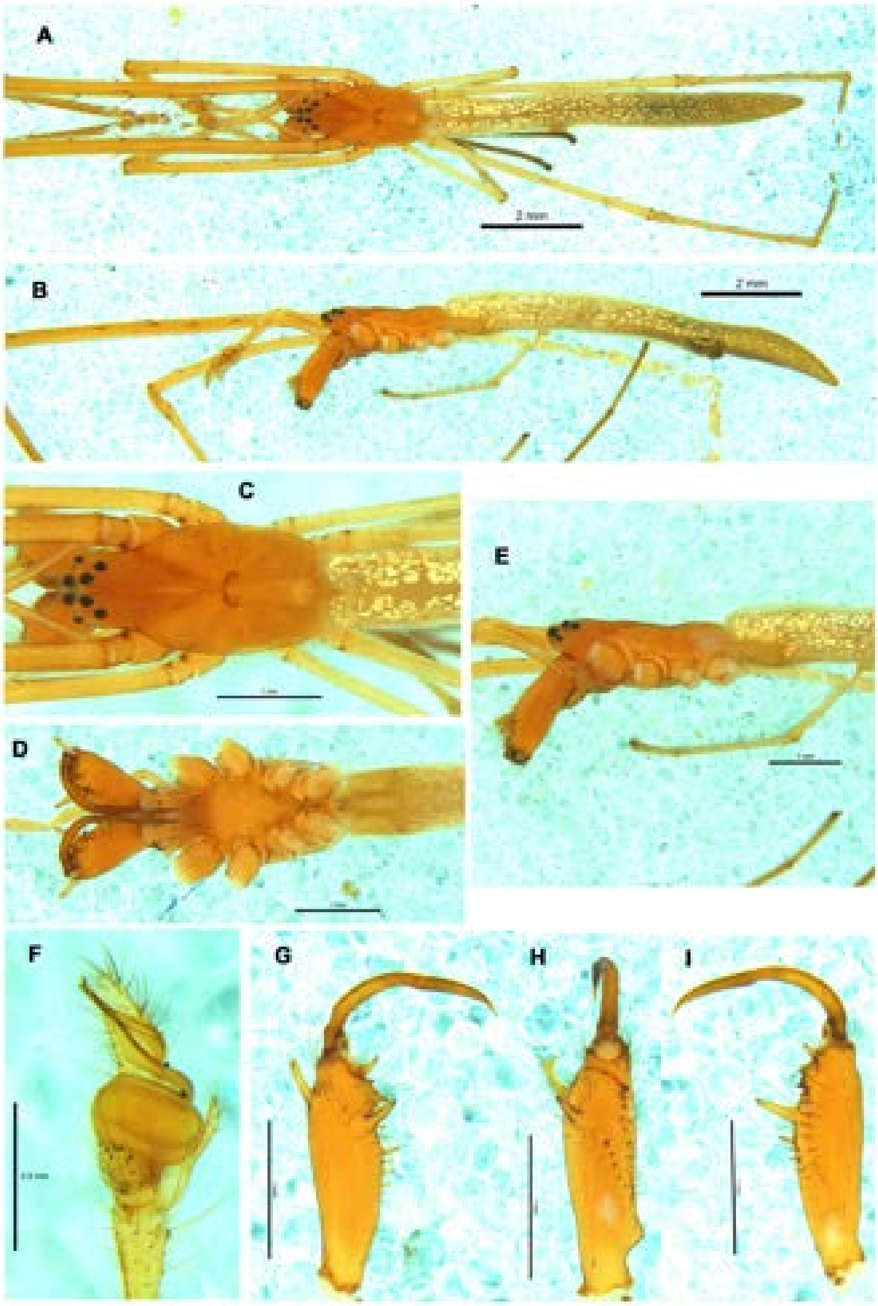

Figure 3.64: Male of *Tetragnatha javana*. **A**, general appearance, dorsal view. **B**, same, lateral view. **C**, carapace, dorsal view. **D**, sternum and epigastric plate. **E**, carapace, lateral view. **F**, male palp, ventral view. **G**, left chelicerae, promargin. **H**, same, median view. **I**, same, retromargin. **Scale bars**. **A**–**B**, 2 mm. **C**–**E**, **G**–**I**, 1 mm. **F**, 0.5 mm.

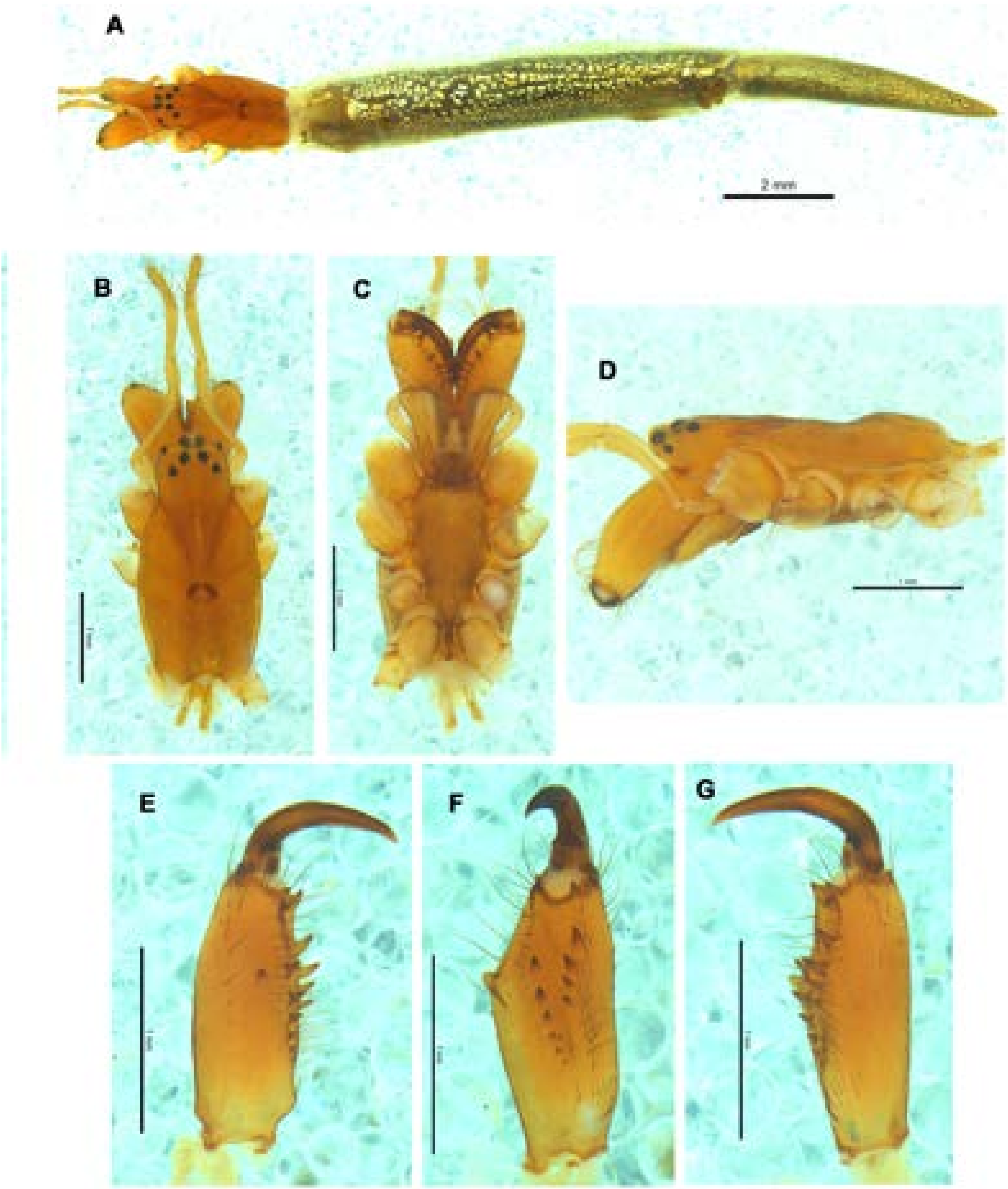

Figure 3.65: Female of *Tetragnatha javana.* **A**, general appearance, dorsal view. **B**, carapace, dorsal view. **C**, sternum. **D**, carapace, lateral view. **E**, left chelicerae, promargin. **F**, same, median view. **G**, same, retromargin. **Scale bars**. **A**, 2 mm. **B–G**, 1 mm.

Natural history: *Tetragnatha nitens* are abound during the later vegetative state of paddy.

Tetragnatha serra Doleschall, 1857

(Fig. 3.69)

Tetragnatha serra Doleschall, 1859: pl. 8, Fig. 5 (♂); Zhu, Song, and Zhang, 2003: 180, Figs 95A–F (♀).

(For complete list of references, see World Spider Catalog, 2021)

Remarks: First report from India.

Habitat: *Tetragnatha serra* can be found on shrubs in the wetland.

Distribution: India (New record), Thailand to China (Hong Kong) and New Guinea (World Spider Catalog, 2021).

Tetragnatha vermiformis Emerton, 1884

(Fig. 3.70)

Tetragnatha vermiformis Gravely, 1921a: 438, Figs 1a–g (♂♀); Castanheira et al., 2019: 490, Figs 17A–J, 18A–I, 19A–F, 20F (♂♀).

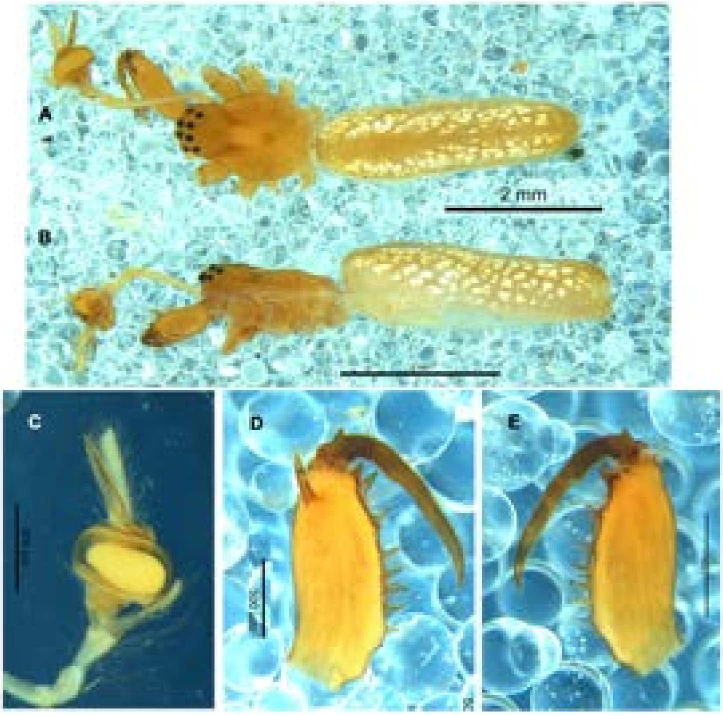

Figure 3.66: Male of *Tetragnatha squamata*. **A**, general appearance, dorsal view. **B**, same, lateral view. **C**, male palp, vetral view. **D**, left chelicerae, promargin. **E**, same, retromargin. **Scale bars**. **A**–**B**, 2 mm. **C**–**E**, 0.5 mm.

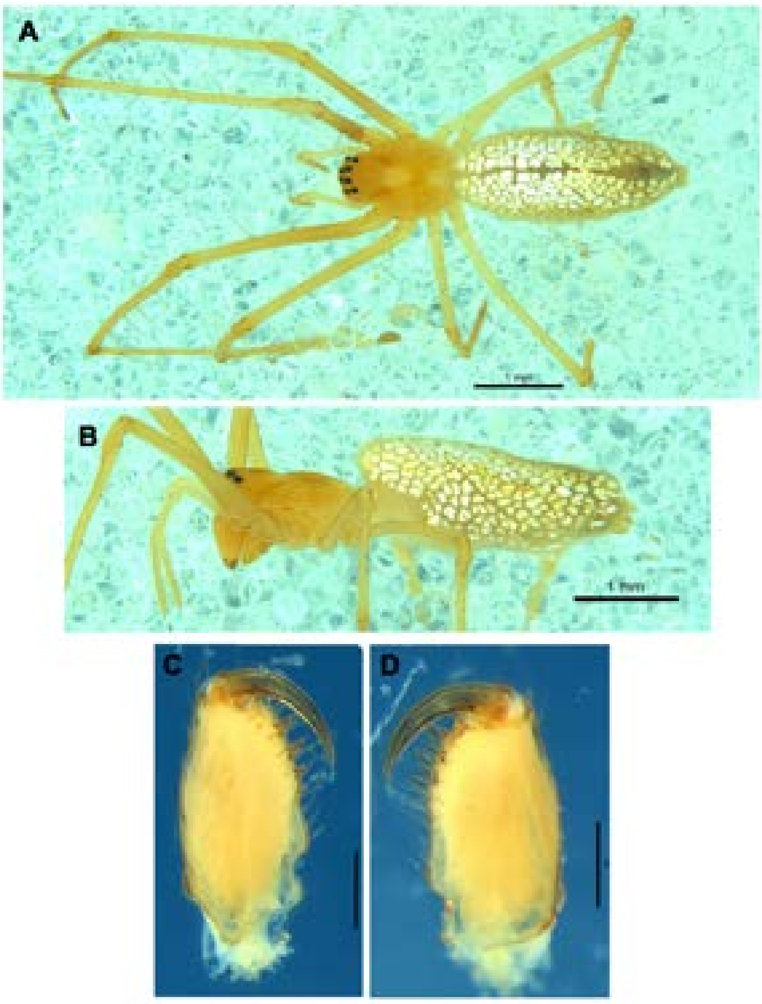

Figure 3.67: Female of *Tetragnatha squamata*. **A**, general appearance, dorsal view. **B**, same, lateral view. **C**, male palp, vetral view. **D**, same, retrolateral view. **Scale bars**. **A–B**, 1 mm. **C–D**, 0.2 mm.

(For complete list of references, see World Spider Catalog, 2021)

3.3.30.5 *TYLORIDA* Simon, 1894

Tylorida is a less species-rich genus distributed in Oriental, Ethiopian and Australian region (World Spider Catalog, 2021). The genus is represented by 8 nominal species globally and of these 4 species are currently known from India (World Spider Catalog, 2021). The members of the genus are common inhabitants of wetland landscapes.

Diagnosis: *Tylorida* species can be distinguished from other Tetragnathids by the following characters: Very long leg I, single row of straight trichobothria on each of legs I-IV, femur IV with smooth trichobothrial shaft; male palp with short,

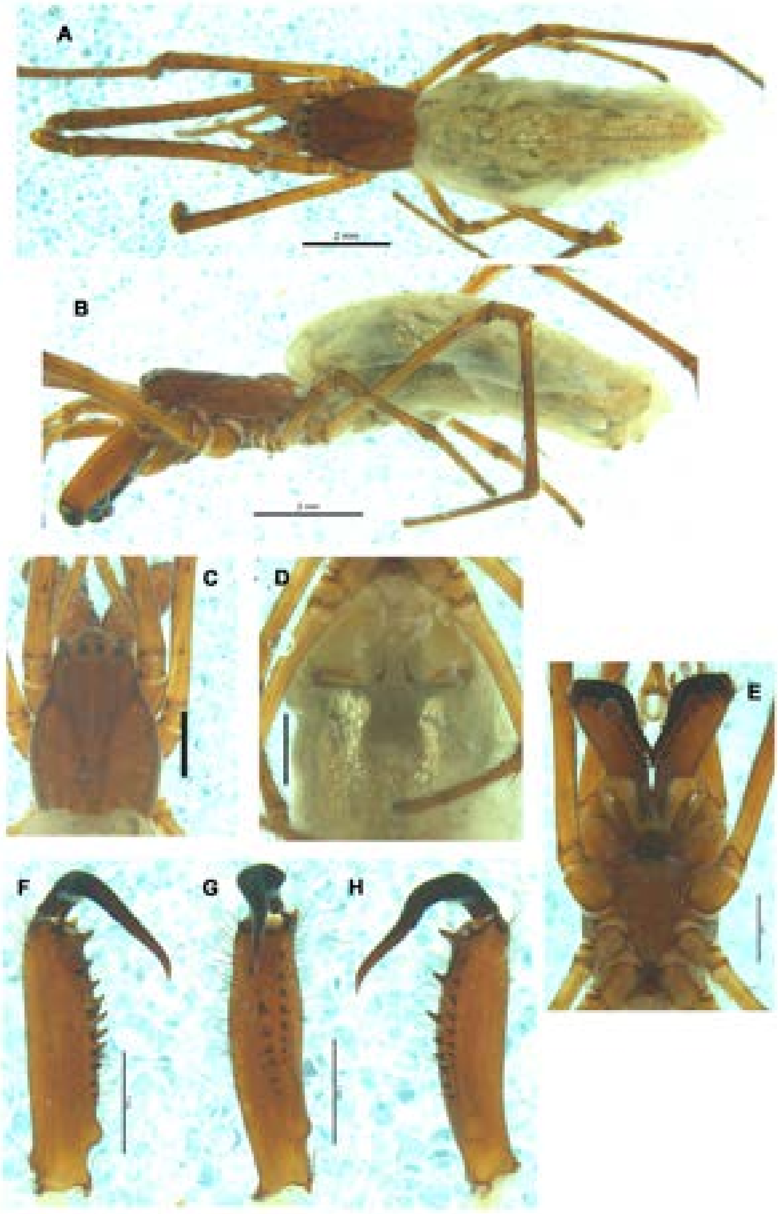

Figure 3.68: Female of *Tetragnatha nitens*. **A**, general appearance, dorsal view. **B**, same, lateral view. **C**, carapace, dorsal view. **D**, epigastric plate. **E**, sternum, lateral view. **F**, chelicerae, promargin. **G**, same, median view. **H**, same, retromargin. Scale bars. **A**–**B**, 2 mm. **C**–**H**, 1 mm.

acute embolus with a broad, twisted embolic base, short lamelliform conductor dorsal to embolus, tegulum ventrally swollen with a distomedian triangular process; epigyne with long, tubular fertilization ducts connected to copulatory ducts and spermathecal bulb (Sankaran, Malamel, et al., 2017).

Type species: *Tylorida striata* (Thorell, 1877)

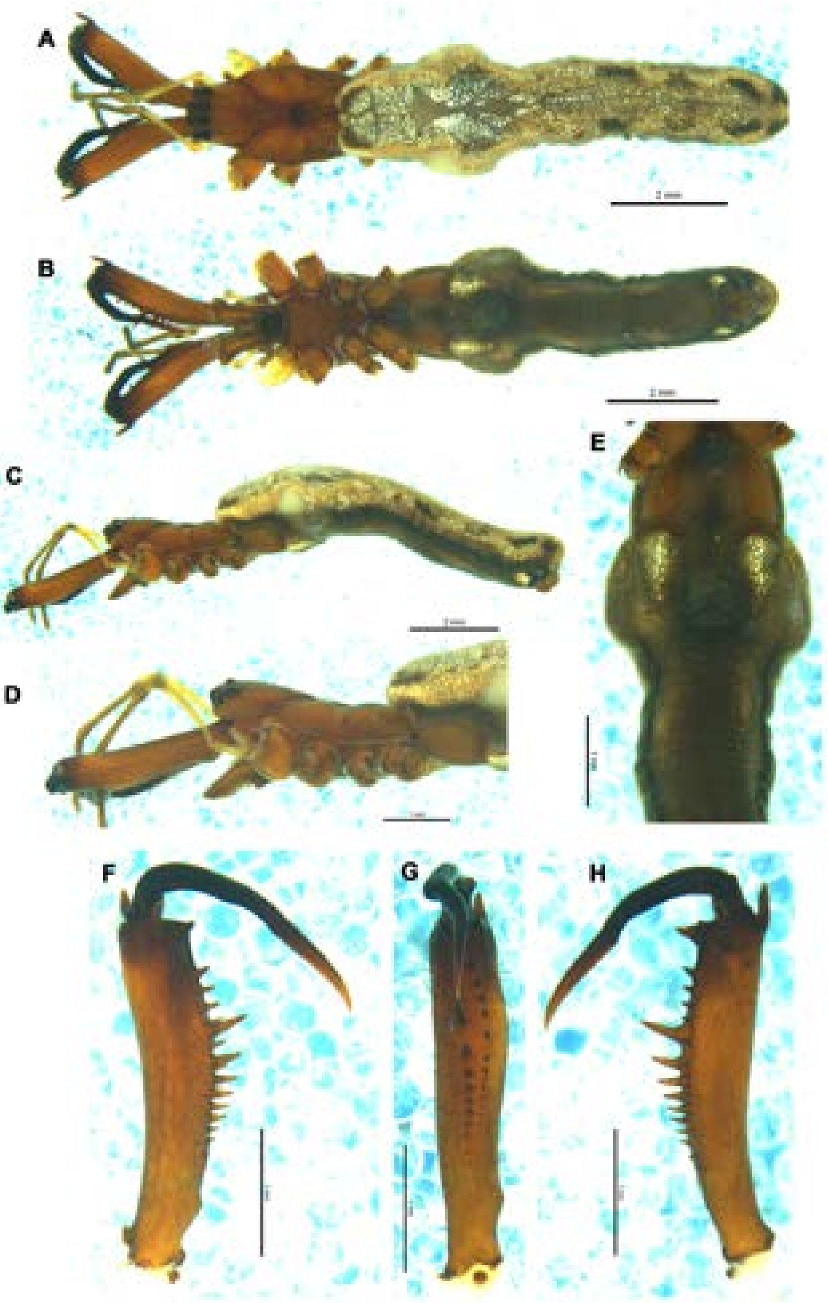

Figure 3.69: Female of *Tetragnatha serra*. **A**, general appearance, dorsal view. **B**, same, ventral view. **C**, same, lateral view. **D**, carapace, lateral view. **E**, epigastric plate. **F**, chelicerae, promargin. **G**, same, median view. **H**, same, retromargin. Scale bars. **A**–**C**, 2 mm. **D**–**H**, 1 mm.

Species sampled from the Muriyad Kol Wetland.

Tylorida striata (Thorell, 1877)

Figs 3.A.14C and 3.A.14D

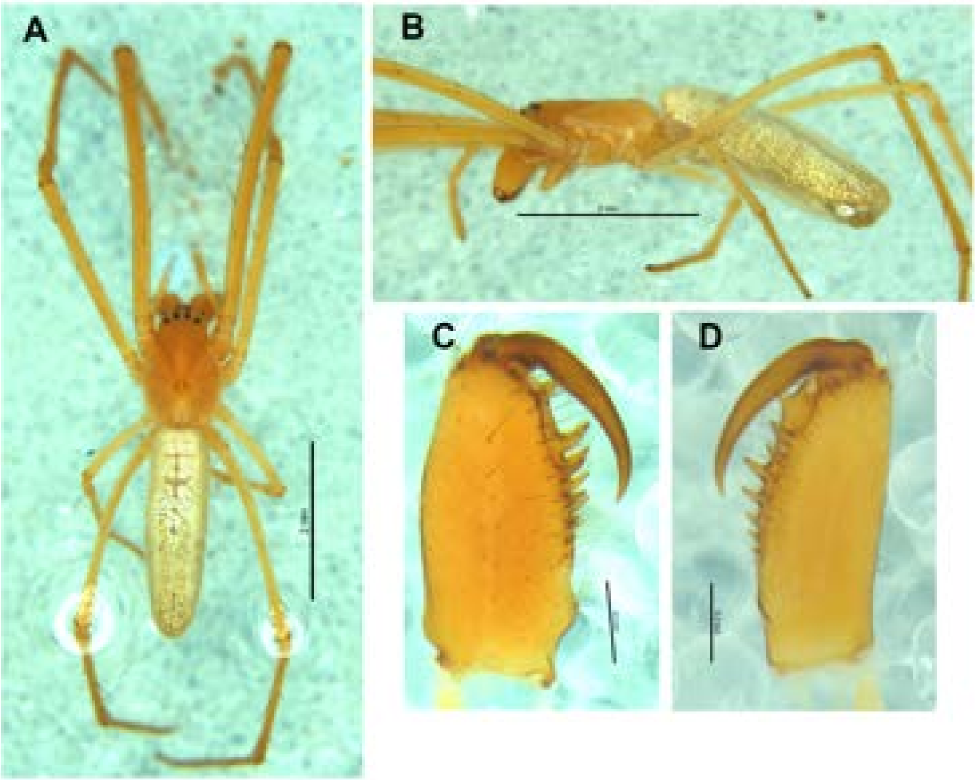

Figure 3.70: Female of *Tetragnatha vermiformis*. **A**, general appearance, dorsal view. **B**, same, lateral view. **C**, chelicerae, promargin. **D**, same, retromargin. Scale bars. **A**–**B**, 2 mm. **C**–**D**, 0.2 mm.

Tylorida striata Barrion and Litsinger, 1994: 328, Figs 1748–1750 (♂♀); Álvarez-Padilla, Dimitrov, et al., 2009: 141, Figs 8f, 9f (♂♀); Tanikawa, 2009: 410, Figs 33–34 (♂♀); Álvarez-Padilla and Hormiga, 2011: 800, Figs 114A–G, 115A–F, 116A–F, 117A–F, 118A–D (♂♀); Yin et al., 2012: 470, Figs 215a–h (♂♀); Sen, Dhali, et al., 2015: 96, Figs 546–551, pl. 20 (♀); Sankaran, Malamel, et al., 2017: 308, Figs 1D, 2B, 7D–F, 12F–G, 13A–F, 14A–G (♂♀).
(For complete list of references, see World Spider Catalog, 2021)

Habitat: Paddy fields, grasses and shrubs.

Natural history: *Tylorida striata* are commonly found in the middle to top strata of paddy. The specimens were collected by hand directly from the horizontal web. The adult spiders were observed resting in an upside down position in its retreat at the junction of the rachis and panicle of grass or in the case of paddy between leaf blade and culm or tiller. The subtriangular shape of the abdomen together with its bright green striations effectively camouflages the spider against its background.

Tylorida ventralis (Thorell, 1877)

Fig. 3.A.14B

Meta ventralis Thorell, 1877: 423 (♂♀)

Leucauge pondae Tikader, 1970: 44, Figs 25a–d (♂♀); Tikader, 1982a: 89, Figs 175–178 (♂♀).

Leucauge ventralis Tikader, 1982a: 85, Figs 168–171 (f).

Tylorida ventralis Kulkarni and Lewis, 2015: 2, Figs 1a, 2a, 3a, 5a (m); Sen, Dhali, et al., 2015: 101, Figs 585–589, pl. 21 (♀); Sankaran, Malamel, et al., 2017: 310, Figs 1E–F, 2C, 7G–I, 12H–I, 15A–F, 16A–J, 17A–O, 18A–O, 19A–E (♂♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Tylorida ventralis* is commmon in most habitats of the wetlands and surrounding areas.

Natural history: *Tylorida ventralis* inhabit shrubs, bushes, lower branches of trees and between tree branches in most terrestrial habitats. It is mostly found near water bodies.

3.3.31 FAMILY THERIDIIDAE Sundevall,1833

COB WEB SPIDERS OR TANGLE WEB SPIDERS OR COMB-FOOTED SPIDERS

Family Theridiidae represents small to medium sized araneomorphs, ecribellate, entelegyne, three clawed, eight-eyed , with cosmopolitan distribution (Jocqué & Dippenaar-Schoeman, 2006). Cob web spiders or tangle web spiders or comb-footed spiders, as they are commonly known, is a diverse group which construct irregular space webs with threads radiating in various directions. They overpower prey in a wrap-bite mode of attack with silky silk (Jocqué & Dippenaar-Schoeman, 2006). Theridiidae boasts a large variety of web forms from gumfoot webs (*Achaearanea, Latrodectus, Coleosoma, etc*) to sticky, elastic trap lines leading to the ground surface (Benjamin & Zschokke, 2002). Other kleptoparasitic members (*Argyrodes, Faiditus, and Neospintharus*) live in the webs of larger spiders and prey on smaller prey caught by the host's web. The family currently has 2510 species in 124 genera globally, and 85 of them are known from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following characters: Carapace variable shape, frontal region modified in some genera, especially in males; eyes in two rows, usually surrounded by brownish ring; tarsus IV with a comb of slightly curved serrated bristles; abdomen oval to round, sometimes high or elongated; epigyne variable; male palp without any apophysis in tibia and patella, no paracymbium, but a hook on the distal margin of cymbium functioning as a lock mechanism, tegulum with typical theridiid tegular apophysis (Jocqué & Dippenaar-Schoeman, 2006).

Type genus: *Theridion* Walckenaer, 1805.

3.3.31.1 *ARGYRODES* Simon, 1864

Argyrodes is a moderately species-rich genus with worldwide distribution, also known as dewdrop spiders they are known for their kleptoparasitism (World Spider Catalog, 2021). The genus currently comprises 98 nominal species globally, with 15 species known from India (World Spider Catalog, 2021).

Diagnosis: *Argyrodes* species can be distinguished from other theridiids by the following combination of characters: Male palpal patella without a spur; male clypeus and eye region usually modified with projections or grooves (Levi & Levi, 1962).

Type species: *Argyrodes argyrodes* (Walckenaer, 1841)

Species sampled from the Muriyad Kol Wetland.

Argyrodes bonadea (Karsch, 1881)

Argyrodes bonadea Bösenberg and Strand, 1906: 129, pl. 5, Fig. 52, pl. 12, Fig. 264 (♂♀); Malik et al., 2015: 32, Figs 2A–D (♀).
(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Argyrodes bonadea* were found in paddy fields, riparian, mixed crops and uncultivated areas.

Argyrodes flavescens O. Pickard-Cambridge, 1880
Fig. 3.A.14E

Argyrodes flavescens Yin, Peng, et al., 2012: 280, Figs 99a–e (♂♀). (For complete list of references, see World Spider Catalog, 2021)

Habitat: *A. flavescens* were found in bushes and shrubs in all habitats.

Natural history: *A. flavescens* , commonly called the red and silver dewdrop spider, is one of the most common kleptoparasite found in the region. They mostly inhabit the webs of araneids, and are also found in *Stegodyphus sarasinorum* webs.

Argyrodes gazedes Tikader, 1970

Argyrodes gazedes Tikader, 1970 11, Figs 5a–d (♂♀); Sen, Dhali, et al., 2015: 83, Figs 475–480, pl. 19 (♀).

Habitat: *A. gazedes* were found shrubs and undergrowth in mixed crops, uncultivated and riparian habitats.

Argyrodes kumadai Chida & Tanikawa, 1999

Fig. 3.A.14F

Argyrodes kumadai Yoshida, 2009: 386, Figs 281–283 (♂♀).
(For complete list of references, see World Spider Catalog, 2021)

Remarks: First report from India.

Habitat: *A. kumadai* were found shrubs and undergrowth in banana plantations, mixed cropped plots, uncultivated and riparian habitats.

Distribution: India (New record), China, Taiwan and Japan (World Spider Catalog, 2021).

3.3.31.2 ***ARIAMNES*** Thorell, 1869

Ariamnes is a moderately species-rich genus with a worldwide distribution (World Spider Catalog, 2021). The genus currently comprises 34 nominal species globally, with 3 species known from India (World Spider Catalog, 2021).

Diagnosis: *Ariamnes* species can be distinguished by the following characters: Carapace flat, longer than it is wide, rectangular, and narrows towards the eyes; abdomen extremely elongated, resembling a twig; spinnerets located approximately one-eighth of the way from the anterior end of abdomen.

Type species: *Ariamnes flagellum* (Doleschall, 1857)

Species sampled from the Muriyad Kol Wetland.

Ariamnes flagellum (Doleschall, 1857)

Fig. 3.A.14G

Ariamnes flagellum Thorell, 1869: 37; Agnarsson, 2004: 478.

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Ariamnes flagellum* were found in banana plantations, mixed crops and uncultivated areas.

Natural history: *Ariamnes flagellum* were found to hang on a single strand of silk between branches of shrubs and understory of trees during night time. The elongated shape of the spider and its green colour gives an impression of a green twig hanging on a strand, possibly attracting prey.

3.3.31.3 *CHIKUNIA* Yoshida, 2009

Chikunia is a less species-rich genus distributed in the Oriental region (World Spider Catalog, 2021). The genus currently comprises 3 nominal species globally, with a single species known from India (World Spider Catalog, 2021).

Diagnosis: *Chikunia* species can be distinguished from other Araneids by the following characters: Resembles *Chrysso* O. Pickard-Cambridge 1882 and *Meotipa* Simon 1894 but is distinguished from them by orange or black abdomen and short legs and from *Chrysso* by less sclerotised abdomen in male and from *Meotipa* by wide abdomen in female. In *Chrysso* and *Meotipa* legs are long abdomen is bright in color. In *Chrysso* male abdomen is sclerotised anteriorly. While in *Meotipa*, abdomen is not as wide and usually with large posterior tip in both sexes Yoshida, 2009.

Type species: *Chikunia albipes* (Saito, 1935)

Species sampled from the Muriyad Kol Wetland.

Chikunia nigra (O. Pickard-Cambridge, 1880)
Fig. 3.A.14H

Chrysso nigra Levi, 1962: 209, Figs 1–2.

Chikunia nigra Grinsted et al., 2012: 1027 (Transfer from *Chrysso*). (For complete list of references, see World Spider Catalog, 2021)

Habitat: *C. nigra* found in uncultivated plots.

Natural history: *C. nigra* were found in the foliages of understory of trees.

3.3.31.4 *CHRYSSO* O. Pickard-Cambridge, 1882

Chrysso is a moderately species-rich genus distributed in the Oriental, Palearctic, Nearctic and Neotropical regions (World Spider Catalog, 2021). The genus currently comprises 64 nominal species globally, with 3 species known from India (World Spider Catalog, 2021).

Diagnosis: *Chrysso* species can be distinguished by the following combination of characters: Chelicerae with no teeth or one to three teeth on anterior margin, none posterior or sometimes several small teeth; colulus absent; often very long, leg I longer than IV; abdomen usually longer than wide or high, very rarely higher than long; epigyne often with openings indistinct; male Palp with cymbium often shallow, variously shaped; paracymbial hook indistinct. Median apophysis and radix separate sclerites (Levi & Levi, 1962).

Type species: *Chrysso albomaculata* O. Pickard-Cambridge, 1882

Species sampled from the Muriyad Kol Wetland.

Chrysso angula Tikader, 1970)
Fig. 3.A.15A

Theridula angula Tikader, 1970: 15, Figs 8a–c (♂♀).
Chrysso angula Sen, Saha, et al., 2011: 878, Figs 1–19.
(For complete list of references, see World Spider Catalog, 2021)

Habitat: *C. angula* found in uncultivated plots.

Chrysso urbasae (Tikader, 1970)
Fig. 3.A.15B

Linyphia urbasae Tikader, 1970: 19, Figs 11a–c (♀).
(For complete list of references, see World Spider Catalog, 2021)

Habitat: *C. urbasae* found in uncultivated plots.

Natural history: *C. urbasae* were found in the foliages of understory of trees.

3.3.31.5 *COLEOSOMA* O. Pickard-Cambridge, 1882

Coleosoma is a less species-rich genus distributed in the Oriental, Palearctic, Nearctic and Neotropical regions (World Spider Catalog, 2021). The genus currently comprises 10 nominal species globally, with 2 species known from India (World Spider Catalog, 2021).

Diagnosis: *Coleosoma* species can be distinguished by the following combination of characters: Carapace of females as in *Theridion*, not modified; that of male oval with projecting clypeus. Chelicerae small, without teeth or with one or two teeth on anterior margin; male abdomen sometimes constricted in middle; no colulus; epigyne lightly sclerotized, consisting of indistinct slits or a depression. male palpal embolus prominent on venter (Levi & Levi, 1962).

Type species: *Coleosoma blandum* O. Pickard-Cambridge, 1882

Species sampled from the Muriyad Kol Wetland.

Coleosoma floridanum Banks, 1900

Fig. 3.A.15C

Coleosoma floridanum Levi and Levi, 1962: 46, Fig. 103–104 (♂).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *C. floridanum* found in all habitats, especially grasslands and paddy fields.

Natural history: *C. floridanum* were collected from the undergrowth in most habitats, and among tillers in paddy fields.

3.3.31.6 ***EPISINUS*** Walckenaer, in Latreille, 1809

Episinus is a moderately species-rich genus with a worldwide distribution (World Spider Catalog, 2021). The genus currently comprises 62 nominal species globally, with 2 species known from India (World Spider Catalog, 2021).

Diagnosis: *Episinus* species can be distinguished by the following combination of characters: Carapace slightly longer than wide; clypeus low and flat, projected anteriorly; chelicerae small, with one or two teeth on anterior margin, sometimes absent; abdomen usually widest behind the middle and with humps, tubercles, or occasionally small nipples; colulus replaced by two setae; male palpus extremely complicated.

Type species: *Episinus truncatus* Latreille, 1809

Species sampled from the Muriyad Kol Wetland.

Episinus affinis Bösenberg & Strand, 1906
Fig. 3.A.15D

Episinus affinis Bösenberg and Strand, 1906: 136, pl. 5, Fig. 55, pl. 12, Fig. 251 (♀); Song et al., 1999: 119, Figs 61A–B, I (♂♀).
(For complete list of references, see World Spider Catalog, 2021)

Habitat: *E. affinis* found in uncultivated plots.

Natural history: *E. affinis* were collected from the undergrowth just above the soil surface, on twigs among the litter.

3.3.31.7 *EURYOPIS* Menge, 1868

Euryopis is a moderately species-rich genus with a worldwide distribution (World Spider Catalog, 2021). The genus currently comprises 77 nominal species globally, with 2 species known from India (World Spider Catalog, 2021).

Diagnosis: *Euryopis* species can be distinguished by the following combination of characters: Clypeus frequently high in males, usually lower in females; chelicerae weak, very small in males, larger in females; abdomen overhanging carapace, usually pointed behind, frequently covered with strong bristles; no colulus visible; males of several smaller species with ventral abdominal scuta; abdomen frequently with silvery spots or other markings. Epigynum a simple pit or depression more or less sclerotized; two pairs of seminal receptacles present. Palp simple; conductor irregular in shape, frequently the only strongly sclerotized portion of bulb; median apophysis is a lobe which is broadly attached to the tegulum (Levi, 1954).

Type species: *Euryopis flavomaculata* (C. L. Koch, 1836)

Species sampled from the Muriyad Kol Wetland.

Euryopis episinoides Simon, 1895

Euryopis episinoides Rajoria, 2016: 57, Figs 1–6 (♂).
(For complete list of references, see World Spider Catalog, 2021)

Habitat: *E. episinoides* were collected from foliage and barks of trees surrounding paddy fields.

3.3.31.8 *MEOTIPA* Simon, 1894

Meotipa is a less species-rich genus distributed in the Oriental and Ethiopian regions, also introduced to the New World and Eastern Palearctic regions (World Spider Catalog, 2021). The genus currently comprises 15 nominal species globally, with 6 species known from India (World Spider Catalog, 2021).

Diagnosis: *Meotipa* species can be distinguished by the following combination of characters: Abdomen skewed, spiny; AMEs dark, while other eyes pearl white. Chelicerae with one tooth on the apex of the median edge and 0–2 denticles on the apical margin; male palpal cymbium truncated, barely extending beyond the alveolus, embolus not so long.

Type species: *Meotipa picturata* Simon, 1895

Species sampled from the Muriyad Kol Wetland.

Meotipa picturata Simon, 1895
Fig. 3.A.15E

Meotipa picturata Levi and Levi, 1962: 47, Figs 112–113 (♀); Murthappa et al., 2017: 590, Figs 1A–J, 2A–F, 4A–D (♂♀). (For complete list of references, see World Spider Catalog, 2021)

Habitat: *M. picturata* were collected from foliages in riparian, mixed plantations, uncultivated areas.

Natural history: *M. picturata* were found under the leaves in lower canopies of trees.

Meotipa multuma Murthappa et al., 2017
(Figs 3.A.15F and 3.71)

Meotipa multuma Murthappa et al., 2017: 590,Figs 1A–J, 2A–F, 4A–D (♀); Sekhar and Sunil Jose, 2021: 81, Figs 1–8 (♂♀).

Habitat: *M. multuma* were collected from paddy fields and grasslands.

Natural history: *M. multuma* were found among the paddy tillers or leaves, usually under the leaf surface.

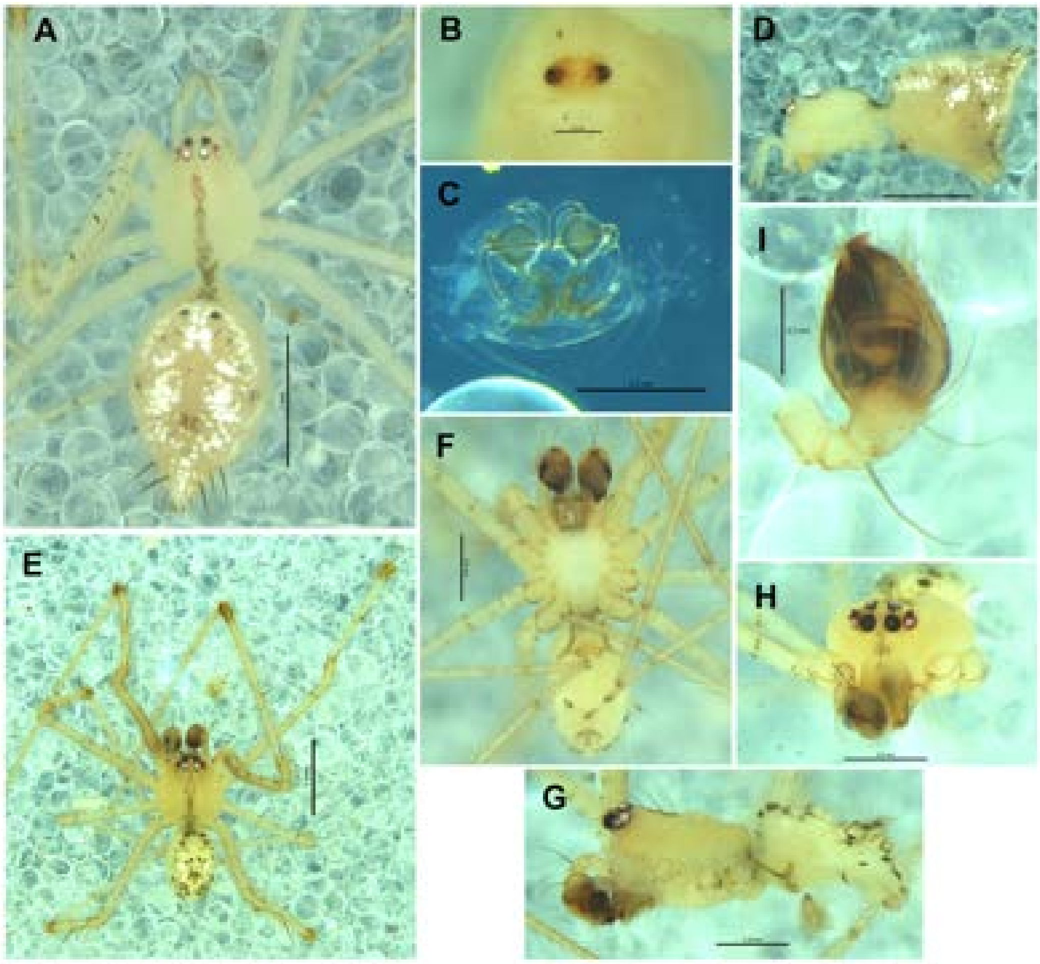

Figure 3.71: Male and female of *Meotipa multuma*. Female (**A**–**D**) and male (**E**–**I**). **A**, general appearance, dorsal view. **B**, intact epigyne, ventral view. **C**, seperated epigyne, ventral view. **D**, general appearance, lateral view. **E**, general appearance, dorsal view. **F**, same, ventral view. **G**, same, lateral view. **H**, carapace, frontal view. **I**, male left palp, ventral view. Scale bars. **A, D, E**, 1 mm. **B, C, I**, 0.2 mm. **F**–**H**, 0.5 mm

3.3.31.9 *MOLIONE* Thorell, 1892

Molione is a less species-rich genus distributed in the Oriental region (World Spider Catalog, 2021). The genus currently comprises 6 nominal species globally, with 1 species known from India (World Spider Catalog, 2021).

Diagnosis: *Molione* species can be distinguished the following combination of characters: Carapace oval; abdomen without colulus, extremely sclerotized epigastric area, and presence of a sclerotized ring around spinnerets. Male palpus cymbium with hooded paracymbium.

Type species: *Molione triacantha* Thorell, 1892

Species sampled from the Muriyad Kol Wetland.

Molione trispinosa (O. Pickard-Cambridge, 1873)

(Figs 3.A.16A and 3.72)

Phoroncidia trispinosa O. Pickard-Cambridge, 1873d: 125, pl. 14, f. 9 (Df).

Molione trispinosa Simon, 1894a: 550.

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *N. rufipes* were collected from inside buildings and crevaces or grooves in trees.

Natural history: *N. rufipes* commonly called the red house spider is commonly found inside buildings, particularly in dark corners. They are nocturnal and comes out of their hide outs afterdark.

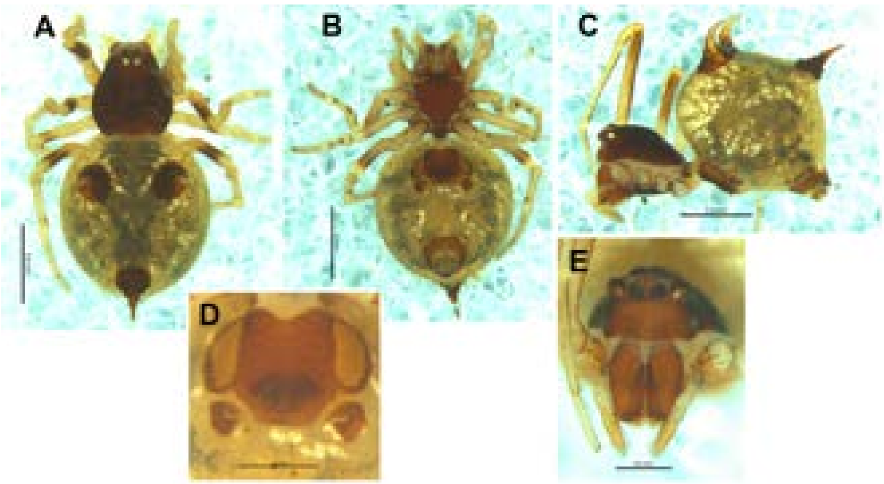

Figure 3.72: Female of *Molione trispinosa*. **A**, general appearance, dorsal view. **B**, same, ventral view. **C**, same, lateral view. **D**, intact epigyne, ventral view. **E**, carapace, frontal view. Scale bars. **A–C**, 0.5 mm. **D–E**, 0.2 mm.

3.3.31.10 ***NESTICODES*** Locket, 1982

Nesticodes is a monotypic genus with a worldwide distribution (World Spider Catalog, 2021).

Diagnosis: *Nesticodes* species can be distinguished by the following combination of characters: Male palpal embulus stout joining an overhanging conductor, cymbium sub-truncate apex, median apophysiis naviculate, as high as wide, palpal patella having distal apical spur; epigyne lobate plate; stridulating apparatus developed in males, males smaller than females Archer, 1950.

Type species: *Nesticodes rufipes* (Lucas, 1846)

Species sampled from the Muriyad Kol Wetland.

Nesticodes rufipes (Lucas, 1846)
Fig. 3.A.15G

Nesticodes rufipes Sekhar and Sunil Jose, 2017: 22, pl. II, Figs 7–8 (Transfer from *Theridion*); Sekhar and Sunil Jose, 2017: 478, Figs 1A–F (♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *N. rufipes* were collected from inside buildings and crevaces or grooves in trees.

Natural history: *N. rufipes* commonly called the red house spider is commonly found inside buildings, particularly in dark corners. They are nocturnal and comes out of their hide outs afterdark.

3.3.31.11 *NIHONHIMEA* Yoshida, 2016

Nihonhimea is a less species-rich genus distributed in the Oriental, Australian, Neotropical and Palearctic region (East) (World Spider Catalog, 2021). The genus currently comprises 7 nominal species globally, with 4 species known from India (World Spider Catalog, 2021).

Diagnosis: *Nihonhimea* species can be distinguished by the following combination of characters: Epigyne with a depression; two openings on both sides of the depression; thick and short duct; globular seminal receptacles. Male palpal embolus is thick and slightly curved, with a small base; conductor concave; median apophysis concave; tegulum is small; and paracymbium hooded (Yoshida, 2016).

Type species: *Nihonhimea japonica* (Bösenberg & Strand, 1906)

Species sampled from the Muriyad Kol Wetland.

Nihonhimea mundula (L. Koch, 1872)
Fig. 3.A.15H

Parasteatoda mundula Saaristo, 2010: 261, Figs 37.95–101 (♂♀).

Nihonhimea mundula Yoshida, 2016: 22 (Transfer from *Parasteatoda*).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *N. mundula* were found in wooded areas in the region.

Natural history: *N. mundula* inhabits shady areas such as hollow trunks of trees, disused buildings or in the undergrowths.

3.3.31.12 *PARASTEATODA* Archer, 1946

Parasteatoda is a less species-rich genus distributed in the Oriental, Australian, Palearctic, Nearctic and Neotropical regions (World Spider Catalog, 2021). The genus currently comprises 44 nominal species globally, with 3 species known from India (World Spider Catalog, 2021).

Diagnosis: *Parasteatoda* species can be distinguished by the following combination of characters: The base colour ranges from greyish brown to blackish brown, with some being bright orange. Abdomen with a broad and longitudinal cardiac pattern, as well as some transverse flecks. Carapace oval. The abdomen is nearly spherical, with a small posterior projection. Large depression in the epigyne, spermathecae nearly spherical

Type species: *Parasteatoda tepidariorum* (C. L. Koch, 1841)

Species sampled from the Muriyad Kol Wetland.

***Parasteatoda* sp.**

3.3.31.13 *PHORONCIDIA* Westwood, 1835

Phoroncidia is a moderately species-rich genus with a worldwide distribution (World Spider Catalog, 2021). The genus currently comprises 80 nominal species globally, with 4 species known from India (World Spider Catalog, 2021). Currently, four species are known from India, namely *Phoroncidia aculeata* Westwood 1835, *Phoroncidia maindroni* (Simon 1905), *Phoroncidia septemaculeata* O. Pickard-Cambridge 1873 and *Phoroncidia testudo* (O. Pickard-Cambridge 1873) (World Spider Catalog 2019). *P. septemaculeata* O. Pickard-Cambridge 1873 was described based on a few specimens collected by Mr G. H. K. Thwaites in 1871 from Sri Lanka and it was mostly derived from the somatic features of the species. Recently, Patil et al. (2018) reported two subadult males presumed to be *Phoroncidia septemaculeata* from the Maharashtra state in India. Until now, no mature specimen of the species has been reported and its genitalia remains unknown. Here, a detailed redescription of *P. septemaculeata* is provided, including illustrations of male and female genitalia for the first time, based on fresh materials collected from different localities in the Coastal Plains and Western Ghats of Kerala state and Coastal plains of Tamil Nadu.

Diagnosis: *Phoroncidia* species can be distinguished from other Theridiids by the following combination of characters: presence of a sclerotized ring surrounding the spinnerets, colulus often replaced by two setae; eyes project anteriorly above the clypeus, small chelicerae, legs are short, fourth leg usually longer than the first; abdomen is heavily sclerotized with pronounced folds or humps or strong spines, tubercles or extensions. Epigyne heavily sclerotized plates with openings, often indistinct, in the centre or on the posterior border. Palps with a paracymbial hook on or near the edge of the cymbium, and the median apophysis is normally not in contact with the hook (Kariko, 2014; Levi, 1964).

Type species: *Phoroncidia aculeata* Westwood, 1835

Species sampled from the Muriyad Kol Wetland.

Phoroncidia septemaculeata O. Pickard-Cambridge, 1873

(Figs 3.73 to 3.77)

Phoroncidia septemaculeata Pickard-Cambridge, 1873: 124, pl. 14, Fig. 8

Phoroncidia aculeata Levi and Levi, 1962: 57, Figs 235–237 (Misidentification, not examined)

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

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

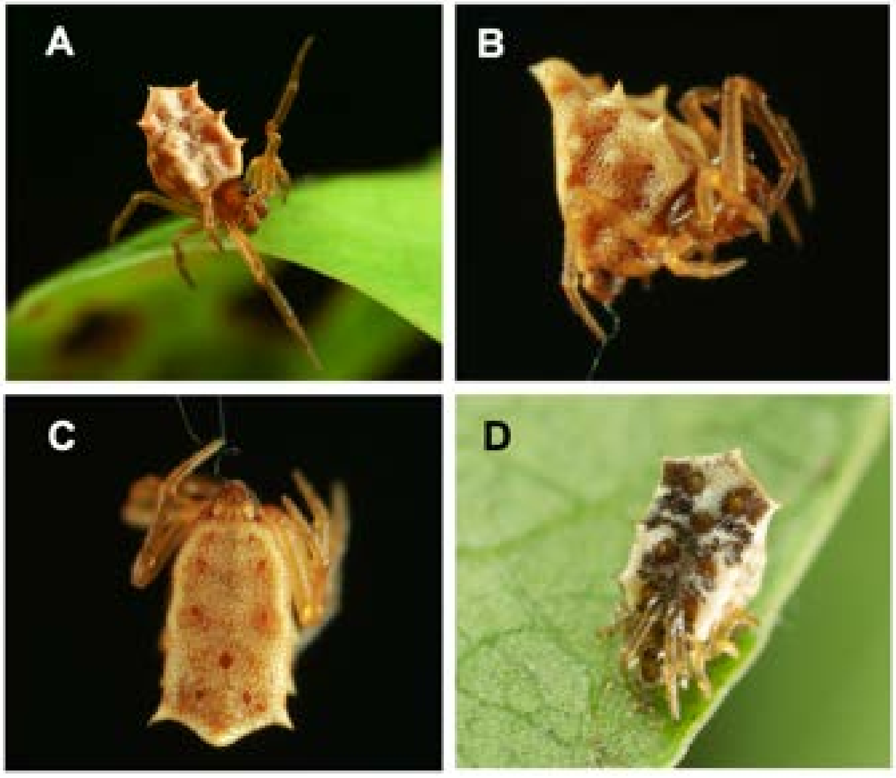

Figure 3.73: Live images of *Phoroncidia septemaculeata*. **A**, male, frontal view. **B**, same, lateral view. **C**, same, posterior view. **D**, immature female from Christ college campus, Kerala, showing different colouration.

Material examined: INDIA: Kerala: Ernakulam, Aluva, Manalpuram (10°07´21.3″N 76°21´07.1″E, 2 m alt), 17.10.2015, K. S. Nafin leg., night collection, 1 ♂(CATE10301D), 1 ♀(CATE10301A); Wayanad, WWS, Bathery range (11°42´09.8″N 76°20´39.6″E, 868 m alt), 9.7.2015, P. P. Sudhin & K. S. Nafin leg., beating method, 4 ♂♂(CATE10301F); Thrissur, Kodungallur, Sankukulangara Kavu (10°16´39.5″N 76°09´59.6″E, 9 m alt), 7.4.2017, N. V. Sumesh leg., 1 ♀, 1 ♀(CATE10301C); Thrissur, Irinjalakuda, Christ college campus (10°21´18.0″N 76°12´47.9″E, 15 m alt), 13.9.2018, K. S. Nafin leg., 1 ♂, 1 ♀(CATE10301E). Tamil Nadu: Kancheepuram, Vedanthangal Bird Sanctuary (12°32´40.0″N 79°51´14.3″E, 122 m alt), 28.2.2016, Pooja Anilkumar leg., 1 ♀(CATE10301B).

Diagnosis: *P. septemaculeata* can be readily distinguished from its congeners by the subtriangular shape of abdomen in lateral aspect, which is slightly humped anteriorly, anterior abdomen adorned with seven short and stout spines originating from protuberances, and shield-shaped posterior (Figs 3.73A–C, 3.74B, H, K). The

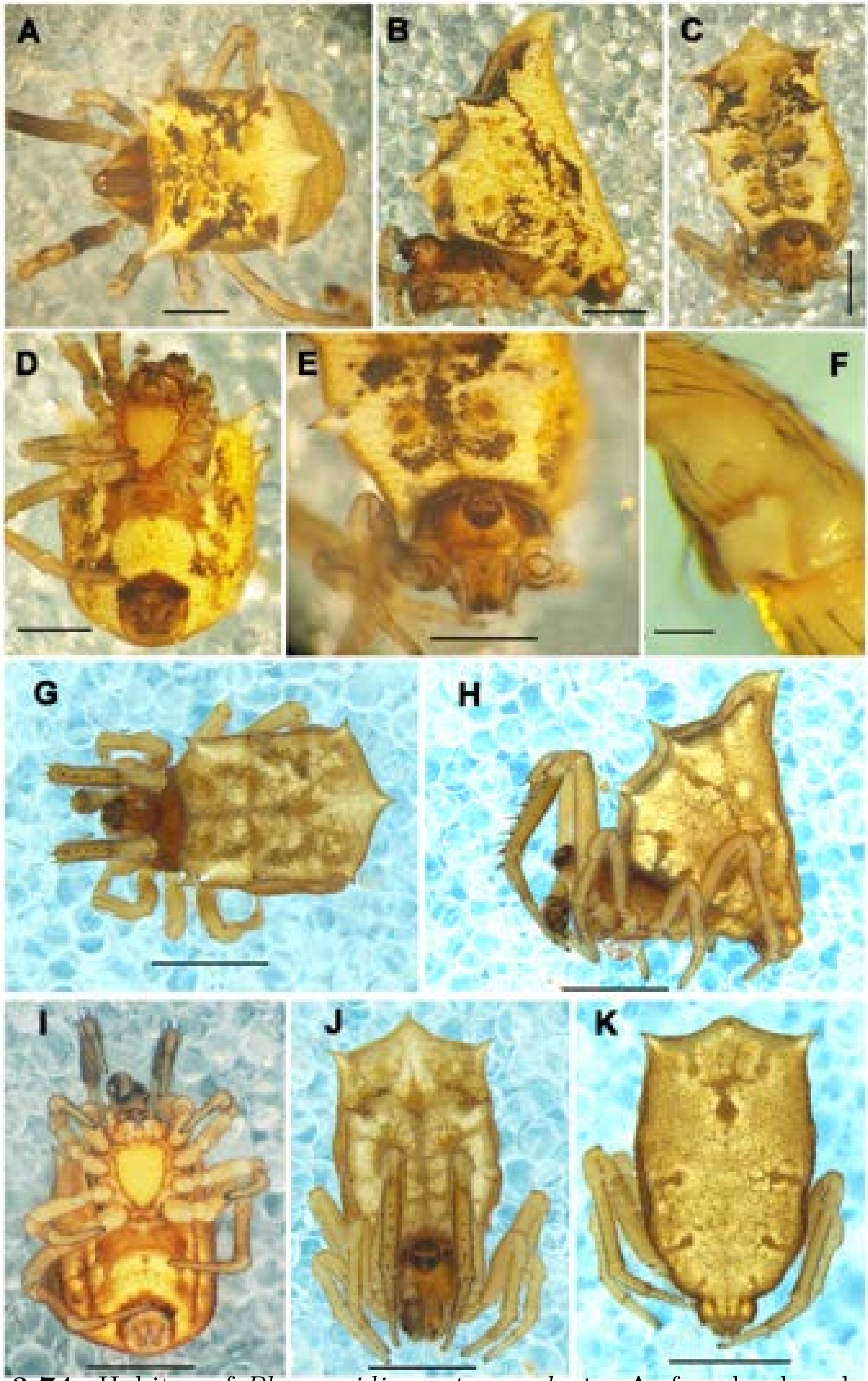

Figure 3.74: Habitus of *Phoroncidia septemaculeata*. **A**, female, dorsal view. **B**, same, lateral view. **C**, same, frontal view. **D**, same, ventral view. **E**, Same, eye region. **F**, male, Patella IV, showing lyriform organ. **G**, Same, dorsal view. **H**, same, lateral view. I, same, ventral view. **J**, same, frontal view. **K**, same, posterior view. Scale bars: **AE**, 1 mm; **F**, 0.1 mm; **G–K**, 1 mm.

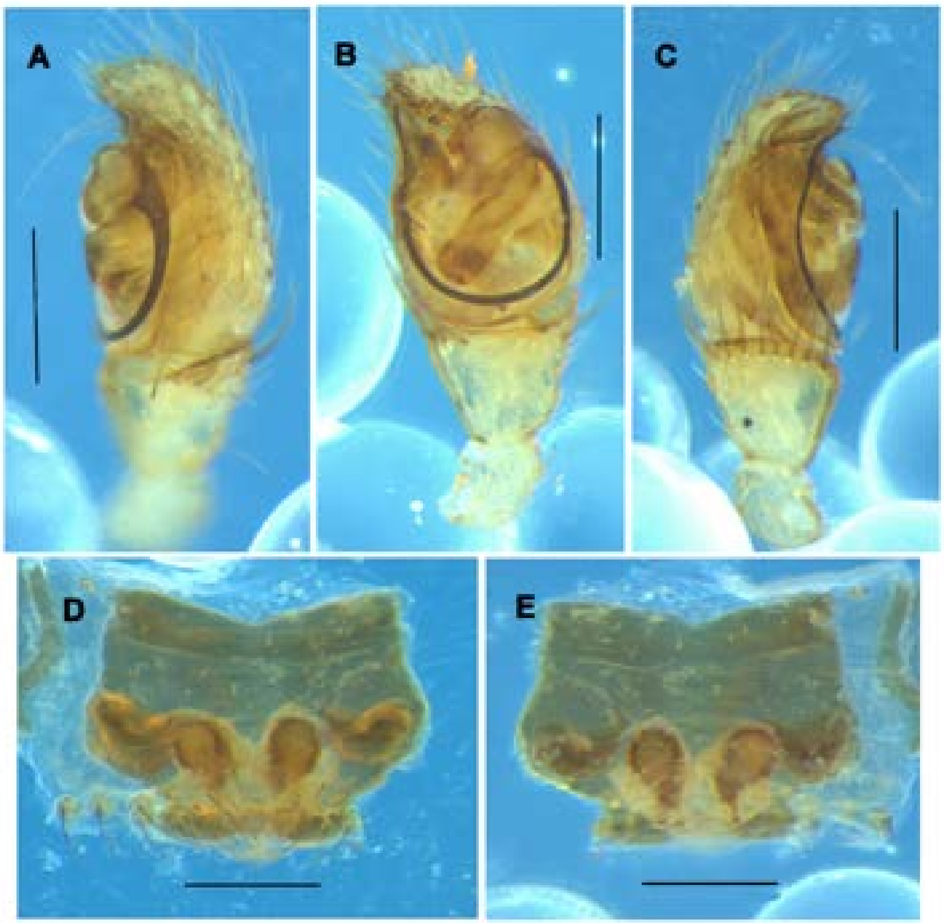

Figure 3.75: Male and female genitalia of *Phoroncidia septemaculeata*. **A**, male left palp, retrolateral. **B**, same, ventral view. **C**, same, prolateral view; **D**, epigynum, ventral view. **E**, same, dorsal view. Scale bars: **A–E**, 0.2 mm.

genitalia of *P. septemaculeata* is closest to *P. americana*, but can be distinguished from the latter by the following features: male palp with conductor on the prolateral side ventral to TTA (positioned retrolaterally, dorsal to embolic base in *P. americana*), embolic base lobed, almost heart-shaped, with a deep v-shaped excavation on prolateral side (irregularly shaped with a shallow excavation distally in *P. americana*); vulva of female genitalia with copulatory duct forming a loop over the posterior half of spermathecae (forms a loop almost over the entire spermathecae in *P. americana*), posterior spermathecae and fertilisation duct slightly bent laterally (bent 180 degrees medially in *P. americana*)(compare Figs 3.75AC, E, 3.76AC, F with Levi, 1955: pl. 1, Figs 1, 2, 4–6, 9, Levi and Levi, 1962: fig. 245 and Agnarsson et al., 2007: Fig. 49).

Redescription: MALE (CATE10301C) (Figs 3.73A–C, Figs 3.74G–K,

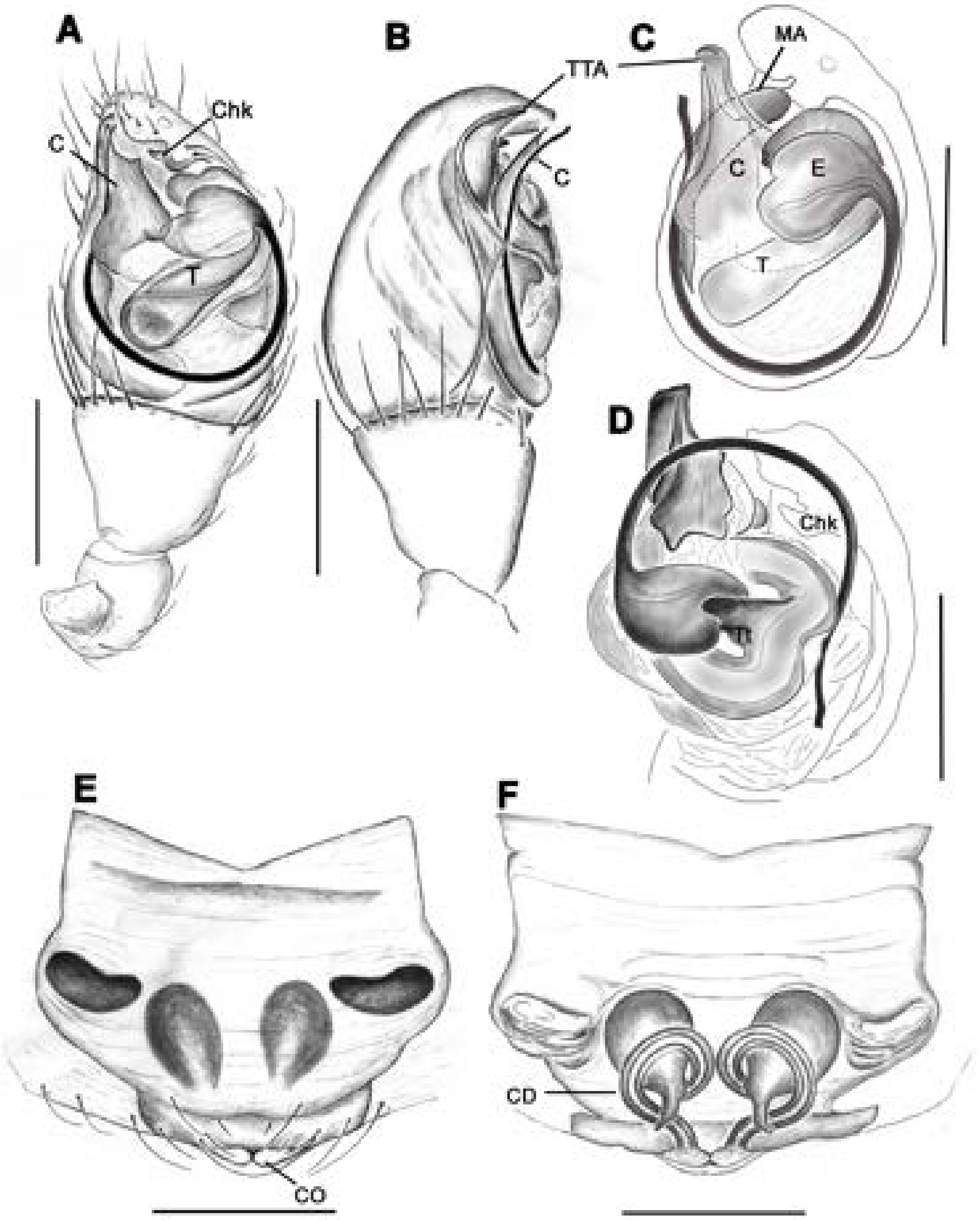

Figure 3.76: Illustrations of male and female genitalia of *Phoroncidia septemaculeata*. **A**, male left palp, ventral view. **B**, same, prolateral view. **C**, same loosened, ventral view. **D**, same, expanded, ventral view. **E**, epigynum, ventral view. **F**, same, dorsal view. Abbreviations: C—conductor, CD—copulatory duct, Chk—cymbial hook, CO—copulatory opening, E—embolus, MA—median apophysis, Tt—tegular tooth, TTA—theridioid tegular apophysis. Scale bars, 0.2 mm.

Figs 3.75A–C, Figs 3.76A–D): Measurements: Body length 2.27, carapace length 1.20, width 0.93, height at PME 0.76, sternum length 0.52, width 0.45, clypeus height 0.28, abdomen length 1.86, width 1.49, height 2.78. Eye diameters: AME

Figure 3.77: Map showing distributional records of *Phoroncidia septemaculeata*. ●—new record, ?—question mark indicates that the type locality in Sri Lanka is unknown and locality in Malaysia is unknown.

0.08, ALE 0.05, PLE 0.04, PME 0.07. Eye interdistances: AME–AME 0.06, AME–ALE 0.03, PLE–PME 0.06, AME–PME 0.08, PME–PME 0.03. Leg formula: I, IV, II, III.

Carapace orange-brown, ocular area profoundly produced than female, covered with short spines, longitudinal rows of spines behind PME; AME largest, separated by half their diameter. MOQ almost square, ALE and PLE subequal and touching each other, PME slightly smaller than AME, with tapetum, located on top of the turret; thoracic area devoid of spines; chelicerae small, anterior inner margin with a row of long dark setae, with two closely situated promarginal teeth apically; labium and maxillae pale yellow-brown; sternum yellow-orange, shield-shaped with impressed dots, with sparsely situated long setae (Fig. 3.74I). Abdomen yellow to pale yellow, subtriangular laterally, projecting over the base of carapace, covered with circular impressed dots with a single setae (Fig. 3.74H); anteriorly adorned with seven short and stout spines originating from protuberances of abdomen, anteriorly with nine circular orange-brown spots and seven each on lateral and posterior, all symmetrically arranged, few dark patches also present on the anterior face (Figs 3.74G–H, J); ventral abdomen pale yellow, epigastric pale orange-brown, sclerotised. Legs yellow, Leg I longest, with a row of four long, prominent spines on dorsal tibia, tibia II with a row of small spines on prolateral and retrolateral, patella I–III with one dorsal spine, distal tibia I–III with short spines (Fig. 3.74H); basal half of tibia I–IV with two rows of trichobothria dorsally, lyriform organ

Table 3.10: *Phoroncidia septemaculeata.* Measurements of legs and palp

Male	**Leg segments**	**I**	**II**	**III**	**IV**	**Palp**
	Femur	1.29	0.70	0.60	1.00	0.44
	Patella	0.38	0.25	0.22	0.38	0.12
	Tibia	0.86	0.44	0.38	0.75	0.17
	Metatarsus	0.47	0.27	0.22	0.36	–
	Tarsus	0.51	0.37	0.35	0.47	0.40
	Total	3.51	2.03	1.77	2.96	1.13
Female	**Leg segments**	**I**	**II**	**III**	**IV**	**Palp**
	Femur	1.41	0.83	0.73	1.50	–
	Patella	0.44	0.39	0.28	0.47	–
	Tibia	0.91	0.52	0.53	1.06	–
	Metatarsus	0.49	0.30	0.28	0.48	–
	Tarsus	0.58	0.37	0.45	0.61	–
	Total	3.83	2.41	2.27	4.12	–

present on retrolateral patella I–IV (Fig. 3.74F).

Palp. (Figs 3.75A–C, Figs 3.76A–D). Palp yellow, tibia bell-shaped, distal rim with a regular row of long setae; cymbium stout, covered in setae, tapering distally, cymbial hook tapering, hook tip blunt (Fig. 3.76D); embolus long, originating at 2–3 o'clock, tip of embolus at 12 o'clock; embolic base lobed, almost heart-shaped, with a deep v-shaped excavation on the prolateral (Figs 3.76A, C); conductor long and wide, positioned ventrally above TTA, with tip of embolus resting on the conductor (Figs 3.76A–D); TTA surface smooth, tip bent ventrally; MA without hood (Fig. 3.76C); when palp is expanded, large tegular tooth articulates with v-shaped excavation of embolic base, thereby locking the embolus in place (Fig. 3.76D).

Redescription: FEMALE (CATE10301C) (Figs 3.74A–E, 3.75D–E, 3.76E–F): Measurements: Body length 3.36, carapace length 1.41, width 1.21, height at PME 0.93, sternum length 0.71, width 0.61, clypeus height 0.28, abdomen length 1.95, width 2.06, height 3.82. Eye diameters: AME 0.08, ALE 0.06, PLE 0.07, PME 0.07. Eye interdistances: AME–AME 0.07, AME–ALE 0.05, PLE–PME 0.05, AME–PME 0.12, PME–PME 0.04. Leg formula: IV, I, II, III.

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

Epigynum (Figs 3.75D–E, 3.76E–F). Epigynum orange-brown, highly sclerotised, with a pair of bean-shaped sclerotised spots on the lateral sides, copulatory opening situated on arch-like protrusion beneath posterior margin of epigynal plate (Fig. 4E); spermathecae separated from each other, pear-shaped, tapering posteriorly, with apical end slightly bent laterally; fertilisation duct bent laterally (Figs 3.75E, 3.76F); copulatory duct long, forms a loop around the posterior spermathecae before entering it posteriorly on the dorsal side (Fig. 3.76F).

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

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

3.3.31.14 ***PHYCOSOMA*** **O. Pickard-Cambridge, 1880**

Phycosoma is a less species-rich genus with a worldwide distribution (World Spider Catalog, 2021). The genus currently comprises 26 nominal species globally, with a single species known from India (World Spider Catalog, 2021).

Diagnosis: *Phycosoma* species can be distinguished by the following combination of characters: Carapace sub-ovoid, eye region slightly projecting, very high and concave clypeus, sub-globose abdomen, sternum broadly produced between coxae IV; leg I longer than IV. female epigynal spermathecae spherical and ducts with minimal coils. Male pedipalps with a large median apophysis, embolus long and forms a circle, conductor with a small projection, and accessory apophysis usually attached to the embolus.

Type species: *Phycosoma oecobioides* O. Pickard-Cambridge, 1880

Species sampled from the Muriyad Kol Wetland.

Phycosoma labialis (Zhu, 1998)

Dipoena labialis Zhu, 1998: 241, Figs 158A–D (♀); Song et al., 1999: 112, Figs 55A–B (♀).

Phycosoma labialis Zhang and Zhang, 2012: 38, Figs 20–24.

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Phycosoma labialis* commonly found in grasslands and paddy fields.

3.3.31.15 ***PROPOSTIRA*** Simon, 1894

Propostira is a less species-rich genus distributed in the Oriental region, specifically India and Sri Lanka (World Spider Catalog, 2021). The genus currently comprises 2 nominal species globally, both known from India (World Spider Catalog, 2021).

Type species: *Propostira quadrangulata* Simon, 1894

Species sampled from the Muriyad Kol Wetland.

Propostira quadrangulata Simon, 1894
Fig. 3.A.16B

Propostira quadrangulata Simon, 1894: 510, Figs 513–515 (♀); Levi and Levi, 1962: 45, Fig. 96–97 (♀).

Habitat: *P. quadrangulata* were found in foliages in riparian and uncultivated plots.

3.3.31.16 ***THWAITESIA*** O. Pickard-Cambridge, 1881

Thwaitesia is a less species-rich genus with pantropical distribution (World Spider Catalog, 2021). The genus currently comprises 23 nominal species globally, with 2 species known from India (World Spider Catalog, 2021).

Diagnosis: *Thwaitesia* is closer to *Episinus* and *Spintharus*, but it can be distinguished from them by the following combination of characters: Posterior median eyes separated from each other by about an eye diameter (less than an eye diameter in *Episinus* and two or more eye diameter in *Spintharus*); abdomen distinctly pigmented with prominent silvery plate-like spots, dorsally with black, green, yellow, golden and red patterns (not covered with distinct plate-like silvery spots in *Episinus* and *Spintharus*); male palpal alveolar cavity with conspicuous sclerite (absent in *Episinus* and *Spintharus*) (Levi & Levi, 1962; Pickard-Cambridge, 1881).

Type species: *Thwaitesia margaritifera* O. Pickard-Cambridge, 1881

Species sampled from the Muriyad Kol Wetland.

Thwaitesia margaritifera Gravely, 1921
Figs 3.A.16C, 3.A.16D and 3.78 to 3.80

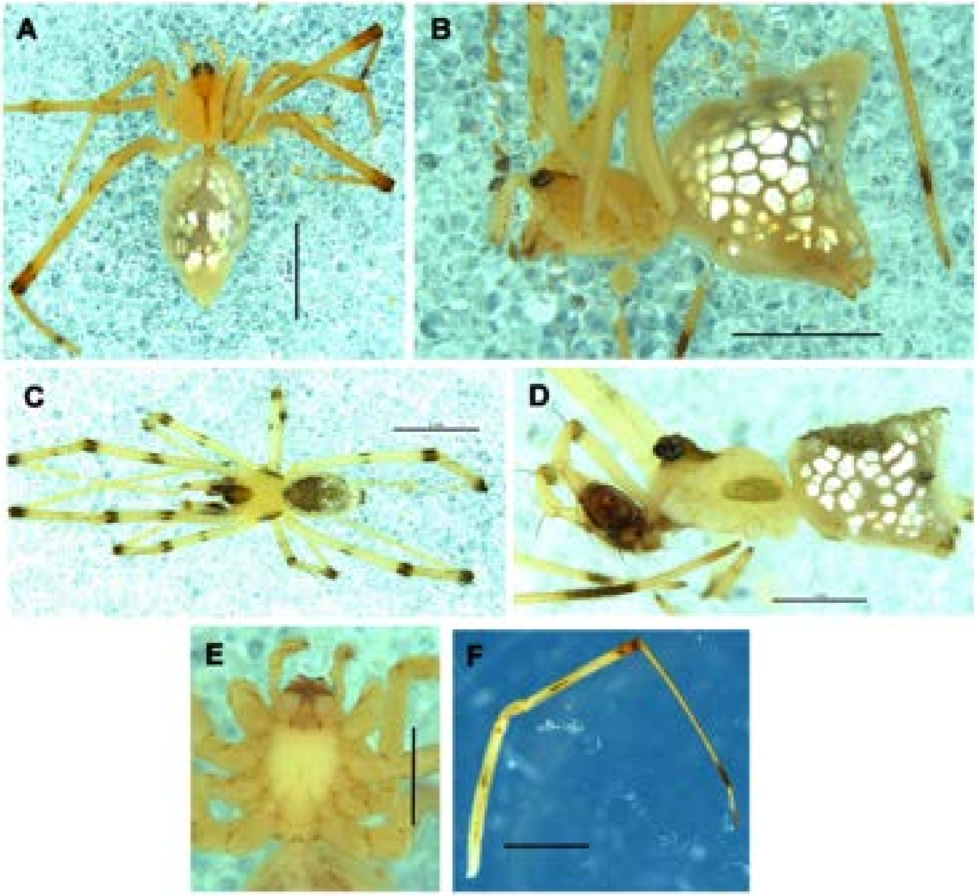

Figure 3.78: Habitus of *Thwaitesia margaritifera*. Female (**A–B**) and male (**C–F**). **A**, general appearance, dorsal view. **B**, same, lateral view. **C**, same, dorsal view. **D**, same, lateral view. **E**, carapae, ventral view. **F**, left leg I, prolateral view. Scale bars. **A–D**, 2 mm. **E, F**, 1 mm.

Thwaitesia margaritifera Pickard-Cambridge, 1881: 766, pl. 66, Fig. 1 (Original description); Simon, 1894Simon, 1894: 514, fig. 526; Levi and Levi, 1962: 54, Figs 207–210; Zhu, 1998: 286, Figs 193A–D; Song et al., 1999: 149, Figs 83 O–P; Gupta and Siliwal, 2012: 77, Figs 3A–G; Agnarsson, 2004: Figs 83G, 84D–F.

Thwaitesia dangensis Patel and Patel, 1972: 295, Figs 2a–e. (not examined), syn. nov.

Types: Syntypes eight females and one male of *T. margaritifera*,from Sri Lanka, G. H. K. Thwaites leg., deposited in OUMNH, NOT EXAMINED.

Material examined: INDIA: Kerala: Thrissur, Kol wetlands, Konthipulam (10°23´16.7″N 76°14´32.4″E), 3 m alt, 15.9.2015, K. S. Nafin leg., beating, 1 ♀(CATE 10303A); Thrissur, Vellangalloor (10°18´24.5″N 76°12´17.6″E), 13 m alt, Varun Das leg., 29.12.2016, by hand, 1 ♂(CATE 10303E); Kannur, Dharmasala,

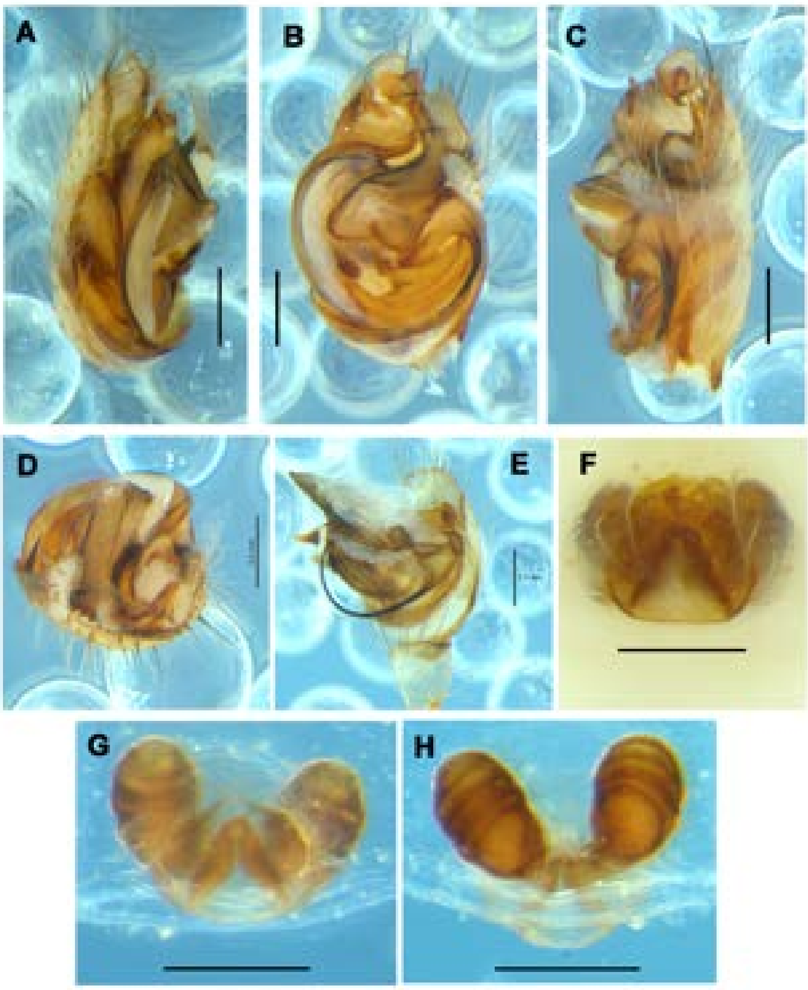

Figure 3.79: Male and female genitalia of *Thwaitesia margaritifera*. **A**, male left palp, prolateral view. **B**, same, ventral view. **C**, same, retrolateral view. **D**, same, ventral view. **D**, epigyne, ventral view. **E**, vulva, dorsal view. Scale bars. **A–E**, 0.2 mm.

Neeliyar Kottam sacred grove (11°59´6.1″N 75°21´49.0″E), 31 m alt, 19.2.2018, N.V. Sumesh & K.S. Nafin leg., by hand, 1♀(CATE 10303F); Wayanad, WWS, Bathery Range (11°40´48.3″N 76°20´38.1″E), 850 m, P.P. Sudhin & K.S. Nafin leg., 17.6.2015, beating, 1♀, 1 ♂(CATE 10303C); Wayanad, WWS, Kurichiad Range (11°45´55.3″N 76°14´57.4″E), 843 m alt, P.P. Sudhin & K.S. Nafin leg., 16.6.2014, by hand, 1♂(CATE090101A); 3 ♂♂, 1 ♀(CATE 10303B).

Redescription. FEMALE (10303A) (Figs 3.78AB, EF, 3.79FH, 3.80DE). Measurements: Body length 4.67. Carapace length 1.77, width 1.49, height at PME 1.07, height (at the middle) 1.17. Abdomen length 2.83, width 1.95, height 3.12. Eye diameters: AME 0.11, ALE 0.10, PME 0.12, PLE 0.09. Eye interdistances:

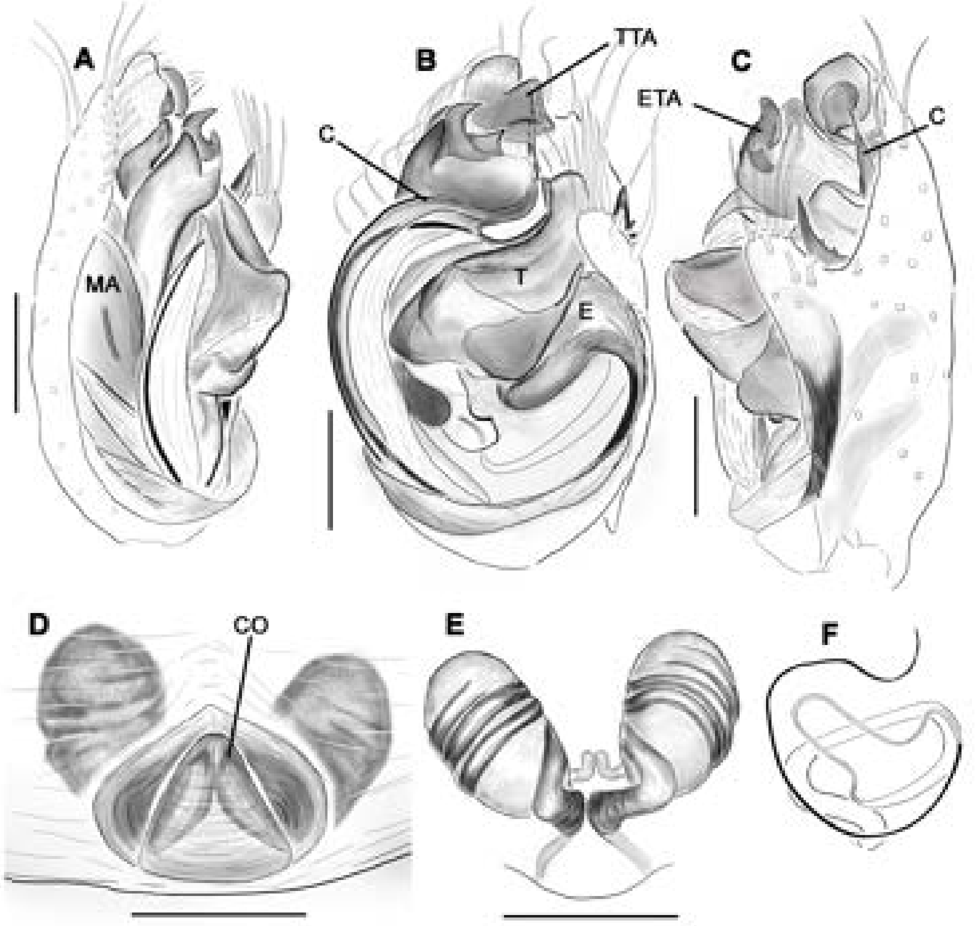

Figure 3.80: Illustrations of male and female genitalia of *Thwaitesia margaritifera*. **A**, male left palp, prolateral view. **B**, same, ventral view. **C**, same, retrolateral view. **D**, same, ventral view. **D**, epigyne, ventral view. **E**, vulva, dorsal view. **F**, male, sperm duct trajectory. Abbreviations: CO—copulatory opening, E —embolus, ETA—extra tegular apophysis, MA—median apophysis, T—tegulum, TTA—theridioid tegular apophysis. Scale bars. **A**–**E**, 0.2 mm.

AME–AME 0.09, AME–ALE 0.03, ALE–ALE 0.41, PME–PME 0.11, PME–PLE 0.02, PLE–PLE 0.38, AME–PME 0.09. Clypeus height 0.28. Length of chelicera 0.51. Leg formula: 1423.

Carapace pale yellow, head region red-orange, longitudinal band red orange, almost extending to posterior margin (Fig. 3.78A); head elevated and projecting forward, with eyes at the anterior end; thorax convex, elevated, indented longitudinally (Fig. 3.78B). Clypeus high, sloping with base projecting forward. Chelicerae pale yellow, subconical, weak and slender, with three teeth, small and pointed. Maxillae and labium pale yellow. Sternum pale yellow, shield-shaped (Fig. 3.785E). Legs pale yellow, banded appearance, tibia I, IV and tarsi I with

Table 3.11: *Thwaitesia margaritifera.* Measurements of legs and palp

Male	**Leg segments**	**I**	**II**	**III**	**IV**	**Palp**
	Femur	3.60	2.38	1.67	3.67	0.66
	Patella	0.73	0.58	0.43	0.65	0.16
	Tibia	3.13	1.52	0.97	2.68	0.29
	Metatarsus	4.14	2.19	1.6	3.71	–
	Tarsus	1.08	0.78	0.74	1.24	0.59
	Total	12.68	7.45	5.33	11.95	1.70
Female	**Leg segments**	**I**	**II**	**III**	**IV**	**Palp**
	Femur	3.37	2.24	1.48	2.88	–
	Patella	0.71	0.45	0.32	0.57	–
	Tibia	3.22	1.62	1.06	2.56	–
	Metatarsus	4.31	2.15	1.49	3.84	–
	Tarsus	1.13	0.89	0.75	1.72	–
	Total	12.72	7.35	5.10	10.90	–

red-orange tinge distally, metatarsi I & IV with reddish brown bands distally, femur I with longitudinal discontinuous black lines laterally, tibia I lateral with black lines in middle and diagonal line distally (Fig. 3.78F); leg II with faded bands; Leg III bands absent; tibia IV distally with small diagonal black line prolaterally and black spot retrolaterally, black spot in middle on prolateral side, patella IV distal margin with black line. patella and tibia with a few spines; tarsal comb bristles distinctly notched. Abdomen pale yellow, higher than in males almost quadrangle with posterior conical end with black spot, laterally with irregularly shaped shiny silvery spots, very sparse silvery spots dorsomedially (Figs 3.78A–B). Ventrum devoid of spots, two setae in place of colulus, anterior spinneret with one spigot.

Epigyne (Figs 3.79FH, 3.80D–E). Epigyne onion-shaped, with large inverted V-shaped raised septum having atrium on either sides, copulatory opening situated anteriorly inside atrium,copulatory openings close to each other, copulatory ducts with two loops over spermathecae, spermathecae ovoid, fertilisation duct posteriorly situated, oriented anteriorly. A mating plug in the form of an amorphous secretion was observed in one of the females.

MALE (10303A) (Figs 3.78C–D, 3.79A–E, 3.80A–C, F). Measurements: Body length 3.30. Carapace length 1.38, width 1.17, height at PME 1.02, height (at the middle) 1.00. Abdomen length 1.92, width 1.27, height 1.91. Eye diameters: AME 0.12, ALE 0.09, PME 0.10, PLE 0.09. Eye interdistances: AME–AME 0.12,

AME–ALE 0.02, ALE–ALE 0.35, PME–PME 0.12, PME–PLE 0.04, PLE–PLE 0.38, AME–PME 0.13. Clypeus height 0.30. Length of chelicera 0.42. Leg formula: 1423.

In all details as female, except the following: Carapace pale yellow, head region orange brown, longitudinal indistinct brown band extending to fovea, thoracic lateral margin with dark mottling from coxae II–IV (Fig. 3.78C); head region higher than in females (Fig. 3.78D); Maxillae and labium brown. Legs pale yellow, banded appearance, with tibia I–IV and metatarsi I, II, IV dark orange-brown distally, mid and distal femur I and distal femur IV with orange-brown bands, light orange-brown bands on mid and distal femur II–III and mid femur IV. Abdomen smaller than in females, dorsal region brown with black mottlings (Fig. 3.78D).

Palp (Figs 3.79A–E, 3.80A–C, F). Palpal segments pale yellow, patella longer than tibia, trichobothria three, cymbium with prominant retrolateral process medially, apically with a brush-like row of long, thick setae; tegulum with a pointed, curved retrolateral process having a row of pointed teeth along its margin (Figs 3.79D, 3.80B–C), embolus long, originating at 3 o'clock, conductor large, with an elongated, pointed distal end, TTA smooth and wide, ETA bifurcated, pointed sclerites (Figs 3.80A–C); spermduct trajectory as in Fig. 3.807F, duct enters MA and switchbacks trajectory (SDT SB III, as in Agnarsson, 2004).

Colouration in live spider. Abdomen dorsally with a pattern formed of red, black and silver. The red longitudinal band extends to the posterior end, with two transverse red bands and silver spots in the rest of the surface. Black mottlings are present on the posterior half and a black spot at the posterior tip. Laterals are covered with silver spots.

Justification for synonymy of *T. dangensis*. *T. dangensis* was described based on a female specimen collected from Dangs district, Gujarat, India. The description and illustration of the somatic features of *T. dangensis* provides hints of its conspecificity with *T. margaritifera*. Features such as the shape of the abdomen and its dorsal pigmentation pattern looks similar to that of T. margaritifera (Figs 5AB; Patel and Patel, 1972: figs 2a, d). Also, the illustration of leg I provided with the description shows the characteristic dark banded appearance of leg segments observed in *T. margaritifera* (Patel and Patel, 1972: fig. 2e). On a closer look, the sketchy illustration of the epigyne also shows resemblance to the epigyne of *T. margaritifera*, when viewed at a posteroventral angle (Patel and Patel, 1972: fig. 2b). All these observations support the conspecificity of *T. dangensis* with *T.*

margaritifera. Thus, the species, *T. dangensis*, should be considered as a junior synonym of *T. margaritifera.*

Habitat: Specimens from the foliages of understory and lower canopies in the agricultural landscapes of Kol wetland and the moist deciduous forests of WWS, Kerala.

Distribution: India (Kerala [new record], Uttarakand), Sri Lanka, China and Vietnam.

3.3.31.17 ***THERIDION*** Walckenaer, 1805

Theridion is a specious genus with widespread distribution (World Spider Catalog, 2021). The genus currently comprises 584 nominal species globally, with 10 species known from India (World Spider Catalog, 2021).

Diagnosis: *Theridion* species can be distinguished by the following combination of characters: Carapace longer than wide, with no stridulating structures, and indistinct fovea; males with enlarged chelicerae; female chelicerae with one or two teeth in promargin and none in retromargin. Abdomen typically spherical, longer than high, and sometimes wider than long, subtriangular, and free of plate or tubercles. epigyne with a weakly sclerotized opening and one pair of seminal receptacles. Male pedipalp with distinct median apophysis conductor and radix, but position varies (Barrion & Litsinger, 1995; Levi & Levi, 1962).

Type species: *Theridion pictum* (Walckenaer, 1802)

Species sampled from the Muriyad Kol Wetland.

Theridion odisha Gravely, 1921

Theridion odisha Prasad et al., 2019: 109, Figs 1–6 (♀).

Habitat: *T. odisha* were found on crevaces on the walls of buildings.

Other species sampled:

Theridion **sp. 1**

Theridion **sp. 2**

3.3.32 FAMILY THERIDIOSOMATIDAE Simon, 1881

RAY SPIDERS

Family Theridiosomatidae represents very small araneomorph spiders, ecribellate, entelegyne, three tarsal claws, eight-eyed, with cosmopolitan distribution (Jocqué & Dippenaar-Schoeman, 2006). They are commonly known as ray spiders, constructs webs of variable shapes in the humid and shaded areas. The web looks orb like yet it lacks a hub, its radii instead of converging in the centre are rather united in groups, each group being connected to the centre by a thread. The spiders sits away from the web and pulls it tightly into a dome-shape by means of a thread attached to the centre of the web, and releases it suddenly entangling any prey that might hit the snare (Barrion & Litsinger, 1995). The family currently has 129 species in 19 genera globally, and only one is known from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following characters: Carapace pear-shaped, low clypeus; eyes in two rows, anterior eye row recurved, posterior eye row procurved or straight; chelicerae robust; abdomen smooth and ovoid to tubercles in variable regions, scutum absent; epigyne usually flat or domed sclerotized plate, spermathecae fused along midline; male palp small to large size, paracymbium absent but simple hook at the base of lateral margin of cymbium, embolus robust sclerite (Jocqué & Dippenaar-Schoeman, 2006).

Type genus: *Theridiosoma* O. Pickard-Cambridge, 1879

3.3.32.1 *THERIDIOSOMA* O. Pickard-Cambridge, 1879

Theridiosoma is a less species-rich genus with widespread distribution (World Spider Catalog, 2021). The genus currently comprises 36 nominal species globally, with 10 species known from India (World Spider Catalog, 2021).

Diagnosis: *Theridiosoma* species can be distinguished from all other theridiosomatids by the following combination of characters: PMEs are juxtaposed, nearly or in fact touching. Embolic division short, tubular embolus with the embolic apophysis fragmented into several long bristle-like parts; median apophysis is consistently a curved lobe attenuate distally with a slight groove along its upper long axis. Females with relatively firm, robust copulatory ducts leading from the bursa to the spermathecae (Coddington, 1986).

Type species: *Theridiosoma argenteolum* O. Pickard-Cambridge, 1879

Species sampled from the Muriyad Kol Wetland.

Theridiosoma sp.

3.3.33 FAMILY THOMISIDAE Sundevall,1833

CRAB SPIDERS

Family Thomisidae represents small to large araneomorph spiders, ecribellate, entelegyne, two clawed, eight-eyed , with cosmopolitan distribution (Jocqué & Dippenaar-Schoeman, 2006). They are commonly called crab spiders due to the way they keep their amterior pair of legs and the ability to scuttle sideways and backwards. Members of the thomisidae are found wandering on foliage and only a few are seen on the ground. They build no web to trap prey, but produces silk to drop lines and for reproductive purposes. Generally considered as ambush predators, some species wait besides flowers or fruits to grab prey that comes by, some frequent promising positions on barks and leaves, while others sit in the open as good mimics of bird droppings. The family currently has 2150 species in 169 genera globally, and 179 of them are known from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following characters: Carapace semicircular, ovoid or elongated, some species with protuberances or eye tubercles; eyes in two rows, laterals usually on tubercles and larger than others; cheliceral teeths usually absent except in Stephanopinae; legs laterigrade, legs I and II longer than others, anteriors leges with series of strong spines on tibiae and metatarsi; abdomen round or ovoid to elongate; anterior spinnerets short, conical, colulus present; epigyne usually with a hook, atrium and guide pockets bordered; male palpal tibia with ventral and retrolateral apophysis (Jocqué & Dippenaar-Schoeman, 2006).

Type genus: *Thomisus* Walckenaer, 1805.

3.3.33.1 *AMYCIAEA* Simon, 1885

Amyciaea is a less species-rich genus distributed in the Oriental and Australian regions (World Spider Catalog, 2021). The genus currently comprises 5 nominal species globally, with a single species known from India (World Spider Catalog, 2021).

Diagnosis: *Amyciaea* species can be distinguished by the following combination of characters: Carapace as long as a wide, high, sloping cephalic region in front; eyes round, lateral eyes ringed with prominent tubercles, both rows recurved but the posterior row strongly recurved, lateral eyes noticeably larger than medians. The spiders of this genus have typically ant-like appearance. Abdomen is longer than wide, and it is covered in fine hairs.

Type species: *Amyciaea forticeps* (O. Pickard-Cambridge, 1873)

Species sampled from the Muriyad Kol Wetland.

Amyciaea forticeps (O. Pickard-Cambridge, 1873)
Figs 3.A.16E and 3.A.16F

Amyciaea forticeps Tikader, 1980b: 169, Figs 234–236 (♂); Sunil Jose, Davis, et al., 2003: 157, Figs 1a–h (♂♀).
(For complete list of references, see World Spider Catalog, 2021)

Habitat: *A. forticeps* were found in foliages in wooded habitats.

Natural history: *A. forticeps* are myrmecophagous and myrmecomorphic spider. They are excellent mimics of *Oecophylla smaragdina* and there prey capture behaviour has been observed widely.

3.3.33.2 *CAMARICUS* Thorell, 1887

Camaricus is a less species-rich genus distributed in the Oriental, Ethiopian and Australian regions (World Spider Catalog, 2021). The genus currently comprises 15 nominal species globally, with 6 species known from India (World Spider Catalog, 2021).

Diagnosis: *Camaricus* species can be distinguished from other Araneids by the following combination of characters:

Type species: *Camaricus formosus* Thorell, 1887

Species sampled from the Muriyad Kol Wetland.

Camaricus formosus Thorell, 1887

Fig. 3.A.16G

Camaricus formosus Tikader, 1980b: 175, Figs 1–2, 243–245 (♂♀); Barrion and Litsinger, 1995: 238, Figs 138a–b (♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *C. formosus* were found in foliages in wooded habitats.

3.3.33.3 ***EPIDIUS*** Thorell, 1887

Epidius is a less species-rich genus mostly distributed in the Oriental and Ethiopian regions, except for a species in Palearctic (Japan) (World Spider Catalog, 2021). The genus currently comprises 16 nominal species globally, with 5 species known from India (World Spider Catalog, 2021).

Diagnosis: *Epidius* species can be distinguished from other genera by the following combination of characters: Male palp with elongated femur and tibia (both are longer than the cymbium); distal tip of palpal tibia with 4 to 6 thick long spines; MA, if present, is fixed. Females can be separated by the presence of oval, dual-chambered spermatheca connected by C-shaped, thick-walled CD (Benjamin, 2017).

Type species: *Epidius longipalpis* Thorell, 1877

Species sampled from the Muriyad Kol Wetland.

Epidius parvati Benjamin, 2000

(Figs 3.A.16H and 3.81)

Epidius parvati Benjamin, 2000: 284, Figs 1–23 (♂♀); Malamel and Sudhikumar, 2017: 1, Figs 1A–F, 2A–D (♂♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *E. parvati* were found in foliages of shrubs and short trees in mixed crop, uncultivated and riparian habitats.

Natural history: *E. parvati* are ambushers found moving about on the surface of leaves and branches. Their green colouration enable them to blend in with the leaves and are at times difficult to spot.

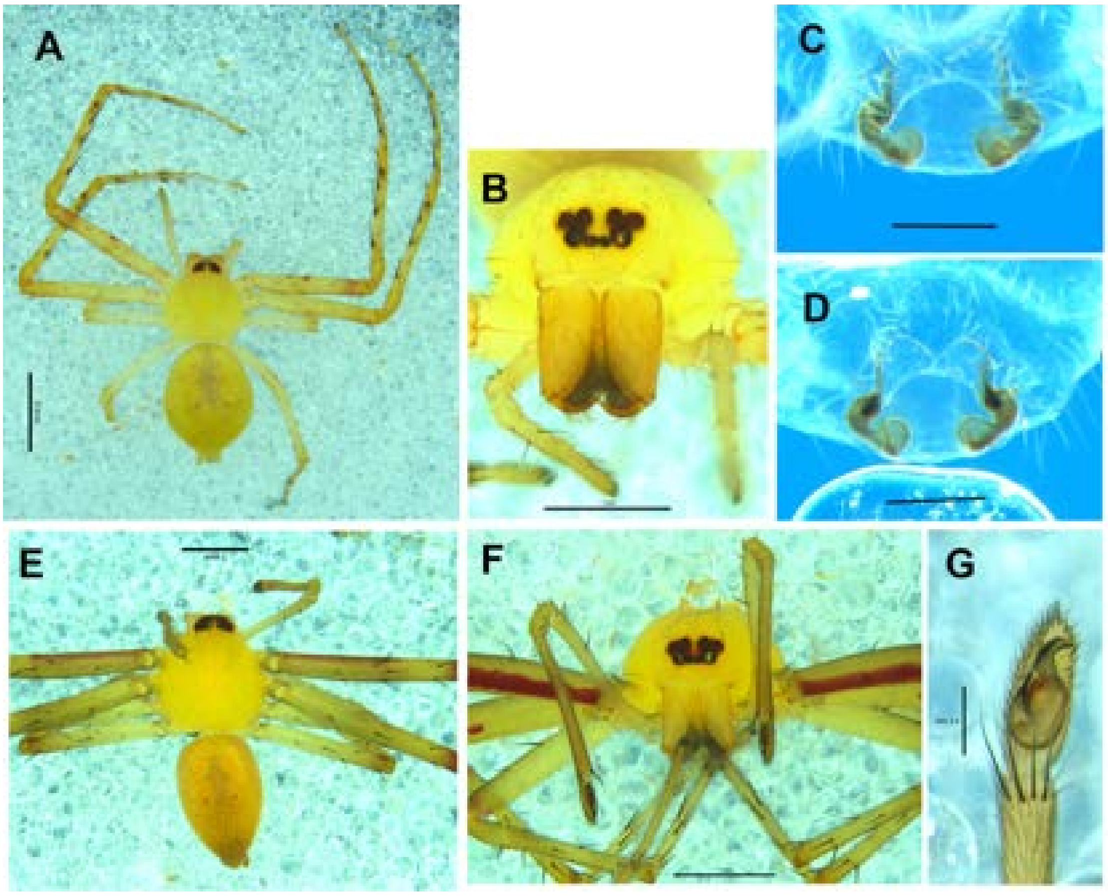

Figure 3.81: Male and female of *Epidius parvati.* Female (**A–D**)and male (**E–G**). **A–B**, general appearance, dorsal view. **B, F**, carapace, frontal view. **C**, epigyne, ventral view. **D**, vulva, dorsal view. **G**, left palp, ventral view. Scale bars. **A**, 2 mm. **B, E–F**, 1 mm. **C–D, G**, 0.2 mm.

3.3.33.4 *INDOXYSTICUS* Benjamin & Jaleel, 2010

Indoxysticus is a less species-rich genus distributed in the Oriental region (World Spider Catalog, 2021). The genus currently comprises 3 nominal species globally, with a single species known from India (World Spider Catalog, 2021).

Diagnosis: *Indoxysticus* species can be distinguished by the following combination of characters: Spermathecae oval-shaped with well-defined chambers; male palpal embolus with broad base and a subtegular prong that originates behind the embolus (Benjamin & Jaleel, 2010).

Type species: *Indoxysticus minutus* (Tikader, 1960)

Species sampled from the Muriyad Kol Wetland.

Indoxysticus minutus (Tikader, 1960)

Xysticus minutus Tikader and Malhotra, 1981: 80, Figs 143–144 (♀); Sen, Dhali, et al., 2015: 67, Figs 364–368, pl. 17 (♀).

Indoxysticus minutus Benjamin and Jaleel, 2010: 162, Figs 3–4, 8–15 (♂♀)

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *I. minutus* were found in the foliages in all habitats.

3.3.33.5 ***PHRYNARACHNE*** Thorell, 1869

Phrynarachne is a moderately species-rich genus distributed in the Oriental and Ethiopian regions (World Spider Catalog, 2021). The genus currently comprises 32 nominal species globally, with 3 species known from India (World Spider Catalog, 2021).

Diagnosis: *Phrynarachne* species can be distinguished by the following combination of characters: Male one-third size of the female; carapace with granulations; small eyes. Chelicerae with two promarginal teeth and one large tooth retromarginally; sternum oval and longer than wide; abdomen with many large and small tubercles; male palpal tibia is well developed and long; epigyne simple with a sclerotized plate, reniform spermathecae.

Type species: *Phrynarachne rugosa* (Walckenaer, 1805)

Species sampled from the Muriyad Kol Wetland.

Phrynarachne tuberosa (Blackwall, 1864)

Phrynarachne tuberosa Simon, 1895: 1045; Roy, Dhali, et al., 2010: 544, Figs 1–6, 14 (♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *P. tuberosa* were found in the foliages in uncultivated plots.

Natural history: *P. tuberosa* belongs to a group of bird dropping spiders. The spider rests on the top surface of leaf with its legs held close to its body, along with the peculiar tubercles on the abdomen, it resembles bird droppings on a leaf.

3.3.33.6 ***MASSURIA*** Thorell, 1887

Massuria is a less species-rich genus distributed in the Oriental and Palearctic (Japan) regions (World Spider Catalog, 2021). The genus currently comprises 8 nominal species globally, with 3 species known from India (World Spider Catalog, 2021).

Diagnosis: *Massuria* are heavily built, short errect setae on the carapace and the submarginal abdominla pattern; male palpal tibia with large thick basal part; RTA with pointed distal process; epigyne of Indian species with a subcircular pit (Lehtinen, 2004).

Type species: *Massuria angulata* Thorell, 1887

Species sampled from the Muriyad Kol Wetland.

***Massuria* sp.**

3.3.33.7 *MISUMENA* Latreille, 1804

Misumena is a less species-rich genus with widespread distribution (World Spider Catalog, 2021). The genus currently comprises 42 nominal species globally, with 7 species known from India (World Spider Catalog, 2021).

Diagnosis: *Misumena* males differ from all other Missumenini except *Pistius* in having a spirally screwed, distally unmodified embolus; they can be seperated from *Pistius* by their pale colouration. Females differ from *Runcinia* by the wider abdomen and the more widely spaced receptacles; seperated from other Old World genera they differ in the presence of violet parts in the abdominal pattern and the relatively simple epigyne (Lehtinen, 2004).

Type species: *Misumena vatia* (Clerck, 1757)

Species sampled from the Muriyad Kol Wetland.

Misumena mridulai Tikader, 1962

Misumena mridulai Sunil Jose and Sebastian, 2001: 184, Figs 1A–B (♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *M. mridulai* were found in the foliages in paddy fields, mixed crops and riparian habitats.

3.3.33.8 *OXYTATE* L. Koch, 1878

Oxytate is a less species-rich genus distributed in the Oriental, Australian, Ethiopian and Palearctic regions (World Spider Catalog, 2021). The genus currently comprises 28 nominal species globally, with 4 species known from India (World Spider Catalog, 2021).

Diagnosis: *Oxytate* species can be distinguished by the following combination of characters: Lateral eyes protrude slightly and surrounded by white rings; abdomen elongates, widens near the front, and gradually tapers to the spinnerets; Legs long, with spines that are much longer in I and II than in III and IV.

Type species: *Oxytate striatipes* L. Koch, 1878

Species sampled from the Muriyad Kol Wetland.

***Oxytate* sp.**

3.3.33.9 *OZYPTILA* Simon, 1864

Ozyptila is a moderately species-rich genus mostly distributed in the Palearctic and Nearctic regions, and a few species in the Oriental and Ethiopian regions (World Spider Catalog, 2021). The genus currently comprises 103 nominal species globally, with 8 species known from India (World Spider Catalog, 2021).

Diagnosis: *Ozyptila* species can be distinguished by the following combination of characters: Carapace, abdomen, and legs covered in clavate or spatulate hairs; clypeus with a row of hairs; eyes are black, medium ocular trapezium is longer than wide; PMEs are closer to one another than laterals. Legs thick and short.

Type species: *Ozyptila claveata* (Walckenaer, 1837)

Species sampled from the Muriyad Kol Wetland.

***Ozyptila* sp.**

3.3.33.10 *RUNCINIA* Simon, 1875

Runcinia is a less species-rich genus mostly distributed in the Oriental region (World Spider Catalog, 2021). The genus currently comprises 27 nominal species globally, with 10 species known from India (World Spider Catalog, 2021).

Diagnosis: *Runcinia* species can be distinguished by the following combination of characters: Carapace slightly wider than long, cephalic region with prominent ocular tubercles, a broad pale band from the eyes to the posterior margin, bordered on the sides by two very broad brown bands; legs I and II are stronger and longer than legs III and IV, with two rows of short, strong spines on the ventral surface of the tibiae and metatarsi I and II; abdomen long, spined, and narrower behind, with prominent longitudinal muscular corrugation on the lateral sides.

Type species: *Runcinia grammica* (C. L. Koch, 1837).

Species sampled from the Muriyad Kol Wetland.

***Runcinia* sp.**

3.3.33.11 *THOMISUS* Walckenaer, 1805

Thomisus is a moderately species-rich genus mostly distributed in the Oriental, Ethiopian and Palearctic regions, and a few species in the New world (World Spider Catalog, 2021). The genus currently comprises 143 nominal species globally, with 46 species known from India (World Spider Catalog, 2021).

Diagnosis: *Thomisus* species can be distinguished by the following combination of characters: Anterior carapace is truncated, with the upper corners strongly and conically protuberant and divergent, bearing lateral eyes; very small eyes; abdomen rhombus, pentagonal in shape, narrow and truncated in front, enlarging to a considerable width behind, with a short blunt conical protuberance at either corner of the dorsal side; Legs long; crab-like appearance.

Type species: *Thomisus onustus* Walckenaer, 1805

Species sampled from the Muriyad Kol Wetland.

Thomisus lobosus (Blackwall, 1864)
Fig. 3.A.17C

Thomisus lobosus Tikader, 1971: 17, Figs 6M–N (♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Thomisus lobosus* were found in the foliages of shrubs and short trees.

Thomisus projectus (Blackwall, 1864)

Thomisus projectus Tikader, 1971: 18, Figs 6J–L (♀).

(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Thomisus projectus* were collected from the paddy fields.

3.3.34 FAMILY TRACHELIDAE Simon,1897

GROUND SAC SPIDERS

Family Trachelidae represents small to medium sized araneomorphs, ecribellate, entelegyne, two clawed with tufts, eight-eyed, with cosmopolitan distribution (Jocqué & Dippenaar-Schoeman, 2006). They are commonly known as Ground sac spiders, and are mostly wanderers that do not use webs for prey capture. It was earlier placed in the Clubionidae, later in Corinnidae when the former was split up, before elevating it to a family status (Deeleman-Reinhold, 2001; Ramírez, 2014). The family currently has 247 species in 19 genera globally, and 6 of them are known from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021).

Diagnosis: Most trachelids are similar to Phrurolithidae Banks, 1892 in having claw tufts with heavily folded setae, claw tuft clasper, reduced spination on posterior legs and dorsally on all femora and male palp without a median apophysis (Ramírez, 2014). It can be distinguished by the lack of ventral distal hook on male palpal femur; most of the trachelids lack macrosetae altogether and males have leg cuspules (Ramírez, 2014).

Type genus: *Trachelas* L. Koch, 1872.

3.3.34.1 *UTIVARACHNA* Kishida, 1940

Utivarachna is a less species-rich genus mostly distributed in the Oriental region (World Spider Catalog, 2021). The genus currently comprises 19 nominal species globally, with a single species known from India (World Spider Catalog, 2021).

Diagnosis: *Utivarachna* species can be distinguished by the following combination of characters: Carapce broad, convex, posteriorly wedge-shaped; a triangular projection of the clypeus margin extends between the cheliceral bases; male palpal the tegulum folded along a more or less transverse line, pushing back the coiled embolus between the tegulum and the inner side of the cymbium; females posterior median spinnerets are similar to those in Gnaphosids with bilobed median spinnerets with five cylindrical gland spigots (Deeleman-Reinhold, 2001).

Type species: *Utivarachna fukasawana* Kishida, 1940

Species sampled from the Muriyad Kol Wetland.

Utivarachna fronto (Simon, 1906)

Trachelas fronto Majumder and Tikader, 1991: 111, Figs 230–234 (♂♀).
Utivarachna fronto Deeleman-Reinhold, 2001: 370, 397.
(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Utivarachna fronto* were collected from foliages in wooded areas in the study area.

3.3.35 FAMILY ULOBORIDAE Thorell,1869

HACKLED-ORB WEAVERS OR TRIANGLE WEB SPIDERS

Family Uloboridae represents small to medium sized araneomorphs, both cribellate, entelegyne, three clawed, eight-eyed, with worldwide distribution (Jocqué & Dippenaar-Schoeman, 2006). These non-venomous spiders are commonly known as hackled-orb weavers or triangle web spiders, and their lack of venom gland is considered to be secondarily evolved trait. The spiders thoroughly wrap their prey in silk and smear it with regurgitated digestive enzymes and ingest the liquified prey. they use non sticky silk on their orb webs, being cribellate their feathery and fuzzy silk easily ensnare prey. The family currently has 287 species in 19 genera globally, and 25 of them are known from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following characters: Venom glands are absent; metatarsi IV dorsally compressed and curved under univariate calamistrum, femora with rows of long trichobothria; epigyne with paired or unpaired caudal projections; male palp with modified tibia, disc-like to conical, embolus thin, circular, coiled or short curved spine, cymbium with two apical setae (Jocqué & Dippenaar-Schoeman, 2006).

Type genus: *Uloborus* Latreille, 1806.

3.3.35.1 *MIAGRAMMOPES* O. Pickard-Cambridge, 1870

Miagrammopes is a moderately species-rich genus with widespread distribution (World Spider Catalog, 2021). The genus currently comprises 69 nominal species globally, with 11 species known from India (World Spider Catalog, 2021).

Diagnosis: *Miagrammopes* species can be distinguished by the following combination of characters: Body dry twig-like, carapace longer than wide; abdomen elongate, thin, almost tubular, and five times as wide as long; legs extremely long and slender, Leg I is stronger than the others, Rows of short spines dorsally on male tibiae I and ventrally on female metatarsi IV, tarsi are shorter than metatarsi, and tarsus IV bears a ventral row of macrosetae; females have tarsal claws, while males have tibial projection.

Type species: *Miagrammopes thwaitesi* O. Pickard-Cambridge, 1870

Species sampled from the Muriyad Kol Wetland.

Miagrammopes thwaitesi O. Pickard-Cambridge, 1870

Miagrammopes thwaitesii Pickard-Cambridge, 1870: 401, pl. 14, Figs 1–12 (♀); Lehtinen, 1967: 464, Fig. 506 (♂).

Habitat: *M. thwaitesi* were collected from understory in uncultivated and riparian plots.

Natural history: *M. thwaitesi*, like other congeners, resemble twigs of trees or shrubs.

Miagrammopes extensus Simon, 1889

Miagrammopes extensa Simon, 1889: 342 (♀).

Habitat: *M. extensa* was collected from understory in uncultivated plots.

3.3.35.2 *ULOBORUS* Latreille, 1806

Uloborus is a moderately species-rich genus with widespread distribution (World Spider Catalog, 2021). The genus currently comprises 80 nominal species globally, with 9 species known from India (World Spider Catalog, 2021).

Diagnosis: *Uloborus* species can be distinguished by the following combination of characters: Carapace broader dorsally, slightly longer than wide; abdomen spear-shaped, rounded anteriorly, and pointed at the back, two substantial but well-separated humps at the widest point; leg I is much longer and more robust in both males and females. Male tibia I has rows of strong spines, whereas female tibia I has substantial hair fringes on the dorsal and ventral surfaces.

Type species: *Uloborus walckenaerius* Latreille, 1806

Species sampled from the Muriyad Kol Wetland.

Uloborus jabalpurensis Bhandari & Gajbe, 2001
Fig. 3.A.17E

Uloborus jabalpurensis Bhandari and Gajbe, 2001: 87, Figs 1–3 (♀); Maheshwari et al., 2019: 28, Figs 1–12 (♂♀).

Habitat: *U. jabalpurensis* were collected from mixed crops, uncultivated and riparian habitats .

Natural history: Spider appears white as it is covered in white plume. They are highly tolerant spiders found among branched of shrubs and in the gardens.

3.3.35.3 *ZOSIS* Walckenaer, 1841

Zosis is a less species-rich genus originally distributed in the New World, but introduced to Oriental, Palearctic, Australian and Ethiopian regions (World Spider Catalog, 2021). The genus currently comprises 9 nominal species globally, with a single species known from India (World Spider Catalog, 2021).

Diagnosis: *Zosis* species can be distinguished by the following combination of characters: Eyes in two rows, PER slightly recurved and PLE not on tubercles; cribellum and calamistrum present; femora II and III with trichobothria; tibia I without brush of hairs; tarsus IV with ventral row of macrosetae and sternum undivided; Epigyne with no ventral atrium; male pedipalp lacks conductor, but with a long, broad and flat tegular spur that function as an embolus guide; paracymbium absent; cymbial setae developed; and femoral tubercle visible (Barrion & Litsinger, 1995).

Type species: *Zosis geniculata* (Olivier, 1789)

Species sampled from the Muriyad Kol Wetland.

Zosis geniculata (Olivier, 1789)

Fig. 3.A.17F

Zosis geniculata Song et al., 1999: 85, Figs 35N–O, 37A (♂♀); Sen, Dhali, et al., 2015: 22, Figs 29–33, pl. 12 (♀).
(For complete list of references, see World Spider Catalog, 2021)

Habitat: *Zosis geniculata* were found in wooded areas in the study area.

3.3.36 FAMILY ZODARIIDAE Thorell,1881

BURROWING OR ANT-EATING SPIDERS

Family Zodariidae represents small to large araneomorphs with a variety of shapes, ecribellate, entelegyne, three clawed, six or eight-eyed, with distribution in the tropical and subtropical regions of the world(Jocqué & Dippenaar-Schoeman, 2006). They are commonly known as burrowing or ant-eating spiders, and are mostly free-living ground-dwellers or tree living and live closely with ants, mimicking their behaviour and chemical signals, some are even ant or termite specialists. The family currently has 1165 species in 87 genera globally, and 30 of them are known from India (Caleb & Sankaran, 2020; World Spider Catalog, 2021).

Diagnosis: Members of the family can be distinguished by the following characters: Chelicerae fangs very short, strong with well developed lateral condyle, serrula absent; legs unpaired claw on onychium, paired claw with numerous tetth inserted on lateral side to the opposing claw; abdomen usually ovoid, scutum present in some males; anterior lateral spinnerets long, posterior spinnerets reduced; male palpal tibia with one or many dorsolateral apophyses, cymbium oval, tegulum complex with many apophysis (Jocqué & Dippenaar-Schoeman, 2006).

Type genus: *Zodarion* Walckenaer, 1826.

3.3.36.1 ***TROPIZODIUM*** Jocqué & Churchill, 2005

Tropizodium is a less species-rich genus distributed in the Oriental, Palearctic, Australian (also Oceania) (World Spider Catalog, 2021). The genus currently comprises 12 nominal species globally, with 5 species known from India (World Spider Catalog, 2021).

Diagnosis: *Tropizodium* species can be distinguished by the following combination of characters: small spiders (1.5–3.6 mm). Male palpal RTA well-developed, greatly extended anteriorly reaching the apex of cymbium; lateral surface of the RTA is often provided with modified, serrated setae; cymbium with one large apical and several pectinated setae (Dankittipakul et al., 2012).

Type species: *Tropizodium peregrinum* Jocqué & Churchill, 2005

Species sampled from the Muriyad Kol Wetland.

Tropizodium kalami Prajapati, et al., 2016

Tropizodium kalami Prajapati et al., 2016: 576, Figs 1A–B, 2A–C, 3A–C, 6A–H, 7A–G (♂♀).

Habitat: *Tropizodium kalami* were collected from the ground in uncultivated plots.

3.4 Discussion

The documentation of 195 species from the Muriyad Kol wetland landscape showed how diverse the spider fauna can be even in such a human-dominated environment. The study is significant in that there was little or no data on the spider fauna of Kol wetlands prior to this study. The study area in the Kol wetlands is a freshwater system surrounded by laterite elevated lands, in contrast to the Vembanad portion of the Vembanad-Kol wetland complex,which is largely a low-lying estuarine landscape. The complex landscape and geographical features of the study area favour a comparatively larger number of species than any previous studies in the Vembanad-Kol wetland complex (Malamel & Sudhikumar, 2020a; Sudhikumar, 2007). Although this study was carried out in only one part of the Kol wetland, it provides basic data on spiders that may be representative of the spider fauna in other parts of the Kol wetland with a similar nature and characteristics.

The spider fauna of the Muriyad Kol wetland landscape was represented by members of the infraorders Mygalomorphae and Araneomorphae, accounting for about 10 percent of the species and 57 percent of the families reported in India (Caleb & Sankaran, 2020). Although only a few species of Mygalomorphae are reported in the study, their occurrence in this agrolandscape is significant and the group is one of the least studied in this part of the country. Some species of Mygalomorphae are considered to be critically endangered or endangered, and some of them are known from the Western Ghats region, such as *Haploclastus kayi* Gravely, 1915, *Poecilotheria rufilata* Pocock, 1899, *Poecilotheria metallica* Pocock, 1899 and *Poecilotheria hanumavilasumica* Smith, 2004 (IUCN, 2021).

Of the species documented in the study, about five percent are new to science. The study also contributed to the taxonomic knowledge of many species, including members of the genus *Tetragnatha*, which are specifically adapted to wetland ecosystems. Twelve species, including a new species (*Tetragnatha concordia* sp. nov.) and the first description of a female (*Tetragnatha cochinensis*) were reported. Additionally, two of the species were recorded for the first time in India. This species-rich genus, like many others, has received less attention and no revisions have been made in India (Castanheira et al., 2019). The focus of the study was on the taxonomic treatment of some lesser known species and genera belonging to different families.

The Salticidae or jumping spiders were the most species-rich of all the families studied in the study area, with 37 species, including 9 new species. *Bianor kolensis* sp. nov., *Cocalus lacinia* Sudhin, Nafin, Sumesh & Sudhikumar, 2019, *Epeus triangulopalpis* Malamel, Nafin, Sudhikumar & Sebastian, 2019, *Hyllus kerala* sp. nov, *Chinattus thamannae* sp. nov., *Piranthus planolancis* Malamel, Nafin, Sudhikumar & Sebastian, 2019, *Stertinius aluva* sp. nov, *Tamigalesus noorae* sp. nov. and *Tamigalesus malabaricus* sp. nov. are the new species of Salticidae found in the study. Jumping spiders are very diverse and taxonomic knowledge of many genera is limited. Recently, the taxonomic study of jumping spiders in India has received a boost due to the increasing number of researchers and taxonomic resources. However, there are still many species to be discovered in the wild and elsewhere. Though easy to spot and collect, many species of jumping spiders are specialists and restricted to specific habitats, so they may have escaped this study. The present study contributed to the knowledge base on some genera of salticids of the region. The oriental genus *Piranthus* was rediagnosed with the discovery of its male, and a new species was described from India; the genus was subsequently recorded in Southeast Asia (Maddison et al., 2020). The newly described jumping spiders such as those belonging to *Epeus, Piranthus, Stertinius, cocalus* and *Hyllus* are arboreal spiders, and are easier to spot in the region. On the other hand, *Bianor* and *Chinattus* were found in open canopy habitats like fallow lands and paddy fields. Also, a redescription and new combination was proposed, *Indopadilla insularis*, which is a common jumping spider in the agroecosystem. The study also discovered two new *Tamigalesus* species, which are found mostly in densely forested areas with a lot of litter. The species such as *Phoroncidia septemaculeata* O. Pickard-Cambridge, 1873, *Argyrodes kumadai* Chida & Tanikawa, 1999, *Larinia tabida* (L. Koch, 1872), *Tetragnatha squamata* Karsch, 1879 and *Tetragnatha serra* Doleschall, 1857 are reported for the first time from

India. The study also redescribed and illustrated the monotypic genus *Psellonus* of the family Philodromidae. In addition, three species of Theridiidae, namely *Phoroncidia septemaculeata, Thwaitesia margaritifera* and *Meotipa multuma* are redescribed.

The sheer number of species described here suggests the need for further faunistic research focused on building taxonomic knowledge of spiders in other agricultural and man-made wetlands. Two of the species described here were also found on the undisturbed estuarine island in the Vembanad region of the Vembanad-Kol wetland complex (Malamel & Sudhikumar, 2020b). The results support the assumption that the complex landscape structure of the wetlands and the diversity of natural and man-made habitats provide refuge for a diverse group of spiders. Food and habitats provided by the agricultural landscapes support numerous non-agricultural species (Liu et al., 2006). Moreover, low intensity agricultural landscapes with high proportion of non-crop habitats sustain greater biodiversity than intensive agricultural landscapes (Ernoult & Alard, 2011; Tscharntke et al., 2005).

Earth is in the midst of the sixth mass extinction event, the first such event to be caused by humans (Kolbert, 2014). Given the severity of the situation, now is unquestionably the greatest moment to collect and document as many species as possible before they become extinct.The only way to do this is to revive the age-old studies of taxonomy and natural history (Cowie et al., 2022, January 10).

3.5 Conclusion

The wetlands of Muriyad Kol are a remarkably fertile and productive ecosystem on which people depend for a variety of vital resources. For more than a century and a half, the wetlands have been modified and cultivated for rice and other crops, and they continue to suffer from the pressures of population growth and its attendant ills. Nevertheless, the heterogeneous landscape provides diverse habitats that harbour a wide variety of spiders. In this survey, 195 spider species were recorded, including 10 new species in the wetland landscape. The Salticidae proved to be the most speciose family, and not surprisingly, all but one of the new species belonged to this family. The study also led to a documentation of the spiders in the study area with descriptions, illustrations and digital photographs of many species. The results also included some redescriptions, first reports of species and genus from India and a revision of the genus *Psellonus*. The natural history of many species was also discussed.

The discovery of many new species in the study shows that our current knowledge on the spider fauna of the region is very limited. The study can serve as a reference for future research or the development of conservation strategies. Future surveys could result in the discovery of many new species of spiders by broadening the scope of the search and identifying non-crop and agricultural habitats in the area that have been overlooked in this work.

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Appendix

Appendix 3.A Checklist of spiders in the Muriyad Kol wetland landscape

Family Species	Remarks
MYGALOMORPHAE	
Halonoproctidae Pocock,1901	
Conothele sp.	
Idiopidae Simon,1889	
Heligmomerus maximus Sanap & Mirza, 2015	
Heligmomerus sp.	
Theraphosidae Thorell,1869	
Annandaliella pectinifera Gravely, 1935	
ARANEOMORPHAE	
Araneidae Simon, 1895	
Anepsion maritatum O. Pickard-Cambridge, 1877	
Araneus ellipticus Tikader & Bal, 1981	
Araneus inustus L. Koch, 1871	
Araneus viridisomus Gravely, 1921	
Araneus mitificus (Simon, 1886)	
Argiope aemula (Walckenaer, 1841)	
Argiope anasuja Thorell, 1887	
Argiope catenulate Doleschall, 1859	
Argiope pulchella Thorell, 1881	
Chorizopes sp 1	
Cyclosa bifida Doleschall, 1859	
Cyclosa confraga Thorell, 1892	
Cyclosa hexatuberculata Tikader, 1982	
Cyrtophora cicatrosa Stoliczka, 1869	
Cyrtophora citricola (Forsskål, 1775)	
Cyrtophora unicolor (Doleschall, 1857)	
Cyrtarachne sundari Tikader, 1963	
Eriovixia laglaizei Simon, 1877	

Continued

3.A.1: (Cont.) Checklist.

Family Species	Remarks
Eriovixia excelsa Simon, 1889	
Gasteracantha dalyi Pocock, 1900	
Gasteracantha geminata Fabricius, 1798	
Herennia multipuncta (Doleschall, 1859)	
Larinia phthisica (L. Koch, 1871)	
Larinia tabida (L. Koch, 1872)	First report from India
Neoscona bengalensis Tikader & Bal, 1981	
Neoscona molemensis Tikader & Bal, 1981	
Neoscona mukerjei Tikader, 1980	
Neoscona sp.	
Neoscona theisi Walckenaer, 1841	
Paravixia dehaani Doleschall, 1859	
Poltys columnaris Thorell, 1890	
Poltys nagpurensis Tikader, 1982	
Araneid sp. 1	
Araneid sp. 2	
Clubionidae Wagner, 1887	
Clubiona sp1	
Matidia sp	
Corinnidae Karsch, 1880	
Castianeira zetes Simon, 1897	
Corinnomma severum (Thorell, 1877)	
Ctenidae Keyserling, 1877	
Ctenus cochinensis Gravely, 1931	
Deinopidae C. L. Koch, 1850	
Asianopis liukuensis (Yin, Griswold & Yan, 2002)	
Cheiracanthiidae Wagner,1887	
Cheiracanthium danieli Tikader, 1975	
Cheiracanthium melanostomum Thorell, 1895	
Eresidae C. L. Koch, 1845	
Stegodyphus sarasinorum Karsch, 1892	
Gnaphosidae Pocock, 1899	
Gnaphosa pauriensis Tikader & Gajbe, 1977	
Urozelotes patulusus Sankaran & Sebastian, 2018	

Continued

3.A.1: (Cont.) Checklist.

Family Species	Remarks
Zelotes sp 1	
Hersiliidae Thorell, 1870	
Hersilia savignyi Lucas, 1836	
Liocranidae Simon, 1897	
Oedignatha sp 1	
Linyphiidae Blackwall, 1859	
Erigone bifurca Locket, 1982	
Erigone sp.	
Atypena cirrifrons (Heimer, 1984)	
Atypena sp.	
Nasoona crucifera (Thorell, 1895)	
Neriene macella (Thorell, 1898)	
Lycosidae Sundevall, 1833	
Hippasa agelenoides Simon, 1884	
Hippasa greenalliae (Blackwall, 1867)	
Lycosa sp.	
Pardosa pseudoannulata Bösenberg & Strand, 1906	
Pardosa sp. 1	
Pardosa sp. 2	
Wadicosa fidelis (O. Pickard-Cambridge, 1872)	
Mimetidae Simon, 1881	
Mimetus Hentz, 1832	
Oecobiidae Blackwall,1862	
Oecobius marathaus Tikader, 1962	
Oonopidae Simon, 1890	
Oonopid sp1	
Oonopid sp 2	
Oxyopidae Thorell, 1870	
Hamadruas sikkimensis (Tikader, 1970)	
Hamataliwa hellia Dhali, Saha & Raychaudhuri, 2017	
Oxyopes birmanicus Thorell, 1887	
Oxyopes javanus Thorell, 1887	
Oxyopes shweta Tikader, 1970	
Peucetia viridana (Stoliczka, 1869)	

Continued

3.A.1: (Cont.) Checklist.

Family Species	Remarks
Pholcidae C.L. Koch, 1851	
Artema atlanta Walckenaer, 1837	
Crossopriza lyoni Blackwall, 1867	
Pholcus phalangioides Fuesslin, 1775	
Pholcus sp. 1	
Smeringopus pallidus (Blackwall, 1858)	
Philodromidae Thorell, 1870	
Psellonus planus Simon, 1897	Genus revision
Philodromus sp.	
Tibellus elongatus	
Palpimanidae Thorell, 1870	
Sarascelis sp.	
Pisauridae Simon, 1890	
Perenethis venusta L. Koch, 1878	
Pisaura sp.	
Salticidae Blackwall, 1841	
Asemonea tenuipes O. Pickard-Cambridge, 1869	
Bianor angulosus (Karsch, 1879)	
Bianor kolensis sp. nov.	New species
Brettus cingulatus Thorell, 1895	
Carrhotus viduus C. L. Koch, 1846	
Chalcotropis pennata Simon, 1902	
Chinattus thamannae sp. nov.	New species
Chrysilla volupe (Karsch, 1879)	Redescription
Cocalus lacinia Sudhin, Nafin, Sumesh & Sudhikumar, 2019	New species
Curubis tetrica Simon, 1902	
Epeus sp. 1	
Epeus triangulopalpis Malamel, Nafin, Sudhikumar & Sebastian, 2019	New species
Epocilla aurantiaca Simon, 1885	
Hyllus semicupreus Simon, 1885	
Hyllus kerala sp. nov.	New species
Indomarengo chavarapater Malamel et al., 2019	

Continued

3.A.1: (Cont.) Checklist.

Family Species	Remarks
Indopadilla insularis (Malamel et al. 2015)	Redescription
Marengo sachintendulkar Malamel et al., 2019	
Maripanthus sp.	
Menemerus bivittatus Dufour, 1831	
Myrmaplata plataleoides O. Pickard-Cambridge, 1869	
Myrmarachne melanocephala MacLeay, 1839	
Myrmarachne sp.	
Phaeacius lancearius Thorell, 1895	
Phintella vittata C. L. Koch, 1846	
Phintelloides jesudasi (Caleb & Mathai, 2014)	
Piranthus planolancis Malamel, Nafin, Sudhikumar & Sebastian, 2019	New species
Plexippus paykulli Audouin, 1826	
Plexippus petersi Karsch, 1878	
Portia fimbriata Doleschall, 1859	
Ptocasius sp.	
Rhene flavigera C. L. Koch, 1846	
Siler semiglaucus Simon, 1901	
Stenaelurilus albus Sebastian,2015	
Stertinius aluva sp. nov.	New species
Tamigalesus munnaricus Żabka, 1988	
Tamigalesus noorae sp. nov.	New species
Tamigalesus sp. nov.	New species
Telemonia dimidiata Simon, 1899	
Thiania bhamoensis Thorell, 1887	
Scytodidae Blackwall, 1864	
Scytodes fusca Walckenaer, 1837	
Scytodes thoracica Latreille, 1802	
Sicariidae Keyserling, 1880	
Loxosceles rufescens (Dufour, 1820)	
Sparasidae Bertkau, 1872	
Heteropoda venatoria Linnaeus, 1767	
Heteropoda sp.1	
Olios milleti (Pocock, 1901)	

Continued

3.A.1: (Cont.) Checklist.

Family Species	Remarks
Pandercetes sp.	
Thelcticopis moolampilliensis Jose & Sebastian, 2007	
Tetragnathidae Menge, 1866	
Glenognatha dentata Zhu & Wen, 1978	
Guizygiella nadleri (Heimer, 1984)	Redescription
Leucage decorata Blackwall, 1864	
Tetragnatha ceylonica Gravely, 1921	
Tetragnatha cochinensis Gravely, 1921	
Tetragnatha concordia sp. nov.	New species
Tetragnatha hasselti Thorell, 1890	
Tetragnatha keyserlingi Simon, 1890	
Tetragnatha viridorufa Gravely, 1921	
Tetragnatha javana Thorell, 1890	
Tetragnatha mandibulata Walckenaer, 1841	
Tetragnatha nitens Audouin, 1826	
Tetragnatha serra Doleschall, 1857	First record from India
Tetragnatha squamata Karsch, 1879	First record from India
Tetragnatha vermiformis Emerton, 1884	
Tylorida ventralis Thorell, 1877	
Tylorida striata (Thorell, 1877)	
Tylorida sp.	
Theridiidae Sundevall, 1833	
Argyrodes flavescence O. Pickard-Cambridge, 1880	
Argyrodes gazedes Tikader, 1970	
Argyrodes kumadai Chida & Tanikawa, 1999	First report from India
Argyrodes bonadea (Karsch, 1881)	
Ariamnes flagellum Doleschall, 1857	
Chikunia nigra (O. Pickard-Cambridge, 1880)	
Chrysso angula (Tikader, 1970)	
Chrysso urbasae (Tikader, 1970)	
Coleosoma floridanum Banks, 1900	
Episinus affinis Bösenberg & Strand, 1906	
Euryopis episinoides (Walckenaer, 1847)	

Continued

3.A.1: (Cont.) Checklist.

Family Species	Remarks
Meotipa picturata Simon, 1895	
Meotipa multuma Murthappa et al., 2017	
Nesticodes rufipes (Lucas, 1846)	
Nihonhimea mundula L. Koch, 1872	
Molione trispinosa (O. Pickard-Cambridge, 1873)	
Parasteatoda sp.	
Phoroncidia septemaculeata O. Pickard-Cambridge, 1873	First report from India
Phycosoma labialis (Zhu, 1998)	
Propostira quadrangulata Simon, 1894	
Thwaitesia margaritifera O. Pickard-Cambridge, 1881	Redescription
Theridion odisha Prasad et al., 2019	
Theridion sp. 1	
Theridion sp. 2	
Theridiosomatidae Simon, 1881	
Theridiosoma sp.	
Thomisidae Sundevall, 1833	
Amyciaea forticeps O. Pickard-Cambridge, 1873	
Camaricus formosus Thorell, 1887	
Epidius parvati Benjamin, 2000	
Indoxysticus minutus (Tikader, 1960)	
Massuria sp.	
Misumena mridulai Tikader, 1962	
Oxytate sp.	
Runcinia sp	
Ozyptila sp.	
Thomisus lobosus Tikader, 1965	
Phrynarachne tuberosa (Blackwall, 1864)	
Thomisus projectus Tikader, 1960	
Trachelidae Simon,1897	
Utivarachna fronto Simon, 1906	
Uloboridae Thorell, 1869	
Miagrammopes thwaitesi O. Pickard-Cambridge, 1870	

Continued

3.A.1: (Cont.) Checklist.

Family Species	Remarks
Miagrammopes extensus Simon, 1889	
Uloborus jabalpurensis Bhandari & Gajbe, 2001	
Zosis geniculata (Olivier, 1789)	
Zodariidae Thorell, 1881	
Tropizodium kalami Prajapati et al., 2016	

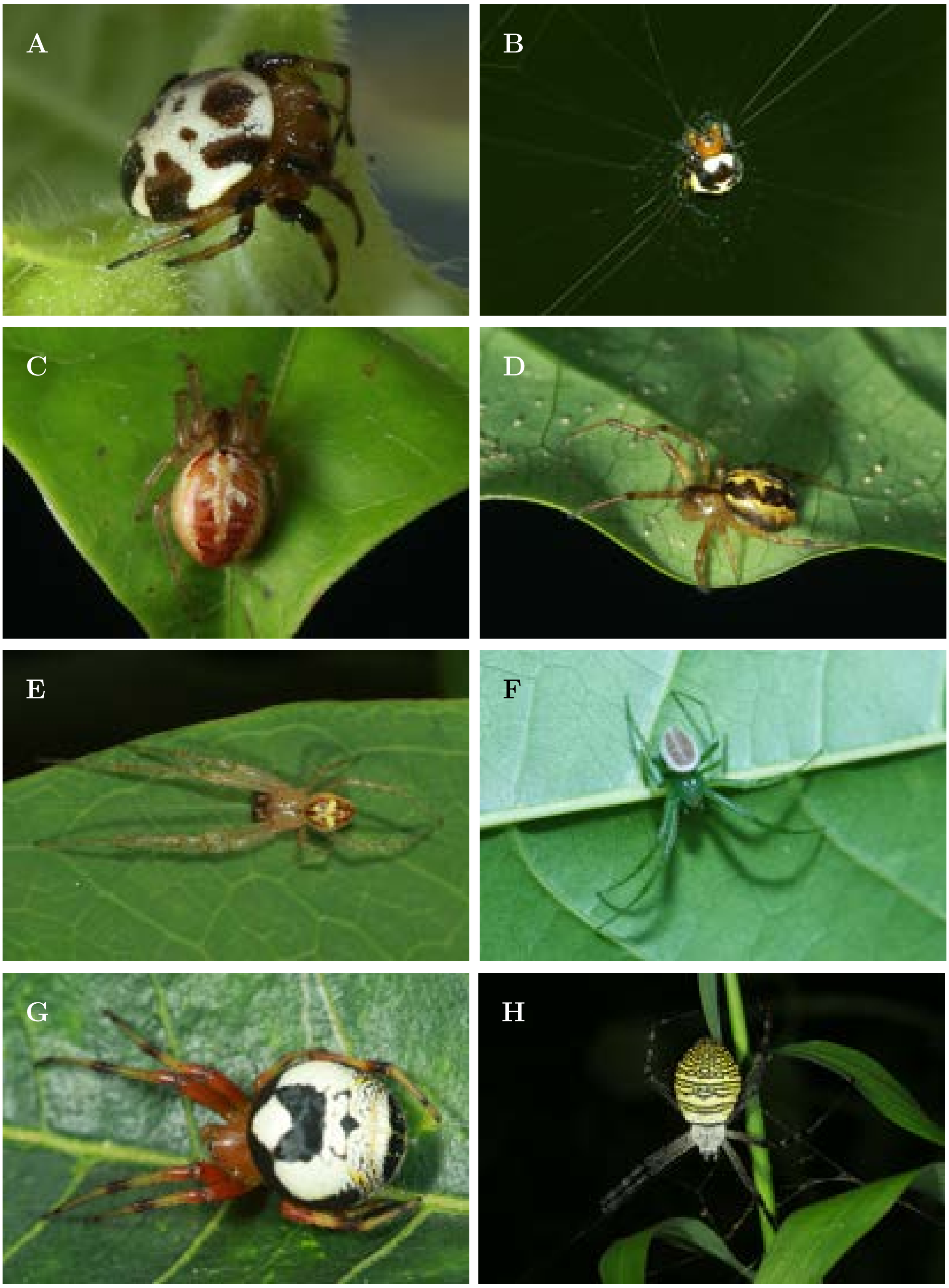

Figure 3.A.1: **Family Araneidae**: A–B *Anepsion maritatum*; C–E. *Araneus ellipticus*. C–D. females, colour variant, E. male; F. *Araneus viridisomus*, female; G. *Araneus mitificus*; H. *Argiope aemula*.

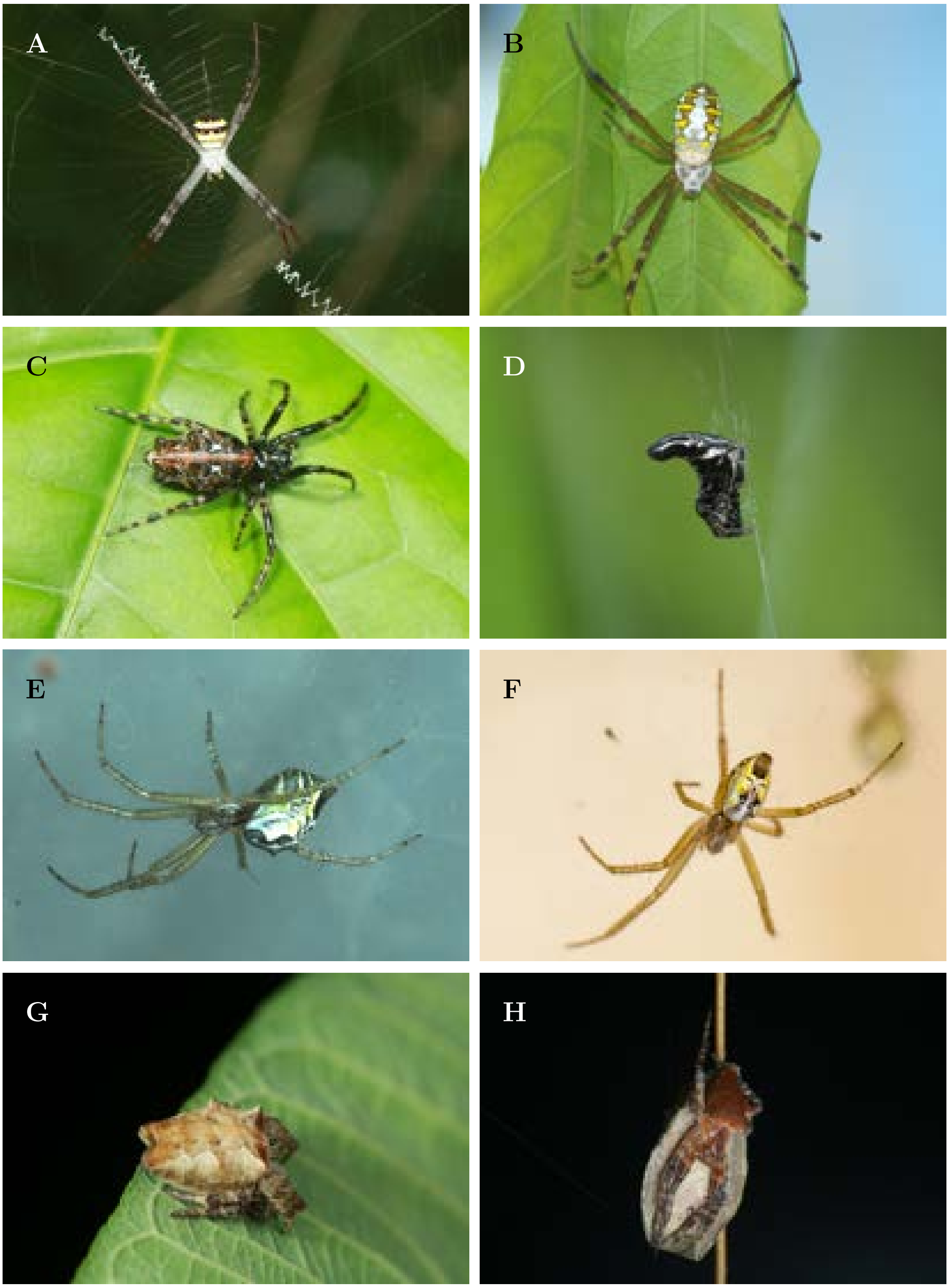

Figure 3.A.2: **Family Araneidae**: A. *Argiope pulchella*; B.*Argiope catanulata*; C. Cyclosa hexatuberculata; D. Cyclosa bifida; E–F. *Cyrtophora cicatrosa*; G. *Cyrtophora citricola*; H. *Cyrtophora unicolor*. A–H. female.

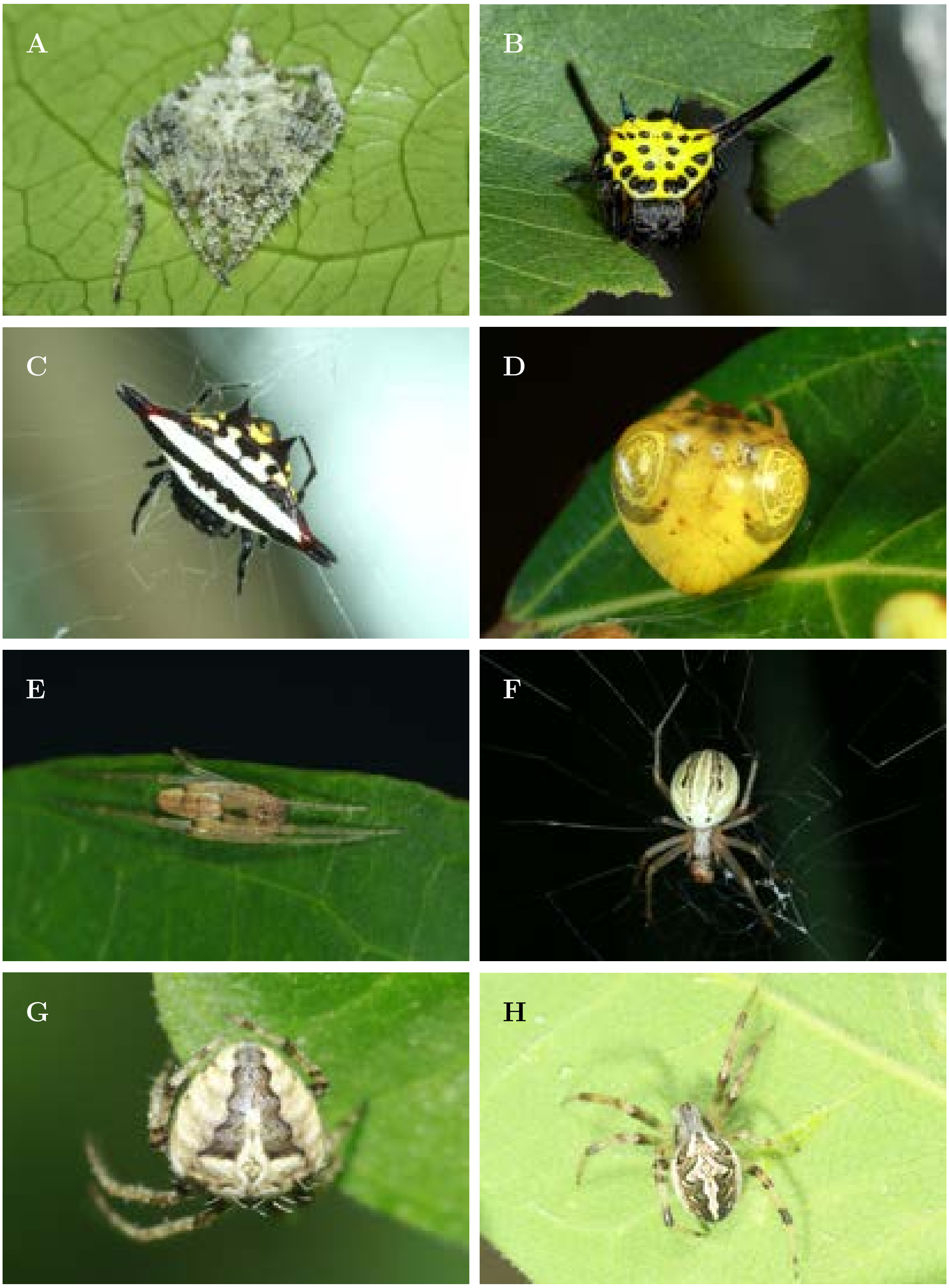

Figure 3.A.3: **Family Araneidae**: A. *Eriovixia laglaizei*; B.*Gasteracantha dalyi*; C. *Gasteracantha geminata*; D. *Cyrtarachne sundari*; E. *Larinia phthisica*; F. *Neoscona molemensis*; G. *Neoscona mukerjei*; H. *Neoscona theisi*. A–H. female.

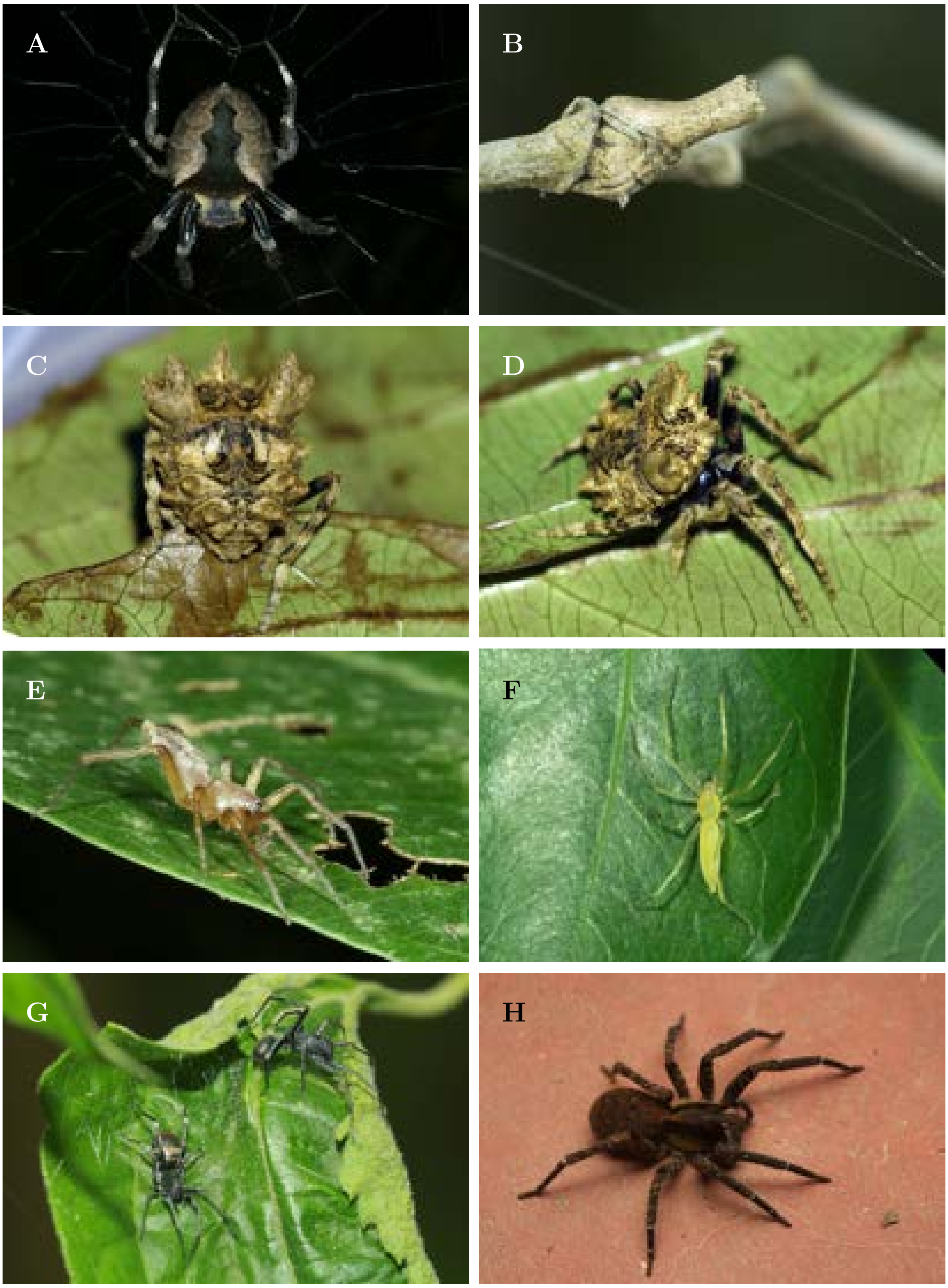

Figure 3.A.4: **Family Araneidae**: A. *Paravixia dehaani*; B. *Poltys columnaris*; C. *Poltys nagpurensis*, posterior view; D. Same, lateral view. **Family Clubionidae**: E. *Clubiona* sp.; F. *Matidia* sp. **Family Corinnidae**: G. *Castianeira zetes*. **Family Ctenidae**: H. *Ctenus cochinensis*.

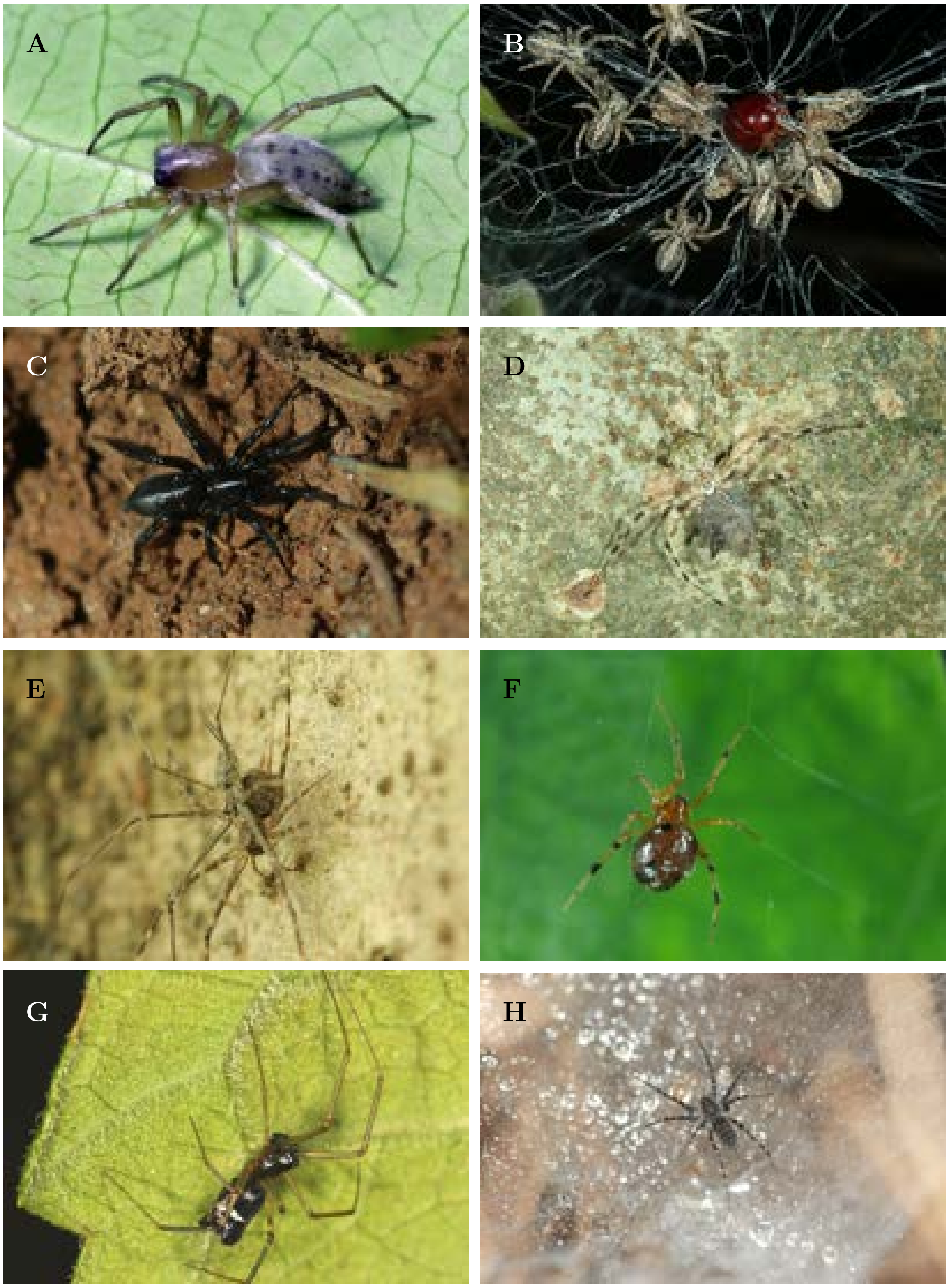

Figure 3.A.5: **Family Cheiracanthiidae**: A. *Cheiracanthium* sp. **Family Eresidae**: B.*Stegodyphus sarasinorum*. **Family Gnaphosidae**: C. *Zelotes* sp. **Family Hersiliidae**: D. *Hersilia savignyi*, with prey *Heteropoda* spider; E. *Hersilia savignyi*, male and female mating. **Family Linyphiidae**: F. *Atypena* sp.; G. *Neriene macella*. **Family Lycosidae**: H. *Hippasa agelenoides*.

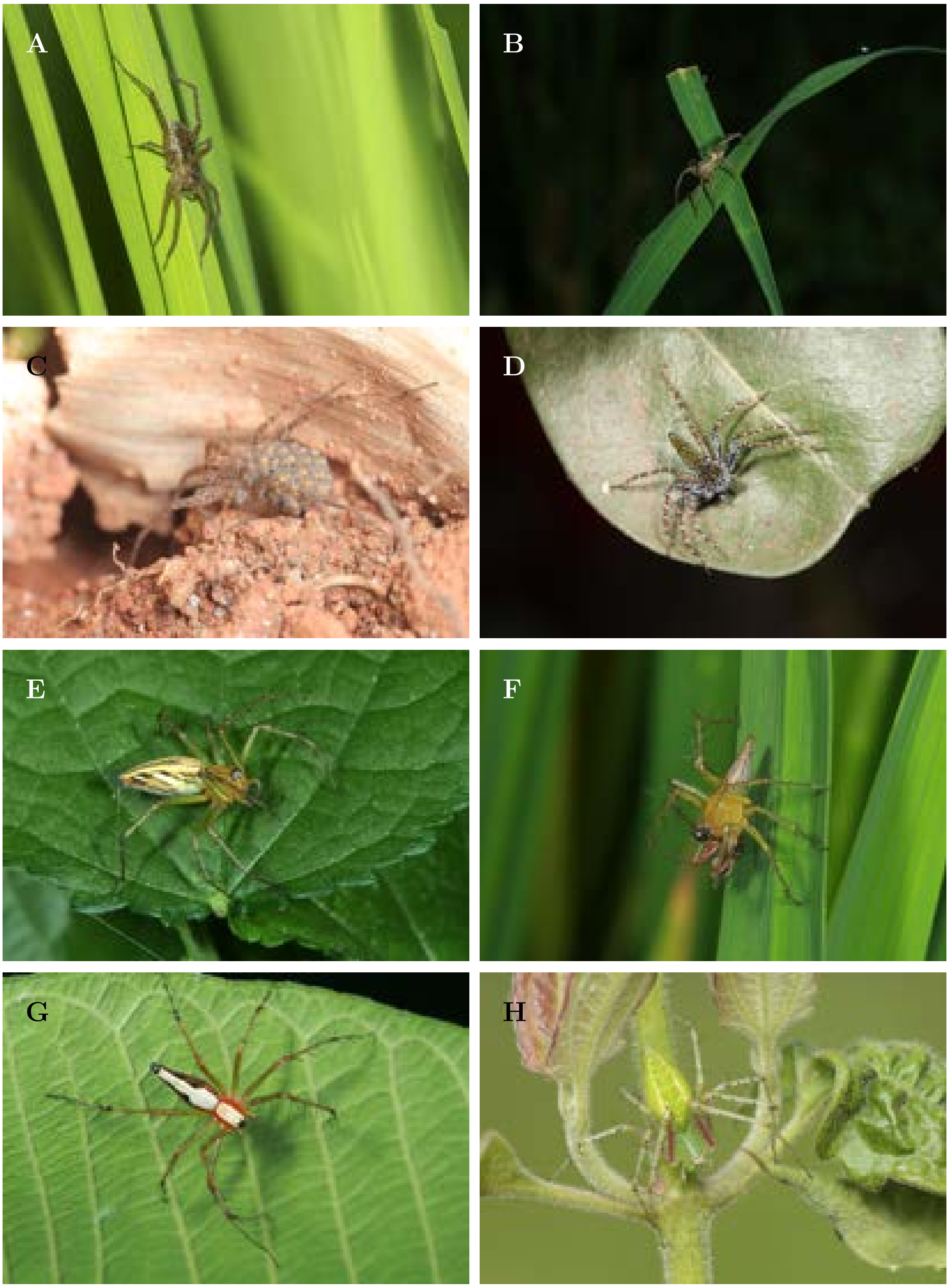

Figure 3.A.6: **Family Lycosidae**: A. *Pardosa pseudoannulata*, female restingng on paddy leaf; B.*Pardosa pseudoannulata*, spotted on the canopy of paddy; C. *Pardosa* sp., female carrying brood on the abdomen. **Family Oxyopidae**: D. *Hamadruas sikkimensis*, female preying on a housefly; E. *Oxyopes javanus*, female; F. *Oxyopes javanus*, male feeding on an insect; G. *Oxyopes shweta*; H. *Peucetia viridana.*

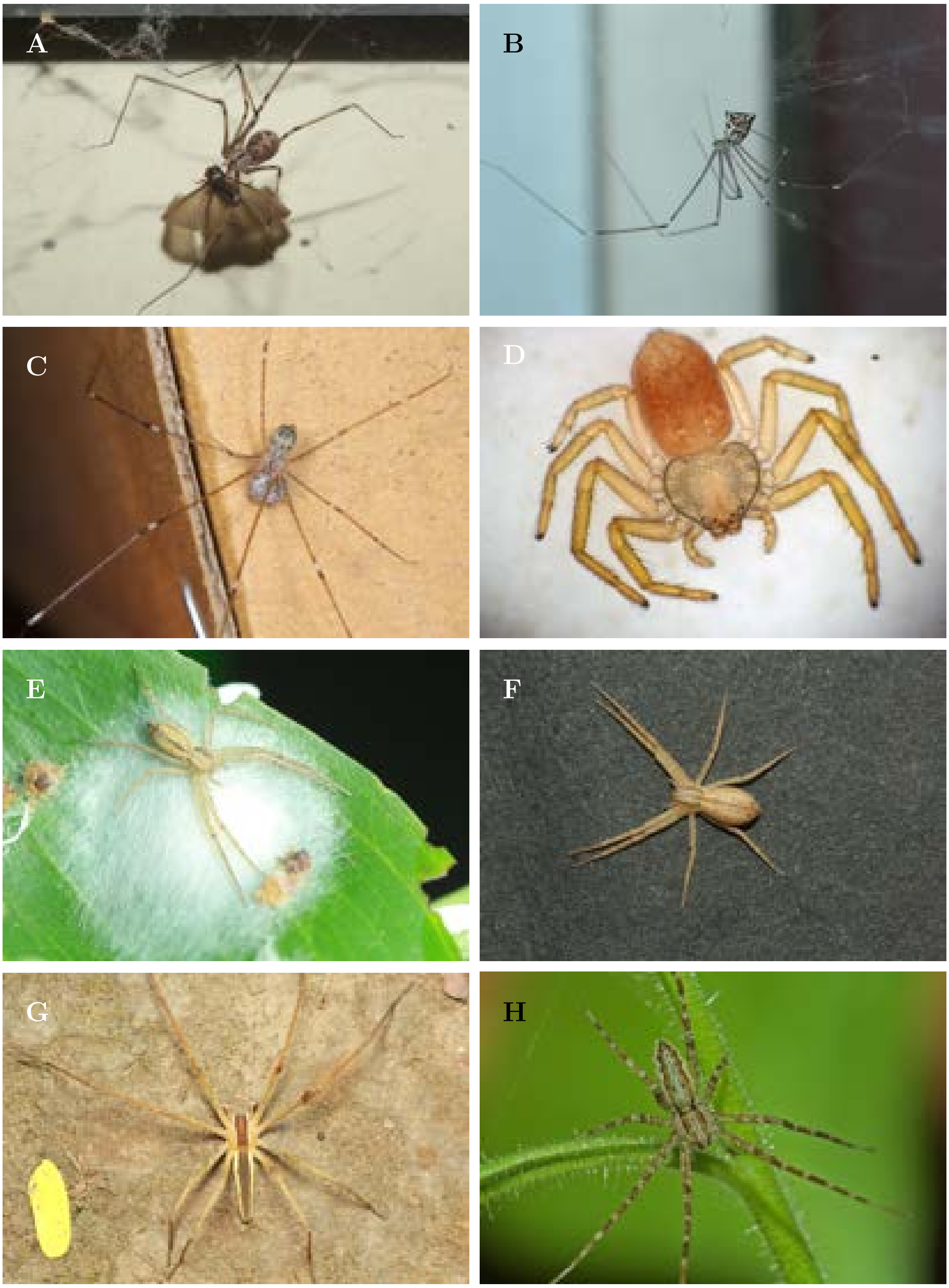

Figure 3.A.7: **Family Pholcidae**: A. *Artema atlanta*, female feeding on a insect; B. *Crossopriza lyoni*; C. *Pholcus* sp., female with egg sac. **Family Philodromidae**: D. *Psellonus planus*; E. *Philodromus* sp., female guarding brood; F. *Tibellus elongatus*. **Family Pisauridae**: G. *Perenethis venusta* ; H. *Pisaura* sp.

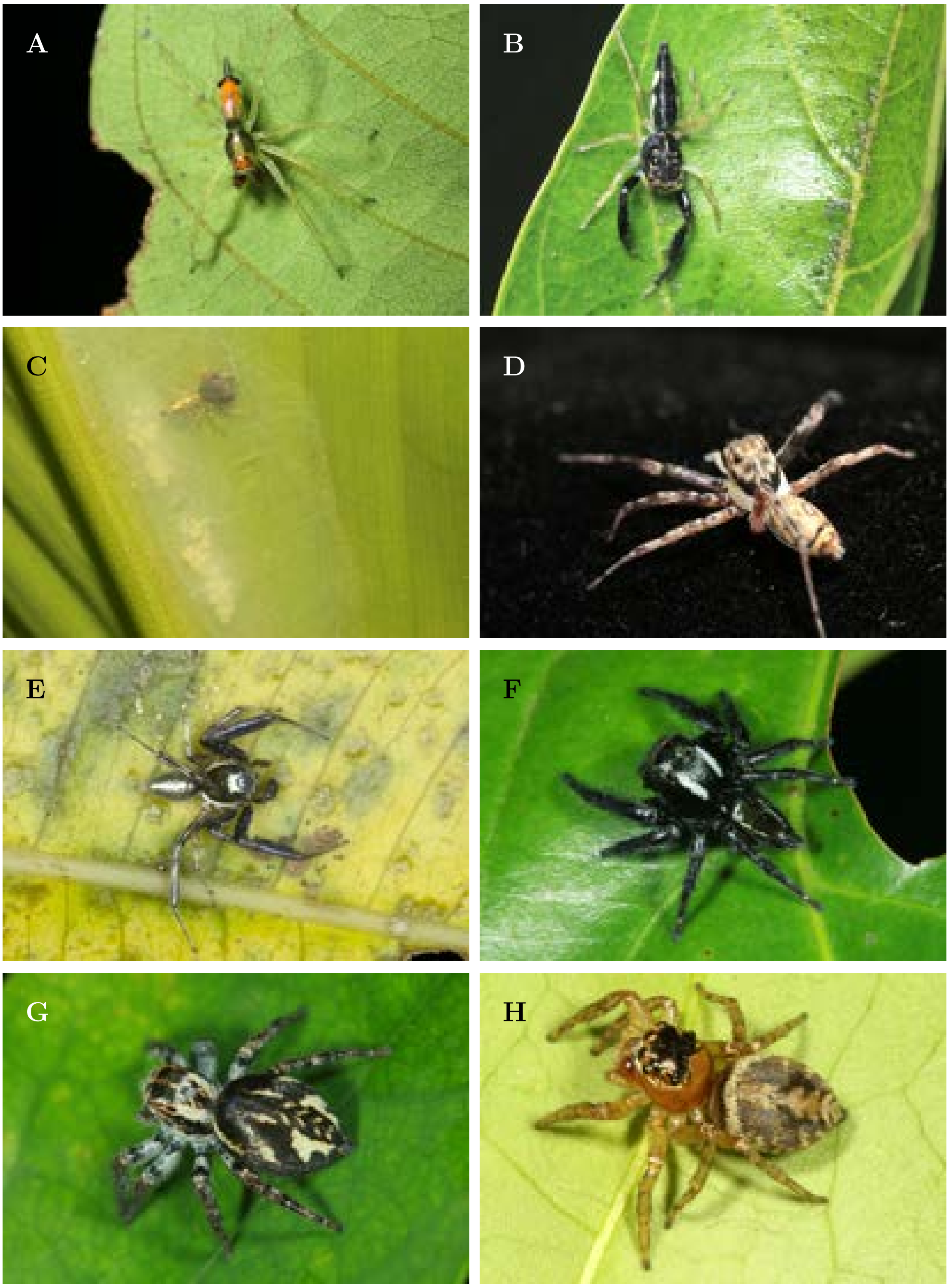

Figure 3.A.8: **Family Salticidae** : A. *Asemonea tenuipes*, male; B. *Indopadilla insularis*; C. *Indopadilla insularis*, female guarding brood; D. *Brettus cingulatus*, female; E. *Brettus cingulatus*, male; F. *Carrhotus viduus*, male; G. *Carrhotus viduus*, female; H. *Chalcotropis pennata*.

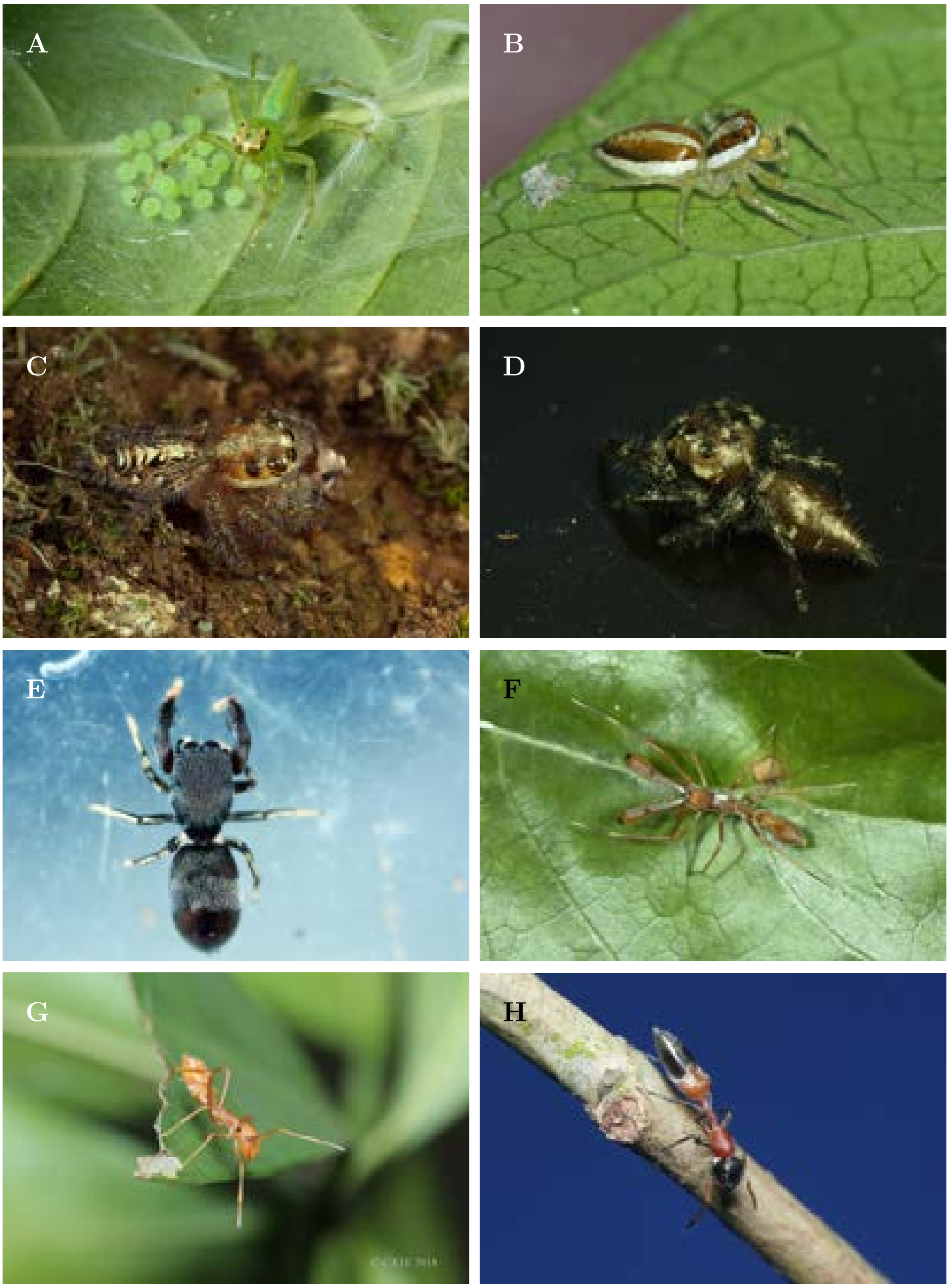

Figure 3.A.9: **Family Salticidae**: A. *Epeus* sp., female guarding eggs; B.*Epocilla aurantiaca*; C. *Hyllus semicupreus*, female; D. *Hyllus semicupreus*, male; E. *Marengo sachintendulkar*, female; F. *Myrmaplata plataleoides*, male; G. *Myrmaplata plataleoides*, female; H. *Myrmarachne melanocephala*.

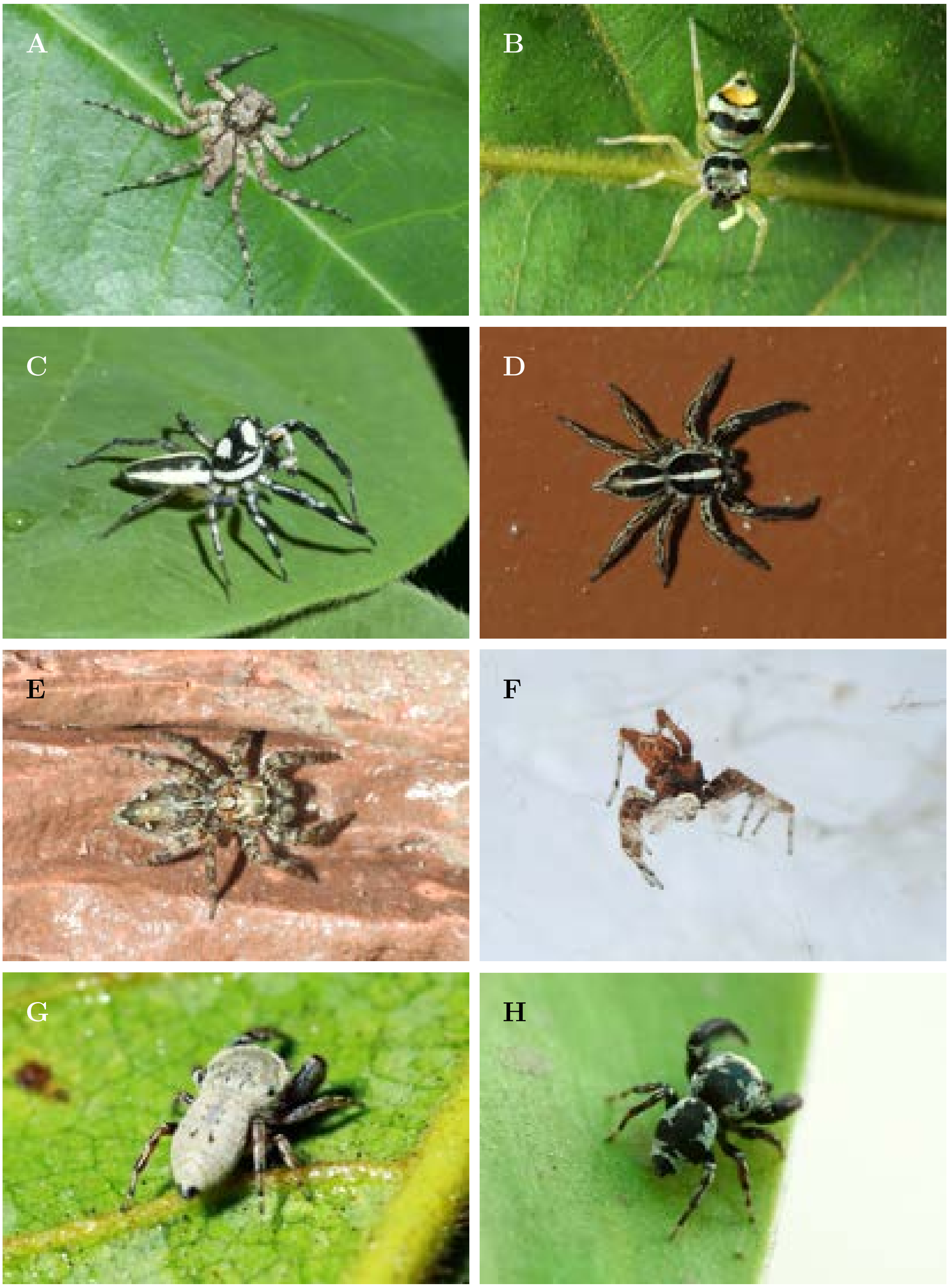

Figure 3.A.10: **Family Salticidae**: A. *Phaeacius lancearius*; B.*Phintella vittata*; C. *Phintelloides jesudasi*, male; D. *Plexippus paykulli* , male; E. *Plexippus paykulli*, female; F. *Portia fimbriata*; G. *Rhene flavigera*, female; H. same, male.

Figure 3.A.11: **Family Salticidae**: A. *Siler semiglaucus*, female; B. same, mating display; C. *Stenaelurilus albus*, female; D. *Telemonia dimidiata*, male; E. *Telemonia dimidiata*, female; F. *Thiania bhamoensis*; G. *Portia* sp. ambushing female *Herennia multipuncta*. **Family Scytodidae**: H. *Scytodes fusca*, female.

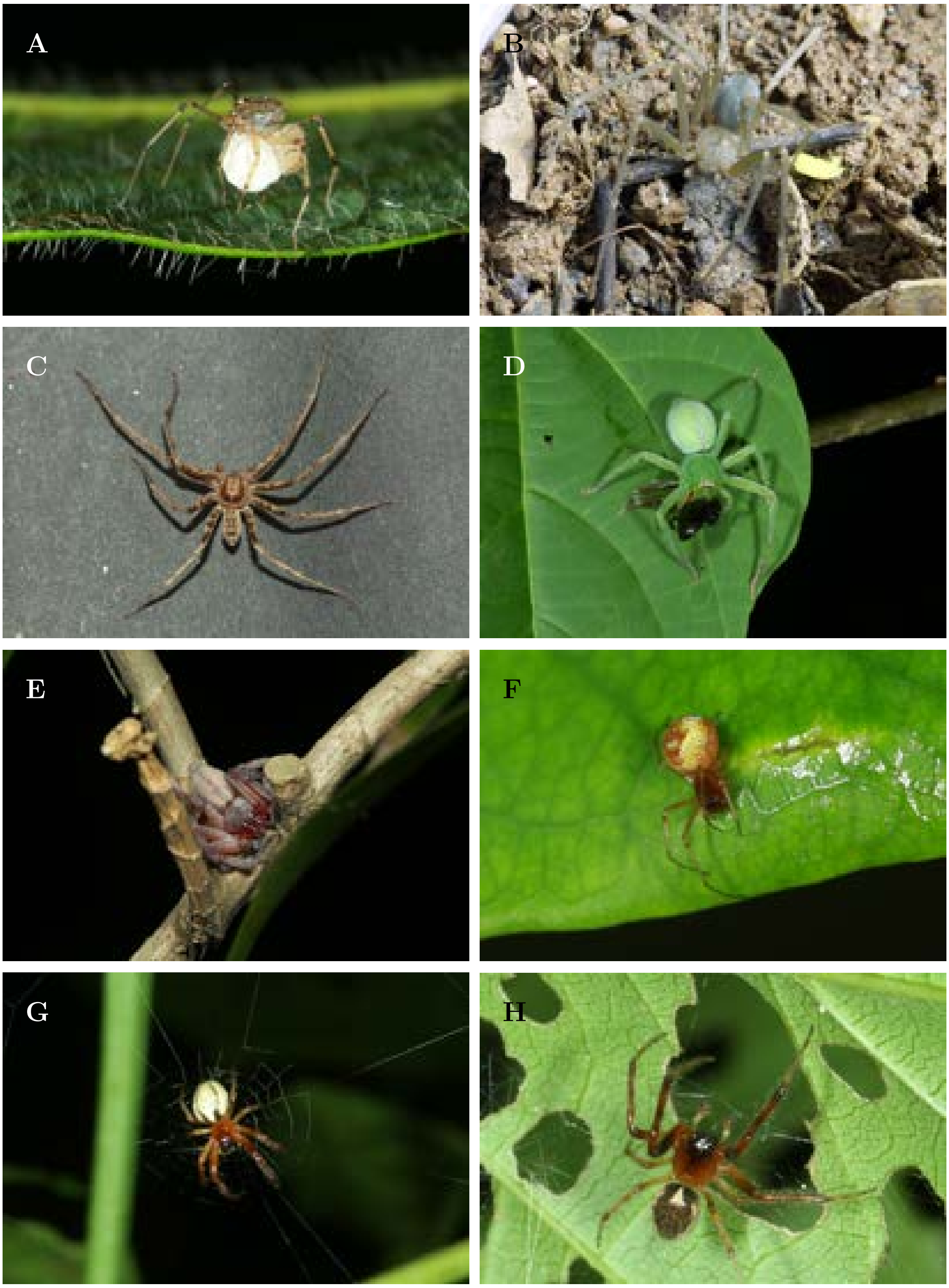

Figure 3.A.12: **Family Scytodidae**: A. *Scytodes thoracica*, female carrying egg sac. **Family Sicariidae**: B. *Loxosceles rufescens*. **Family Sparasidae**: C. *Heteropoda venatoria*, male; D. *Olios milleti*, female with prey; E. *Thelcticopis moolampilliensis*, female. **Family Tetragnathidae**: F. *Glenognatha dentata*; G. *Guizygiella nadleri*, female; H. same, male.

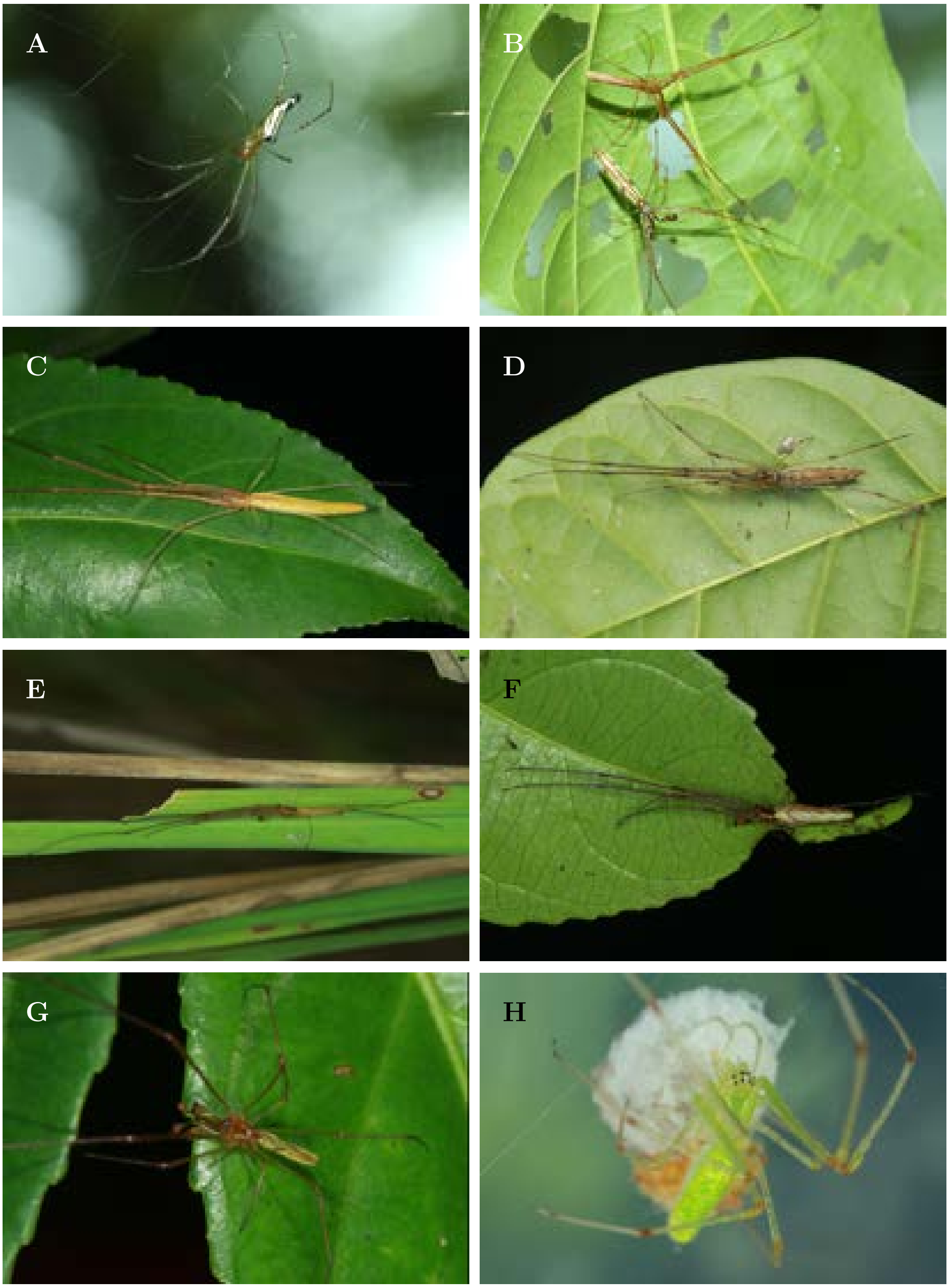

Figure 3.A.13: **Family Tetragnathidae**: A. *Leucage decorata*, female; B. *Tetragnatha viridorufa*, male and female; C. *Tetragnatha javana*, female; D. *Tetragnatha mandibulata*, female; E. *Tetragnatha concordia* sp. nov., male; F. *Tetragnatha nitens*, female; G. *Tetragnatha keyserlingi*, male; H. *Tetragnatha squamata*, female with egg sac.

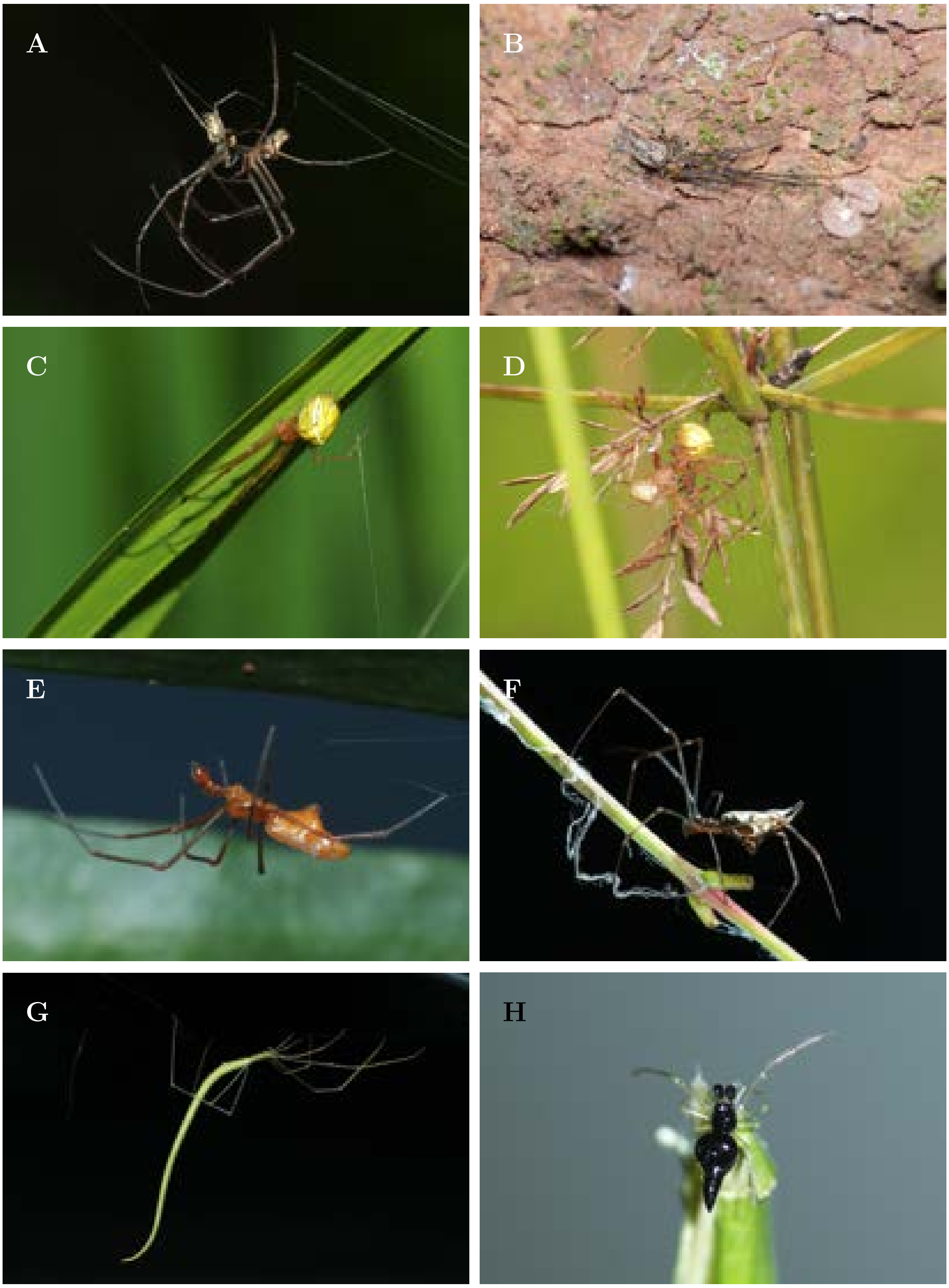

Figure 3.A.14: **Family Tetragnathidae**: A. *Tylorida ventralis*, male and female, mating; B. *Tylorida ventralis*, female; C. *Tylorida striata*, male and female, mating; D. *Tylorida striata*, female. **Family Theridiidae**: E. *Argyrodes flavescence*, male; F. *Argyrodes kumadai*, female; G. *Ariamnes flagellum*, female; H. *Chikunia nigra*, male.

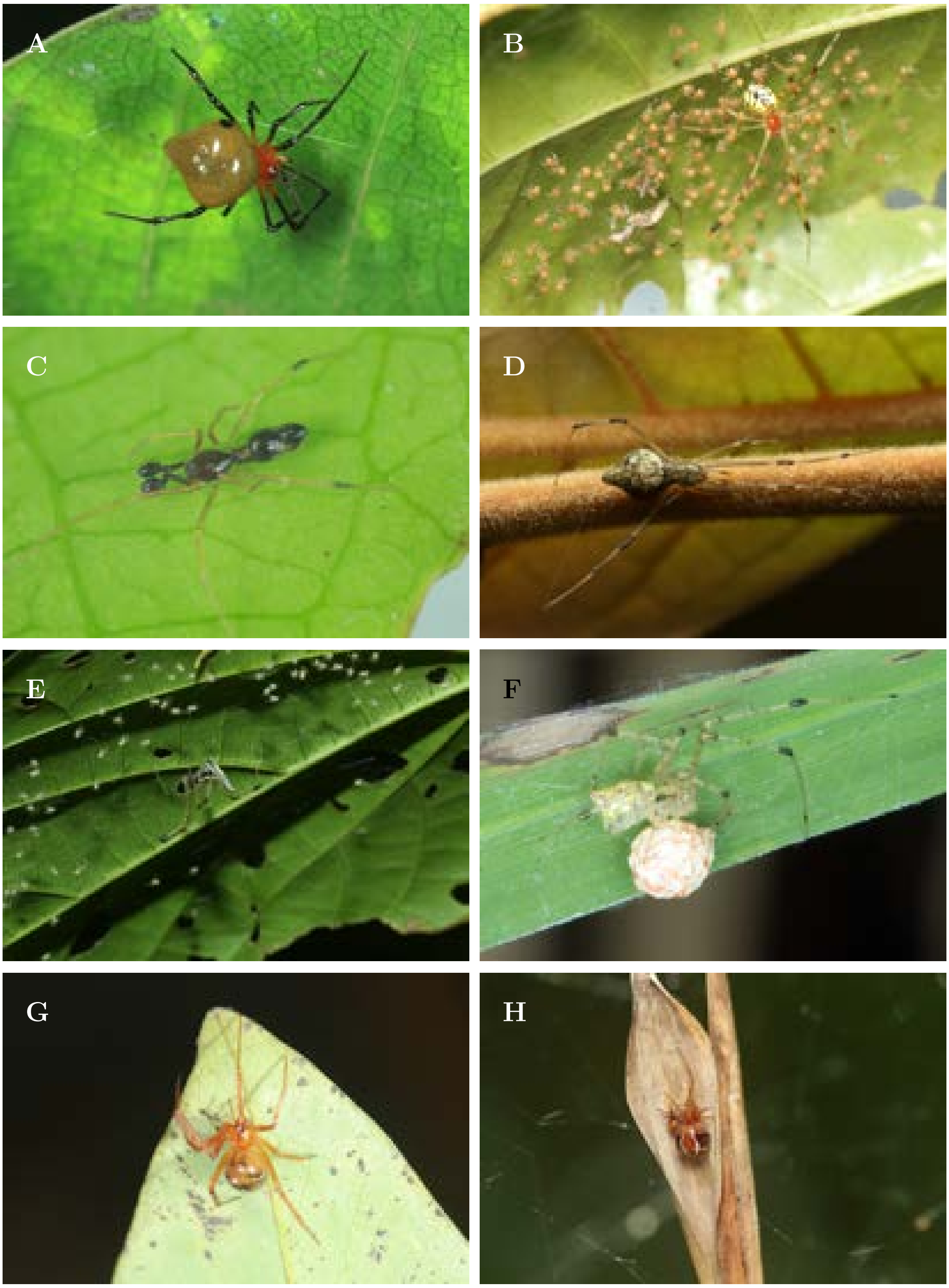

Figure 3.A.15: **Family Theridiidae**: A. *Chrysso angula*, female; B. *Chrysso urbasae*, female guarding brood; C. *Coleosoma floridanum*, male; D. *Episinus affinis*, female. E. *Meotipa picturata*, female guarding brood; F. *Meotipa multuma*, female with egg sac; G. *Nesticodes rufipes*, female; H. *Nihonhimea mundula*, male and female.

Figure 3.A.16: **Family Theridiidae**: A. *Molione trispinosa*, female; B. *Propostira quadrangulata*, female; C. *Thwaitesia margaritifera*, male; D. same, female. **Family Thomisidae**: E. *Amyciaea forticeps*, female; F. same, feeding on *Oecophylla smaragdina*; G. *Camaricus formosus*, female; H. *Epidius parvati*, male.

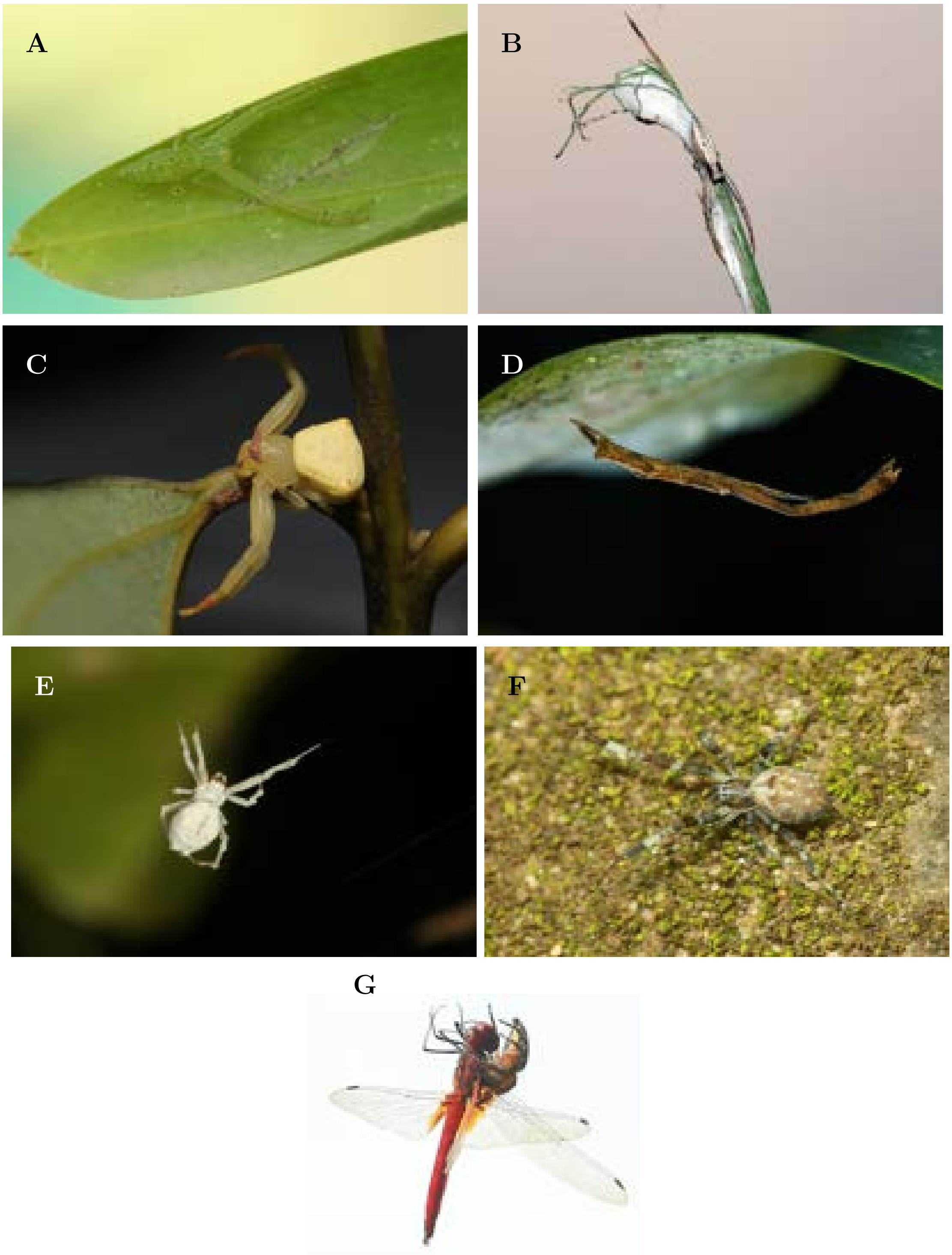

Figure 3.A.17: **Family Thomisidae**: A. *Oxytate* sp., female; B. *Runcinia* sp., female; C. *Thomisus lobosus*, female; **Family Uloboridae**: D. *Miagrammopes* sp., female; E. *Uloborus jabalpurensis*; F. *Zosis geniculata*. G. *Hyllus* feeding on a dragonfly.

4 | Diversity and Community Structure of Spiders

"The value of biodiversity is that it makes our ecosystems more resilient, which is a prerequisite for stable societies; its wanton destruction is akin to setting fire to our lifeboat."

–Johan Rockstrom

4.1 Introduction

It is often desirable to make comparisons between faunas sampled at different times from different places to get a basic knowledge of the diversity and dynamics of animals in an ecosystem. This kind of data is important for making informed decisions on matters of agricultural management, land-use and planning. The amount of information we have about an ecosystem's biodiversity and its interactions will facilitate the development of more sustainable modes of agriculture. Agricultural landscapes play a vital role in the conservation of biodiversity (Bennett et al., 2006; Gonthier et al., 2014). New approaches in development of conservation strategies outside protected areas including wetland agroecosystems requires some degree of baseline knowledge on the diverse fauna that exists there. This is especially a matter of concern in a diverse and biodiversity rich country like India, where data on many groups are virtually non-existent in some of the most threatened hot spots like the Western Ghats and the coastal wetlands.

Agricultural landscapes are spatially heterogeneous with mosaics of different man-made and semi-natural habitats. Most rice agroecosystems in Kerala are generally interspersed with highly fragmented heterogeneous semi-natural habitats that acts as refugia for several species of spiders (Betz & Tscharntke, 2017). The arrangement of these mosaics often strongly influences the composition of species in them (Bennett et al., 2006). Such habitats surrounding agricultural fields acts as repositories of natural pest enemies that spills over or migrate to the crop lands (Tscharntke, Bommarco, et al., 2007). The diversity and species composition of paddy fields vary between regions due to many factors such as differences in geographical location, climate and natural characteristics of the surrounding landscape. The structural diversity of the landscape may influence species richness of spiders and composition of the habitats in floodplain grasslands (Gallé et al., 2011). Understanding the functional importance of landscape moderated changes in community composition and food-web structure is essential for developing management solutions to sustain key ecosystem processes and services such as biological control, pollination or decomposition (Tscharntke, Tylianakis, et al., 2012). Landscape and regional species pools strongly influence local species richness (Gaston, 2000; Lawton et al., 1994).

4.1.1 Studies in agricultural landscapes

Numerous factors influence the distribution of organisms in a landscape, consisting of habitat features and landscape level features. Compostion and structure of vegetation are among the habitat features that influence the species composition and diversity of the invertebrate assemblages including spiders (Gallé et al., 2011; Popescu et al., 2021). Heterogeneity on a landscape scale may influence the diversity and the number of species of the assemblages at a given patch (Dominik, 2019; Miyashita et al., 2012). The predator community's composition in relation to agroecosystem management and landscape structure is crucial information for understanding how diversity affects long-term stability and resilience (Duelli & Obrist, 2003; Oberg et al., 2007).

Some habitats in highly fragmented tropical heterogeneous landscapes provides relatively stable conditions that allows spiders to overcome adverse conditions such as decrease in humidity and dramatic changes in temperature and wind exposure (Pinkus-Rendón et al., 2006). Relatively pristine habitats such as, forest patches, semi-natural woodlands and groves, contained an important proportion of the spider diversity in these fragmented landscapes. However, in agricultural landscapes, managed agricultural habitats undergo regular disturbances, so spiders will colonize cropland while conditions are favourable and retreat to semi-natural habitats when the conditions become hostile (Horváth, 2015; Pinkus-Rendón et al., 2006). The semi-natural habitats tropical and sub-tropical landscapes harboured significantly greater abundance of spiders than the croplands (Li, Liu, et al., 2018; Pinkus-Rendón et al., 2006). The species composition of natural enemies like carabids and spiders were influenced by plant diversity (Lemessa et al., 2015; Li, Liu, et al., 2018). Hedgerows and riparian habitats in agro landscapes act as source populations for spiders moving into the adjacent agroecosystem (Bedford & Usher, 1994; Buddle, Higgins, et al., 2004; Corbett & Rosenheim, 1996)

The composition of faunal communities of spiders can vary between various flood plain habitats like riparian, wetland, wet woodland, pasture and arable units (Greenwood et al., 1995). The number of plant species and regular flooding plays major roles in shaping of the species composition of spiders in floodplain grasslands (Gallé et al., 2011). Improving network functionality in a wetland agrolandscape, by preserving or increasing the density of habitat corridors, have been shown to have a positive effect on the total species richness of target spiders and ground beetles (Kris Decleer, 2015). In plantations, functional diversity and composition were primarily related to the habitat's structural complexity, specifically the amount of litter and ground vegetation density and height, while spider predation was related to plant diversity (Potapov et al., 2020). So, management strategies such as mulching and reduced weeding/herbicide application, as well as intercropping monocultures with other trees, could help to mitigate the negative effects of land-use change on spider communities (Ashton-Butt, 2018; Teuscher, 2016).

In agricultural landscapes, the composition of diverse non-crop land-use categories, as well as tree density, regulate local biodiversity (Lemessa et al., 2015). Studies on the abundance and species composition of spiders in tropical homegardens in non-crop landscapes showed that spiders were more abundant when the homegarden or surrounding area had a lot of trees, and they were the least abundant when both the most tree-rich and tree-poor landscape–garden combinations existed. The greater abundance of spiders was attributed to niche complementarity offered by habitat heterogeneity (Lemessa et al., 2015).

In a diversity study, the measurement of species diversity is always a snapshot and results may vary even for similar habitats (Tews et al., 2004). In smaller spatial scale studies, rarefaction is one of the widely used method to scale down to the number of individuals between habitats (Hurlbert, 1971). The correlations between species diversity and habitat heterogeneity in different locations are subject to equilibrium and nonequilibrium dynamics, which means that if species diversity varies from year to year, the correlations are subject to equilibrium and nonequilibrium dynamics (Tews et al., 2004; Wiens, 1994).

4.1.2 Diversity of spiders in rice agroecosystems

There have been very few landscape-scale studies integrating effects from the landscape to pest control service via changes in the natural enemy community in rice paddy ecosystems (Betz and Tscharntke 2017; Katayama et al. 2015; Tsutsui et al. 2016)(Ali, Kabir, et al., 2020; Baba, Kusumoto, et al., 2018; Betz & Tscharntke, 2017; Katayama et al., 2015; Tsutsui et al., 2016). Spiders in the rice agroecosystems attracted the attention of many researchers and there have been many studies conducted globally in rice growing countries on the diversity of spiders in rice agroecosystems. Settle et al., 1996 studied the arthropod community in the irrigated tropical rice fields on Java, Indonesia; they explored the arthropod community including spiders, its dynamics, levels of biological control and how the large-scale habitat factors. Their studies showed that unfavourable landscape design and water-use patterns can weaken the system and delay the arrival of natural enemies of pests in the paddy fields from the surrounding landscapes. They evolved strategies to 'bridge'natural enemies aimed at improving those weak habitats.

Rodrigues and Mendonça, 2009 reported Oxyopidae and Araneidae were dominant in the rice agroecosystems of Brazil, and documented that most species were found in the forest edges, followed by Rice crop and grasslands. The forest edges had the most diversity in their study and fared higher in species exclusivity. Studies in the Philippines by Barrion, 1999 showed that Tetragnathidae dominated the paddy fields, and Linyphiidae and Theridiidae dominated all non-rice habitats. Families Lycosidae, Linyphiidae, Theridiidae, Tetragnathidae and Clubionidae dominated the agroecosystems in China (Yang et al., 2018). It is also stated that the distribution of spiders in the paddy fields of China were influenced by variation in environments and locations and some other factors. Landscape level studies in Bangladesh showed that spider abundances were significantly higher in landscapes with semi-natural habitats surrounding rice plots and a positive relationship existed between landscape diversity and predator diversity (Ali, Kabir, et al., 2020). Whereas in the agricultural landscapes of Hainan island, Oxyopidae, Araneidae, Tetragnathidae, Thomisidae, Lycosidae and Salticidae were the dominant groups (Barrion, Villareal, et al., 2012). Studies in Japan by (Baba, Kusumoto, et al., 2018) indicated a positive effect on both *Tetragnatha* and Lycosid spiders when there was increase in forested areas within 200 m of the paddy fields, but it also showed a negative effect on Erigonine and *Pachygnatha* spiders.

Abandoned paddy fields in the rice agro landscapes impacted spider communities, abundance and species richness of cursorial spiders were higher in abandoned fields than in the paddy fields, except in the case of orb-weavers which remained the same (Baba, Tanaka, et al., 2019). Increase in successional stage in these fields showed a decreasing trend in the abundance of both the communities, and it also led to changes in species composition compared to that of paddy fields. However, Betz, 2016; Betz and Tscharntke, 2017 studied the relationships of spider families and spider web types in rice fields to local and landscape management practices, and showed that adjacent habitat like homegarden polyculture and banana monoculture had no effect on the spider populations; but maintaining fallow fields in the surrounding landscape helped to promote Erigoninae populations in rice fields. Landscapes with small-scale synchronous fallow lands combined with low-pesticide inputs and pest-resistant rice varieties does not induce pest outbreaks or diminish populations of natural enemies like spiders when embedded in asynchronous cropping on regional scales (Schoenly et al., 2010). Jung et al., 2008 studied the community structure and diversity of ground-dwelling spiders in agricultural field margins of Korea and showed that biodiversity of spider species was higher in levee and dike margins than in the hillock and streamside margins.

Spider assemblages in paddy fields are dominated by highly mobile groups of spiders, which can easily migrate between crops and surrounding habitats. Studies in Sri Lanka by Bambaradeniya et al., 2004; Bambaradeniya, 2000 have shown that 50 percent of the terrestrial arthropods represented predators, the majority of which were spiders. Of the 13 families reported in the study, Araneidae and Tetragnathidae were the dominant ones. The study observed that weed cover and vegetation in the bunds or embankments in paddy fields function as an alternate habitat during fallow period. In Japan, *Tetragnatha praedonia, T. maxillosa, T. caudicula, T. extensa and T. vermiformis, Pardosa pseudoannulata* and *Pirata subpiraticus* were found to be the dominant species in paddy fields (Baba, Kusumoto, et al., 2018; Hamamura, 1969). In Philippines, *Larinia tabida* and *Clubiona japanicola* have been reported as the dominant spiders (Barrion & Litsinger, 1995); Linyphiidae, Theridiidae and Lycosidae were found to be dominant in paddy habitats, while Linyphiidae and Theridiidae dominated all non-rice habitats (Barrion, 1999).

Several studies in China dealed with the spider communities of paddy agroecosystems (Hengmei et al., 2002; Li, Zhao, et al., 2001; Wang et al., 2002). A total of 17 species in 8 families and 13 genera were found to be dominant in the paddy growing areas of south-east, south-west and central China (Yang et al., 2018).

Yang et al., 2018 classified species into three levels based on their dominance and distribution of species; *Pirata subpiraticus, Ummeliata insecticeps, Tetragnatha maxillosa, Tetragnatha caudicula, Clubiona kurilensis* and *Pardosa pseudoannulata* were the most commonly distributed species. Whereas in Hainan island, the dominant spiders were *Araneus inustus* and *Oxyopes* spp. (Barrion, Villareal, et al., 2012). Several works in Korea (Kim & Kim, 1995; Kim, 1998; Park et al., 2005; Song & Lee, 1994) studied the diversity and community structure of spiders in rice agroecosystems.

Studies have documented 232 insect pest species, 183 parasitoids and 192 predators including spiders in the rice agroecosystems in Bangladesh(Ali, Bari, et al., 2019). Modification of existing rice landscapes using ecological engineering techniques and increasing bund margin widths have been shown to promote biocontrol agents, reduces pests and maintains crop yields. Habitat modifications significantly incresed spider populations and found that Tetragnathidae dominated the rice ecosystems (Ali, Bari, et al., 2019; Ali, Kabir, et al., 2020). Other studies from south-east Asia elucidated the diversity of assemblages, functional groups and community dynamics of spiders (Poolprasert et al., 2020; Rattanapun, 2012; Suana et al., 2009).

There are several studies on the diversity of spiders in rice agroecosystems in India (Anitha, Shanker, et al., 2019; Anitha & Vijay, 2016; Betz & Tscharntke, 2017; Chhavi et al., 2021; Kamal et al., 1992; Sankari, 2011; Sebastian, Mathew, PathummalBeevi, et al., 2005; Sudhikumar, 2007). Sudhikumar, 2007 elucidated the diversity of paddy spiders in the Kuttanad rice fields of the Vemmbanad-Kol wetlands, and reported that *Dyschiriognatha dentata, Pardosa pseudouannulata, Erigone bifurca, Tetragnatha mandibulata, Atypena adelinae, Phycosoma martinae, Araeneus ellipticus* and *Tetragnatha cochinensis* were dominant in the region. Families Araneidae and Tetragnathidae, and *Tetragnatha mandibulata* among the species, were reported to be the most dominant species in paddy fields of highland and lowland paddy fields of central Kerala (Sebastian, Mathew, Beevi, et al., 2005). Anis Joseph and Premila, 2016 based on their work from south Kerala also reported family Tetragnathidae and genus *Tetragnatha* as the dominant taxa in the paddy fields.

4.1.3 Community structure

Understanding the patterns of biodiversity is a key goal from a scientific and natural resource management perspective.(Foster & Dunstan, 2010) Seasonality is an important factor to consider regarding the species distributions along time, especially for studies that discuss diversity pattern (Kishimoto-Yamada & Itioka, 2015). Seasonal patterns in the arthropod populations in the tropics can be caused by pronounced variations in precipitation regimes that define dry and rainy seasons, and sometimes no seasonal patterns exists (Kishimoto-Yamada & Itioka, 2015). Spiders have been known to show both patterns (Buddle & Draney, 2004; Pickavance, 2001; Saksongmuang et al., 2020). Rank Abundance Distributions (RAD) allow comparisons of samples taken from geographically separated locations that have few or no species in common. The total number of individuals, the total number of species, and/or the relative abundance of the species, may potentially differ in the RADs between habitats. It is considered a fundamental quantity of the community (Wilson, 1991).

The diversity of spiders in the Muriyad Kol wetland landscape is unexplored and the present study aims to address this. Here, I discuss the diversity and community structure of spiders in the different habitats of the Muriyad Kol wetland: paddy fields, grasslands, banana plantations, mixed crops, uncultivated land and riparian habitats. In particular, this chapter aims to answer the following questions:

1. How do abundance, species richness and diversity of spider communities differ in different habitats and seasons?

2. How do β diversity differ between habitats in terms of variation and turnover?

3. How does community structure of spider assemblages differ in different habitats?

4.2 Methodology

4.2.1 Sampling

Three sites were selected in each of the habitats, namely paddy, grasslands, banana plantations, mixed crops, uncultivated lands and riparian, and samples were taken at each season (pre-monsoon, monsoon and post-monsoon). The collection methods used were as mentioned in Section 3.2.1. The study was conducted during the period from 2014 to 2018. The sampling yielded 162 samples of raw abundance data and includes 27 samples from each habitat. Sampling in the paddy fields was conducted during the reproductive and maturation phases of the crop.

4.2.2 Statistical analysis

All statistical analysis were done in R (R Core Team 2021). The diversities are described as Hill numbers or effective number of species (ENS) or species equivalents. Hill numbers are a mathematically unified family of diversity that incorporate relative abundance and species richness and overcome many of the shortcomings of the commonly used diversity indices like Shannon entropy and Simpson index (Chao, Gotelli, et al., 2014; Hill, 1973). Shannon-Weiner and Gini-Simpson entropies are entropies and not diversities. They do not correspond well to theoretical and intuitive concepts of diversities (Jost, 2006). These indices can be transformed to true diversities or ENS that accurately capture the concept of diversity, which is the number of equally abundant species necessary to produce the observed value of diversity. According to Hill, 1973, Hill numbers or ENS of the order q $\neq$ 1 is defined as in Equation (4.1)

$$^{q}D = \left(\sum_{i=1}^{\mathrm{s}} p_i^q\right)^{1/(1-q)} \tag{4.1}$$

where, S is the number of species and the ith species has relative abundance p_i, i= 1, 2, 3,. . ., S. When q=0, abundance of species do not contribute to 4.1 and only the presence are considered. So, $^0\ D$ is the species richness. However, Equation (4.1) is not defined for q=1, but it tends to be the exponential of Shannon index when q reached 1. Also called Shannon diversity, it is expressed as in Equation (4.2):

$$^{1}D = \lim_{q\to 1} {}^{q}D = \exp\left(-\sum_{i=1}^{\mathrm{s}} p_i \log p_i\right) \tag{4.2}$$

So, Shannon diversity measures species proportion to their frequency. When q=2, Equation (4.3) gives the Simpson diversity as the inverse of Simpson concentration, which weighs in more on the frequencies of abundant and avoids rare species.

$$^{2}D = 1 \Big/ \left(\sum_{i=1}^{\mathrm{s}} p_i^2\right) \tag{4.3}$$

In other words, Shannon and Simpson diversity can be seen as a measure of the diversity of typical and dominant species respectively (Chao, Gotelli, et al., 2014). Thus, it is possible to characterize the species diversity of an assemblage using the Hill numbers, where q = 0 is the species richness, q = 1 is the exponential of Shannon's entropy (Shannon diversity), and q = 2 is the inverse of Simpson's concentration index (Simpson diversity). Two important properties make the Effective number of species based measures more useful. They allow α and β diversity to vary independently of one another across regions with different gamma diversities, and a given value denotes the same amount of diversity so that the within-community and among-community components can be directly compared (Jost, 2007).

4.2.2.1 Alpha diversity

Estimates of species richness (the true diversity of order zero) were provided by Chao1 estimator (Chao, 1984; Chao, Ma, et al., 2016). It uses the numbers of singletons and doubletons to estimate the number of species missing because information on missing species is mainly derived from rare species. The estimates of Shannon and Simpson diversites were computed by using "iNEXT" package (Chao, Gotelli, et al., 2014; Hsieh et al., 2020) using sample-size-based and coverage-based interpolation and extrapolation. It also gives the 95% confidence intervals to define the sampling variation for rarefied and extrapolated samples, constructed using 300 bootstrap replications, facilitating the comparisons of diversities across multiple assemblages (Chao, 1987; Chao & Chiu, 2016a). In a Sample-size based rarefaction and extrapolation curve, the samples are all standardised to an equal size so that they provide useful sampling information for a range of sizes. But in a Coverage-based rarefaction and extrapolation, all samples are standardised to an equal coverage (or sample completeness) that it makes comparing samples of equal completeness over a a range of completeness (Chao, Gotelli, et al., 2014). The diversity profile curve which plots the Hill numbers (q= 0, 1, 2) was ploted for each of the habitats studied using the "SpadeR" package (Species Prediction And Diversity Estimation, Chao, Ma, et al., 2016). Furthermore, slope of the curve also reflects the evenness of species relative abundance. The more steeply the curve declines, the more uneven the distribution of the relative abundance.

The influence of habitat and season on the abundances and observed Richness of spiders were analysed by implementing a generalized linear model (GLM) using the "MASS" package (Venables & Ripley, 2002) and type II Analysis of variance (ANOVA) of the fitted model using "car" package (Fox & Weisberg, 2019). The error distribution used in the GLM was negative binomial, so as to consider the mean-variance relationships of the data at hand (O'Hara & Kotze, 2010). Seasons (pre-monsoon, monsoon and Post-monsoon) and habitat types were included as fixed effects in the model. Sampling plot as a random effect did not explain much of the residual variability in the model when implemented with a generalized linear mixed model (GLMM) fit to the abundance and species Richness of spiders using the package “lme4” (Bates et al. 2015). So the random effect was dropped from the formula and a GLM was performed instead. However, a GLMM was implemented for estimated Shannon diversity with Sampling plot as random effect. A type II ANOVA preserve the principle of marginality, where the main effects are tested in light of one another, but not considering the interaction term. Model selection of generalised linear models were based on comparisons of different models with Akaike Information Criterion (AIC). A least likelihood ratio test was performed to check goodness of fit between different models using lrtest function of the lmtest package version 0.9-37 (Zeileis & Hothorn, 2002). The interaction plot of season and habitat and coefficient plots of the model was displayed using the “effects” package (Fox 2003) and “sjPlot” packages (Lüdecke, 2020) respectively. The model assumptions were verified by plotting residuals versus fitted values and versus each covariates in the model. The residuals were also assessed for the spatial and temporal dependency.

4.2.2.2 Beta diversity

Beta diversity (β) is generally defined as the variation in the identities of species among sites and it provides a direct link between biodiversity at the local scale (alpha diversity, α) and the regional species pool (gamma diversity, γ) (Whittaker, 1960; Whittaker, 1972). Many methods are in existence for measuring the beta diversity (Jost, 2007; Koleff et al., 2003; Tuomisto, 2010a; Tuomisto, 2010b; Vellend, 2001). In the present study, in order to measure variation among all possible pairs of units, with no references to a any gradient or direction, I implement the distance-based tests of homogeneity of multivariate dispersions, which has a direct correspondence with the multivariate dispersions or variance in community structure (Anderson, 2006; Anderson et al., 2006; Legendre et al., 2005). The β diversity for a group of units sampled from the study area can be measured as the average distance or dissimilarity matrix from an individual unit to the group centroid by using an appropriate dissimilarity index. Moreover, the difference in β diversity can be tested by using a multivariate test for homogeneity in dispersions (Anderson et al., 2006).

Bray-curtis was used as the dissimilarity index for producing the dissimilarity matrix using the 'vegdist' function in the "vegan" package (Oksanen et al., 2020). The raw abundance data was double root transformed prior to running. Multivariate homogeneity of groups dispersions (variances) was analysed using the 'betadisper' function in the "vegan" package, it is a multivariate analogue of Levene's test for homogeneity of variances. Non-euclidean distances in the dissimilarity matrix between sites and group centroids are handled by reducing the original distances to principal coordinates. To further test if the dispersions or variances of one or more groups are different, the distances of group members to the group centroid are subject to ANOVA, and a permutation test with 999 permutations that permutes model residuals to generate a permutation distribution of F statistics under the null hypothesis that no difference in variance between groups (Oksanen et al., 2020). The between group comparison of group dispersions was done with a classical t test and a permutation test based on the t-statistic calculated.

The overall abundance-based multiple-site Bray–Curtis, incidence-based multiple site Sorensen dissimilarities and their components across habitats for the spider assemblages were computed using the 'betapart' package (Baselga, Orme, et al., 2021). Multiple-site extension of Bray-Curtis dissimilarity was introduced by Chao and Chiu, 2016b and methods to separate it to components of balanced variation in abundance, and abundance gradients was achieved by Baselga, 2013. These two components are antithetic: (i) Balanced variation in abundance (β_{BAL}) accounts for when the individuals of some species in one site are substituted by the same number of individuals of different species in another site or species abundances change from site to site with different signs for different species and changes balance each other; and (ii) abundance gradients (β_{GRA}) accounts for when some individuals are lost from one site to the other or all the species that change their abundance from one site to the other make it with the same sign (Baselga, 2013; Baselga, 2017). Similarly, incidence-based multiple site Sorensen dissimilarities can be separated into two components: (i) spatial turnover (β_{SIM}) or the replacement of some species by others due to some environmental sorting or spatial or historical constraints; and (ii) nestedness of species (β_{SNE}), when biotas of sites with smaller numbers of species are subsets of the biotas at richer sites (Baselga, 2010; Baselga, 2012).

To estimate the distributions of abundance and incidence based multiple site dissimilarity indices, I subsampled 100 samples 10 times and calculated the average dissimilarity and its components. This comparison allowed assessing whether differences in dissimilarity patterns of spiders of the study area were more related to (a) differences in species replacement and nestedness (incidence-based patterns) or (b) differences in balanced abundance variation and abundance gradients (abundance-based patterns). The data was transformed to into presence-absence tables for computing the incidence-based Sorensen dissimilarity and its components. The advantage here is that these indices operate with absolute abundance which allows for differentiation into these components instead of relative abundance as in the case of Horn ($q = 1$) and Morisita-Horn ($q = 2$) dissimilarity indices.

Seasonal turnover

The overall similarity of the samples among the seasons was estimated using the richness-based Jaccard and Sorensen indices. The Jaccard is a simple index and uses the presence/absence data, ignoring information about abundance. Sorensen index, on the other hand, gives greater weight to species common to the seasons than to those found in only one season. The richness based Sorensen and relative abundance-based Horn index (q=1) were used to find the pairwise dissimilarities between seasons in each a habitat, using the SpadeR package (Chao, Ma, et al., 2016). The latter enabled the investigation into the degree of associations in the distribution and recolonisation of spiders between seasons. The Horn overlap measure is based on the Shannon entropy; when two assemblages are equally diverse and consists of equally common species, Horn and Sorensen gives the proportion of shared species (Gotelli & Chao, 2013).

4.2.2.3 Community structure

Both species richness and species evenness are visually represented by the rank abundance curve. The slope of the line matching the graph reflects species evenness. Since high-ranking species are significantly more abundant than low-ranking species, a steep slope indicates low evenness. Since the abundances of the different species are similar, a narrow gradient indicates high evenness. The term ”relative species abundance” refers to how common or rare a species is compared to other species in a particular location or population. The relative abundance of species follows certain patterns that are among the best known and studied in macroecology. The study of how Rank abundance distribution models (RAD) change with environmental gradients can be done by visually comparing RADs at different sites or categorising the different sites according to which model fits best (Whittaker, 1972; Wilson, 1991). Here, I used RADs to study the changes in the species abundance distributions by ranking observed abundances in the "vegan" package (Oksanen et al., 2020). RADs were fitted by pooling the abundance by habitats. Five distribution models were tested, namely broken stick (Null), niche preemption (Preemption), Log-Normal, Zipf, and Zipf-Mandelbrot (Mandelbrot) (Wilson, 1991). Model selection was done by considering the empirical and estimated values together with the lowest Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). Each of the above fits represent different assemblage structures and provides insights about the dominance, evenness and rareness (Magurran, 2004). The curves show a few dominant species with a larger number of intermediate species, whose number primarily determines the diversity or species richness of the community, and a smaller number of rare species. These curves have different shapes and probably express different patterns of competition and niche differentiation in communities (Whittaker, 1965).

4.3 Results

4.3.1 Regional diversity

The study yielded 10722 (n=162) individuals representing 195 species in 134 genera and 34 families in the Muriyad Kol wetland landscape. The incidence-based estimators Chao1 estimated 203.39 (±6.09, ±SE) species, while first order jackknife and Bootstrap estimators suggested 207.91 (±3.58) and 201.64(±2.45) species respectively (Table 4.3.1). The overall observed Shannon and Simpson diversities were 89.58 and 51.47 species respectively. The estimated Shannon diversity (Hill number, $q = 1$) and Simpson diversity (Hill number, $q = 2$) for the pooled samples were estimated to be 90.47 [89.58, 92.41] and 51.71 [51.47, 53.87] species respectively. The percentage of rare species was 11.79% which accounted for 13 singletons and 10 doubletons in the pooled sample, and the number of unique species in the pooled sample was 13.

Araneidae (1755), Lycosidae (1320), Oxyopidae (586), Salticidae (2265), Tetragnathidae (1608), Theridiidae (790), Thomisidae (621) and Corinnidae (200) were the dominant families in the present study (Table 4.A.1). Whereas, families such as Ctenidae, Deinopidae, Halonoproctidae, Idiopidae, Mimetidae, Palpimanidae, Zodariidae and Sicariidae were rare in the samples collected during the study (Figs 4.3.1A and 4.3.2). Number of species belonging to different families and habitats of the landscape are provided in Fig. 4.3.3 and Table 4.A.2

4.3.1.1 Guild structure

The spider guilds identified in the study were Sensing Web weavers, Sheet Web weavers, Space Web weavers, Orb Web weavers, Specialists, Ambush Hunters, Ground Hunters Hunters and Other Hunters. Of the eight guilds, Other hunters (3698 individuals, 35.51%) dominated, immediately followed by Orb Weavers (3539, 33.02%), Ground hunters (1753, 16.35%), Space web weavers (925, 8.63%, Ambush hunters (625, 5.83%), Sensing web (91, 0.85%), Sheet web weavers (76, 0.71%) and Specialists (9, 0.08%) (Fig. 4.3.1B).

Other hunters were composed of members of families Linyphiidae, Salticidae, Oxyopidae, Clubionidae, Sparassidae, Ctenidae and Miturgidae. Salticidae and Linyphiidae were the most dominant in the group. Other hunters are stalkers or foliage runners. Foliage runners are fast-moving spiders that catch prey by running toward it. Stalkers, on the other hand, rely on visual or vibrational cues to locate and hunt their prey.

Orb weavers are the most common group in rice paddies, grasslands and riparian habitats, which includes the families Araneidae, Tetragnathidae, Theridiosomatidae and Uloboridae. Whereas, Ground hunters were composed of Corinnidae, Philodromidae, Gnaphosidae, Liocranidae, Lycosidae, Oonopidae and Trachelidae. These are often fast-moving spiders that forage mainly on the ground, occasionally climbing into the foliage or canopy to capture prey. They have amazing vision, and while they hunt a lot during the day, they also do so at night.

Pholcidae and Theridiidae have been classified under Space web weavers. They make webs with an irregular structure and without adhesive properties to catch insects. Ambush hunters capture their prey from ambush and usually do not spin webs.Species of Thomisidae, Deinopidae and Sicariidae belong to this guild. Sensing web weavers were composed of Halonoproctidae, Idiopidae, Theraphosidae, Hersiliidae and Oecobiidae. The members of this group are equipped with organs to detect vibrations and use special sensory threads on their webs. The families Eresidae and Pisauridae belong to Sheet web weavers, as they construct sheet-like or domed or cup-shaped or flat webs. The specialists consist of spiders that have specialised in certain groups or species and therefore do not compete directly with other groups.

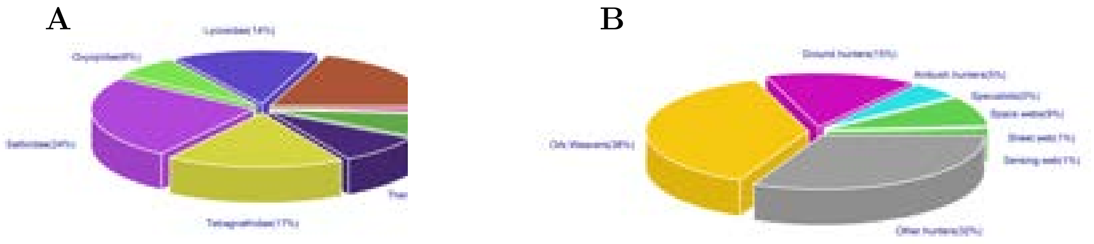

Figure 4.3.1: Family and guild composition of spiders in the Muriyad Kol wetland landscape. **A**, Proportion of relative abundance of families. **B**, Proportion of relative abundance of guilds.

4.3.2 Alpha diversity

Table 4.3.1 provides the diversity and estimates of diversities of spider samples collected from the habitats (Paddy, grasslands, banana plantations, mixed crops, uncultivated plots and riparian) in the Muriyad Kol wetlands. The total abundance was the highest in the uncultivated plots (2123 individuals, n = 27), followed by riparian (1913 individuals) habitat. Paddy and Mixed crops had similar values, with 1870 and 1856 individuals respectively. Similarly, the lowest number of individuals were recorded in the Grasslands (1450 individuals) and Banana plantations (1501 individuals).

The abundance of spiders showed significant variations among the habitats (Fig. 4.3.4). Habitats like grasslands and banana plantations which had comparatively lesser heterogeneity in the vegetation showed lower mean abundance values of 53.74 ±15.4 and 55.7 ±12.16 individuals respectively. In contrast, it was above 70 individuals in the riparian (70.96 ±22.2) and uncultivated plots (78.7 ±14.22). Paddy habitat with 69.26 ±18.16 individuals was among the groups which showed the highest variation in abundances of spiders among the habitats due to the influence of location and management strategies of the crop.

The observed Richness from the pooled samples for the habitats was significantly higher in the mixed cropping (128 species), uncultivated(171) and riparian (133). This was greater than 65% of the overall species diversity. The observed Richness was the lowest (76 species) in the paddy habitat, but grassland and banana plantations had 94 and 85 species respectively. The asymptote estimators Chao1 and First-order Jacknife estimated 201.84 ±14.22 (±SE) adn 202.77 ±8.54 species respectively for the pooled samples from the uncultivated areas. The lowest estimates of 85.85 ±6.67 (Chao1) and 90.44 ±5.23 (Jacknife) species for the pooled samples from the paddy habitats. The grasslands which are closer to the paddy habitats had estimated values of 110.65 ±9.32 and 115.18 ±6.74 species respectively. Other habitats like mixed crops (140.84 ±7.54 & 147.25 ±5.98) and riparian (158.08 ±13.35 & 157.07 ±8.78) had fairly larger estimated values compared to the former habitats. The mean observed Richness for samples from the habitats were of the order, uncultivated plots > mixed crops > riparian > banana plantations > grasslands > paddy (see Table 4.3.1 and Fig. 4.3.13).

The estimated Shannon diverity (Hill number, q= 1) gives an estimated of the 'typical species' found among the habitats. It was the largest (102.22 [98.16, 106.28] species) in the uncultivated plots of the wetland for the pooled samples. The species diversity of riparian and mixed crops were estimated to be 74.03 [70.87, 77.50] and 73.85 [70.88, 77.32] respectively. But it was estimated to be 26.32 [25.68, 27.72] species in the paddy habitats, whereas it was 39.36 [37.76, 41.77 and 33.98 [32.76, 36.14] species in the grasslands and banana plantations. Similar patterns were observed for average observed Shannon diversities among the habitats. The samples from the paddy fields showed the lowest values 15.55 ±2.79 species, and significantly larger values for habitats with higher heterogeneity (uncultivated plots > mixed crops > riparian).

The estimated Simpson diversity (Hill number, q= 2) gives an estimate of the 'dominant' found among the habitats. From the pooled samples, uncultivated plots registered the largest value (71.2 [68.92, 75.93] species), followed by mixed crops and riparian with estimated values of 47.13 [45.99, 50.91] and 45.15 [44.13, 48.65] species respectively. The paddy fields and banana plantations had significantly lower species diversity among the habitats with 16.66 [16.52, 17.65] and 17.68 [17.49, 19.59] estimated species respectively.

The percentage of rare species (singletons and doubletons) was the highest (31.58%) in the grasslands, followed by paddy (31.58%), banana plantations (29.41%), uncultivated plots (29.24%), riparian (27.07%) and mixed crops (25.78%). The pooled sample from the uncultivated plots had the largest number of singletons (33 species) and doubletons (17), whereas the paddy sample recorded the lowest numbers with 14 and 10 species respectively.

Fig. 4.3.6A shows the observed Hill numbers and sample-size-based rarefaction and extrapolation plots with 95% confidence intervals for three sampling curves (Hill numbers of q = 0, 1, 2) up to base sample size of 2900 individuals. The base sample size was decided based on Chao, Gotelli, et al., 2014 and it was double the largest minimum reference sample size (1450 individuals, grasslands). the curves for uncultivated plots and paddy habitats showed significant differences as their confidance interal bands did not overlap (except at lower sample sizes). The curve for the habitats riparian and mixed crops did have significant difference upto their reference sample size, but their confidance intervals overlapped during extrapolation to the base sample size. Extrapolated to the base sample size, the expected species diversities were in the order: uncultivated plots (176.90 [167.45, 186.35] species) > riparian (142.82 [133.01, 152.62]) > mixed crops (134.57 [125.89, 143.25]) > grasslands (106.037 [94.74, 117.32]) > banana plantations (92.75 [81.34, 104.16]) > paddy (71.24 [64.44, 78.05]). At the minimum reference sample size of 1450 individuals (grasslands, 94 species), the rarefied species diversity of the Hill number $q = q = 0$ was the highest for the uncultivated plots (155.68 [149.82, 161.55]), followed by riparian (125.81 [119.79, 131.82]) mixed crops (122.15 [116.84, 127.47]), grasslands (94 observed species), banana plantations (81.27 [75.09, 87.45]) and paddy (63.15 [59.08, 67.21]) habitats. When reduced to a standardised sample size of 100 individuals, the rarefied Species diversity were as follows: Uncultivated plots (59.76 [58.61, 60.90]) > mixed crops (53.10 [52.01, 54.18]) > riparian (52.89 [51.66, 54.11]) > grasslands (37.47 [36.19, 38.76]) > banana plantations (36.04 [34.73, 37.35]) > paddy fields (26.71 [25.74, 27.68]).

The sample-size-based interpolation and extrapolation curve for the Hill number $q = 1$ (Shannon diversity) also showed significant difference (except for very small sizes) for uncultivated plots, grasslands, banana plantations and paddy habitats (Fig. 4.3.6A). At base sample size, the expected species diversitites were of the oder: Uncultivated plots (97.74 [94.03, 101.45]) > mixed crops (72.56 [69.29, 75.83]) > riparian (72.26 [68.42, 76.11]) > grasslands (38.76 [36.42, 41.10]) > banana plantations (32.98 [30.84, 35.13]) > paddy fields (22.84 [21.57, 24.11]). At a standardised sample size of 100 individuals, the rarefied Shannon diversities were estimated as: Uncultivated plots (50.52 [49.13 51.91]) > mixed crops (42.32 [40.87 43.77]) > riparian (41.58 [40.06 43.10]) > grasslands (26.44 [25.05 27.82]) > banana plantations (23.18 [21.92 24.45]) > paddy fields (17.70 [16.92 18.49]).

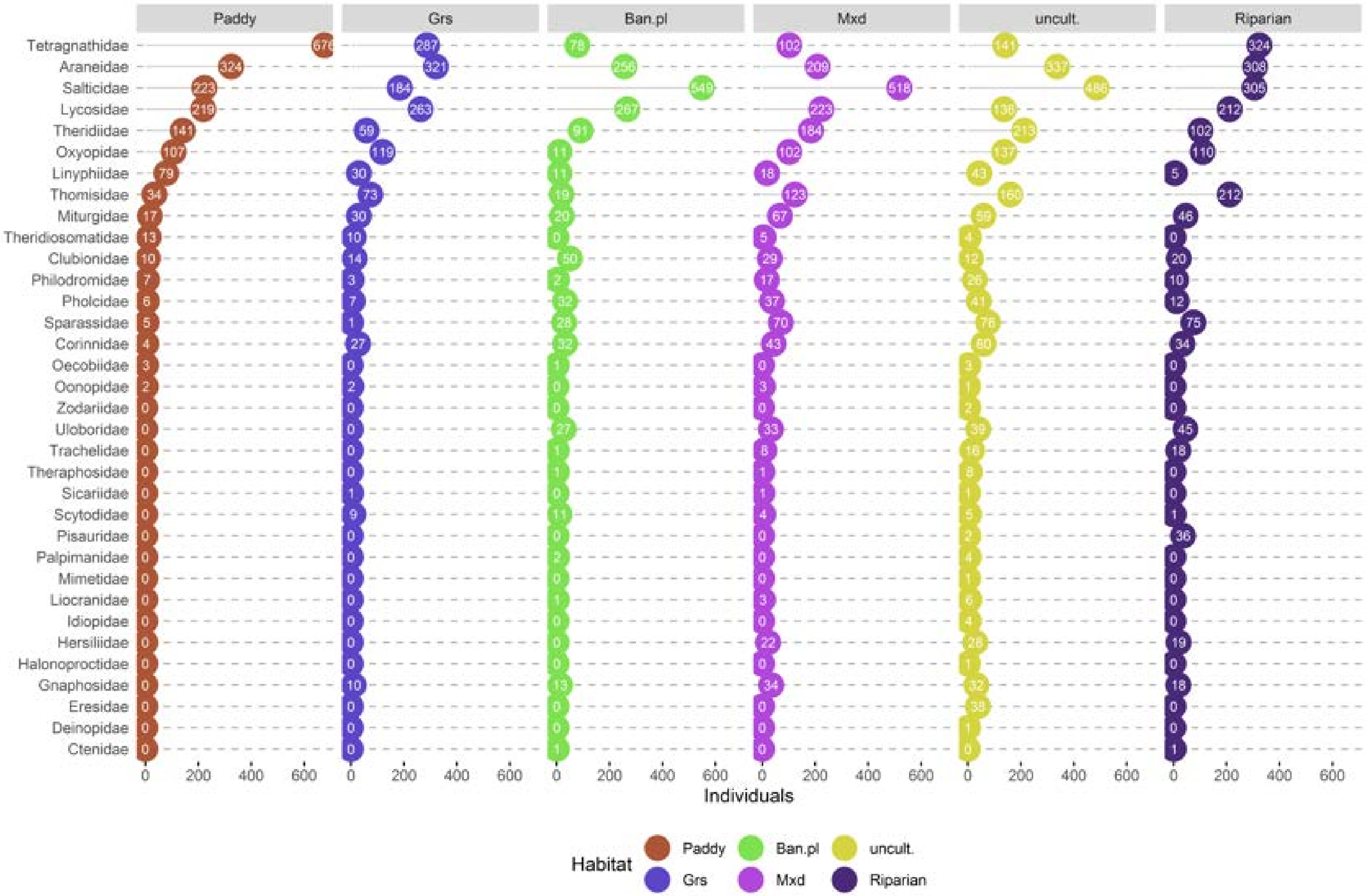

Figure 4.3.2: Families and individuals of spiders sampled from paddy fields, grasslands, banana plantations, mixed crops, uncultivated and riparian habitats in the Muriyad Kol wetland landscape. Circle–number of individuals.

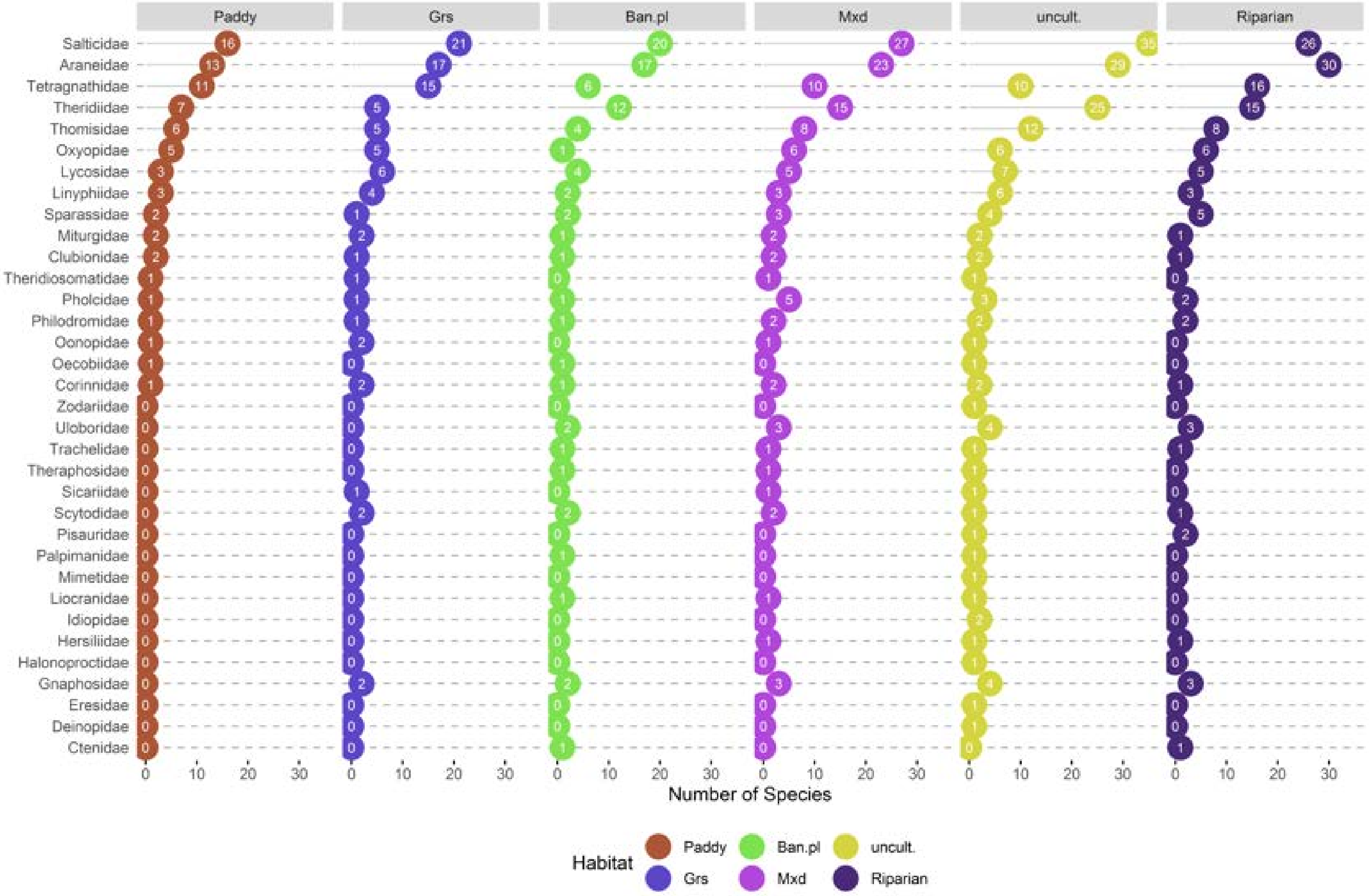

Figure 4.3.3: Families and numbers of species sampled from paddy fields, grasslands, banana plantations, mixed crops, uncultivated and riparian habitats in the Muriyad Kol wetland landscape.

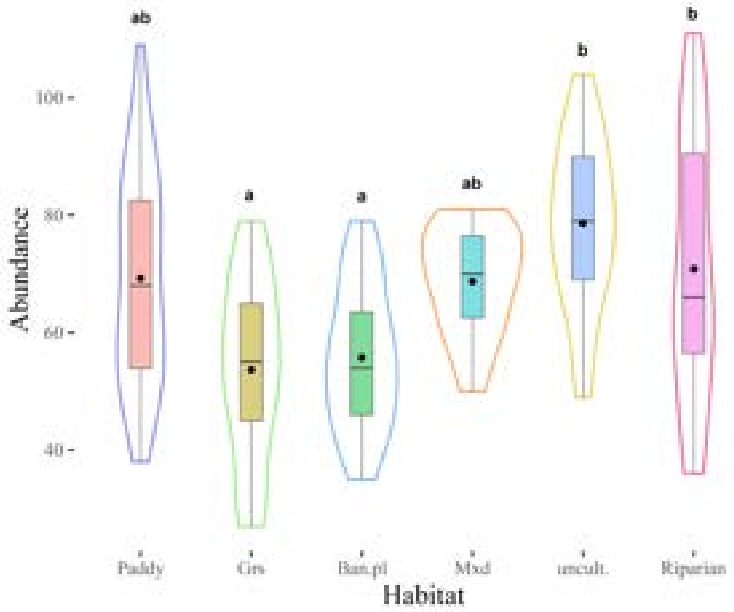

Figure 4.3.4: Abundance of spiders collected from different habitats of Muriyad Kol wetl

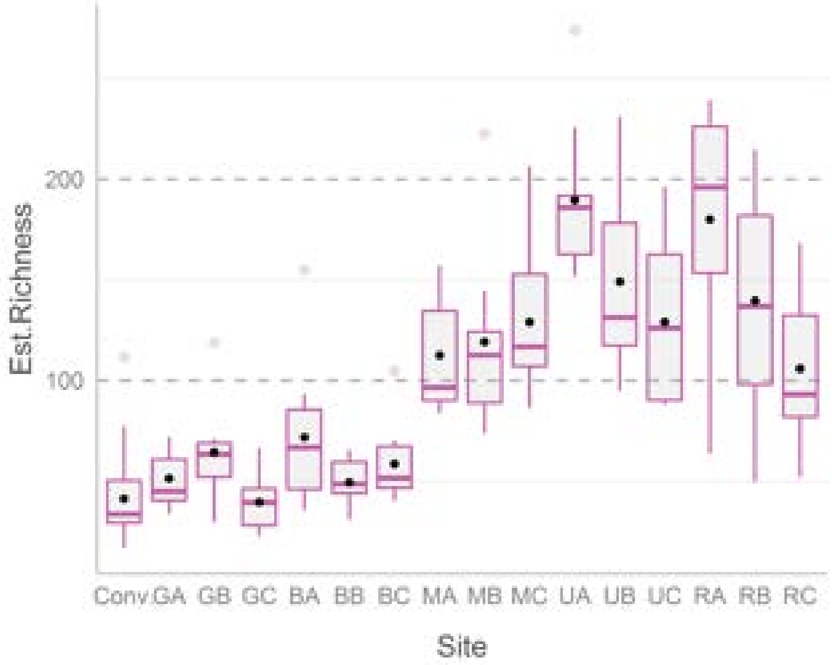

Figure 4.3.5: Estimated Richness of spiders sampled from different sites at Muriyad Kol wetland lakndscape. Conv. –paddy field under conventional method of management.

Table 4.3.1: Estimates of diversity of spiders collected from six selected habitats of Muriyad Kol wetland landscape.

	Paddy	**Grassland**	**Ban.plan**	**Mxd**	**Uncult.**	**Riparian**	**Overall**
Total individuals (samples, sample coverage)	1870 (27, 99.7%)	1450 (27, 98.6%)	1504 (27, 98.9%)	1856 (27, 99%)	2123 (27, 98.5%)	1913 (27, 98.7%)	10716 (162)
Mean abundance, ±SD	69.26 ±18.16	53.74 ±15.4	55.7 ±12.16	68.74 ±8.94	78.7 ±14.22	70.96 ±22.2	66.18 ±17.82
Total observed Richness	76	94	85	128	171	133	195
Estimated Richness							
Chao1 estimator ±SE	85.85 ±6.67	110.65 ±9.32	102.39 ±11.24	140.84 ±7.54	201.84 ±14.22	158.08 ±13.35	203.39 ±6.09
First-order Jacknife estimator ±SE	90.44 ±5.23	115.18 ±6.74	101.37 ±5.40	147.25 ±5.98	202.77 ±8.54	157.07 ±8.78	207.91 ±3.58
Estimated Shannon diversity	26.32	39.36	33.98	73.85	102.22	74.03	90.47
[95% confidence interval]	[25.68, 27.72]	[37.76, 41.77]	[32.76, 36.14]	[70.88, 77.32]	[98.16, 106.28]	[70.87, 77.50]	[89.58, 92.41]
Estimated Simpson diversity	16.66	23.89	17.68	47.13	71.2	45.15	51.71
[95% confidence interval]	[16.52, 17.65]	[23.52, 25.79]	[17.49, 19.59]	[45.99, 50.91]	[68.92, 75.93]	[44.13, 48.65]	[51.47, 53.87]
Mean observed Richness	22.78 ±5.43	26 ±6.35	27.37 ±5.21	47.37 ±5.34	55.11 ±8.81	46.85 ±14.97	37.62 ±15.14
Average observed Shannon diversity, ±SD	15.55 ±2.79	20.35 ±4.71	19.94 ±4.45	41 ±4.91	47.36 ±8.11	38.78 ±12.85	30.64 ±13.96
Average estimated Shannon diversity, ±SE	20.64 ±3.19	33.72 ±6.74	34.69 ±7.95	98.46 ±20.98	123.04 ±27.8	97.13 ±22.77	68.36 ±14.78
Average observed Simpson diversity, ±SD	12.31 ±2.24	16.12 ±3.61	14.51 ±3.83	33.50 ±5.17	38.46 ±8.15	30.18 ±10.26	24.27 ±11.82
Average estimated Simpson diversity, ±SE	14.82 ±2.17	23.29 ±4.85	20.02 ±4.81	66.55 ±15.21	79.79 ±18.51	53.40 ±13.38	43.21 ±10.16
Singletons	14	21	17	20	33	24	13
Doubletons	10	13	8	13	17	12	10
Unique species	15	22	17	20	33	25	13
Rare species %	31.58	36.17	29.41	25.78	29.24	27.07	11.79

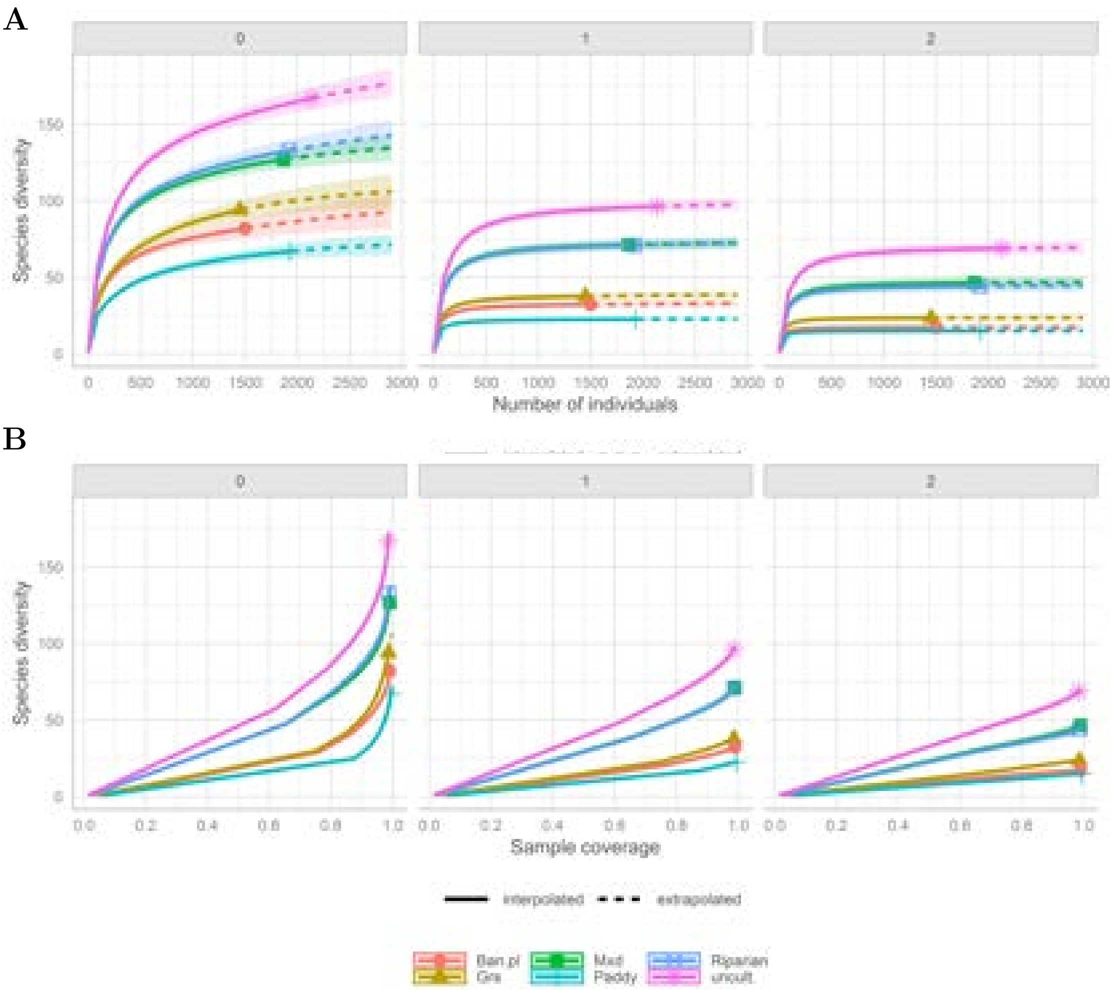

Figure 4.3.6: Sample and coverage-based rarefaction and extrapolation curves: **A.** Sample-size-based rarefaction (solid lines) and extrapolation (dashed lines) of spider species diversity based on Hill numbers ($q = 0, 1, 2$) with 95% confidence intervals for the samples collected from paddy, grasslands, banana plantations, mixed crops, uncultivated and riparian habitats in the Muriyad Kol wetlands. The symbols represent the reference samples; **B.** Coverage-based rarefaction and extrapolation plots with 95% confidence intervals for spider species diversity based on hill numbers, $q = 0, 1, 2$.

The sample-size-based interpolation and extrapolation curve for Simpson diversity ($q = 2$) indicated significant difference (except for very small sizes) for uncultivated plots and banana plantations (Fig. 4.3.6A). At a standardised sample size of 100 individuals, the rarefied Simpson diversities were estimated as follows: Uncultivated plots (41.84 [40.10 43.58]) > mixed crops (32.46 [30.49 34.42]) > riparian (31.36 [29.50 33.22]) > grasslands (19.44 [18.20 20.68]) > banana plantations (15.07 [13.83 16.31]) > paddy fields (13.32 [12.65 14.00]).

The sample coverages for the habitats (Paddy, grasslands, banana plantations, mixed crops, uncultivated plots and riparian) at the base sample size were estimated at 99.7%, 99.6%, 99.5%, 99.5%, 98.9% and 99.2% respectively. When extrapolated, the sample coverage only increased very slightly for all habitats. At the minimum reference sample size 1450 individuals, the sample coverages were paddy (99.1%), grasslands (98.6%), banana plantations (98.9%), mixed crops (98.6%), uncultivated plots (98%) and riparian (98.3%), indicating that sampling was nearly complete in samples from all habitats Fig. 4.3.7. At a standardised sample size of 100 individuals, the sample coverage values were paddy (89%), grasslands (81.9%), banana plantations (82.5%), mixed crops (70.3%), uncultivated plots (63.8%) and riparian (69.7%).

Figure 4.3.6B shows the coverage based interpolation and extrapolation curve for the Hill number $q = 0, 1, 2$ when the coverage is extrapolated to the value for a doubling of the minimum reference sample size. At a coverage of 80%, the species diversity of the order $q = 0$ for the habitats were paddy (24.83 [23.93, 25.73] species), grasslands (41.92 [40.24, 43.59]), banana plantations (29.05 [28.15, 29.95]), mixed crops (67.98 [66.38, 69.58]), uncultivated plots (83.58 [81.77, 85.38]) and riparian (69.06 [67.40, 70.71]). Similarly, the species diversity of the order $q = 1$ at a coverage value of 80% would be paddy (17.08 [16.31, 17.86] species), grasslands (28.18 [26.76, 29.60]), banana plantations (24.84 [23.38, 26.30]), mixed crops (50.79 [48.81, 52.77]), uncultivated plots (65.63 [63.63, 67.64]) and riparian (50.37 [48.05, 52.70]). Furthermore, the expected Simpson diversities ($q = 2$) for the habitats at a coverage value of 80% were paddy (13.01 [12.33, 13.70] species), grasslands (20.24 [18.92, 21.57]), banana plantations (15.59 [14.22, 16.97]), mixed crops (37.00 [34.62, 39.38]), uncultivated plots (51.70 [49.44, 53.96]) and riparian (35.76 [33.29, 38.23]).

4.3.3 Effect of habitat and season on abundance and diversity of spiders

Abundance

There was substantial variability in the distribution of abundances of spiders among habitats and seasons (Fig. 4.3.4). Uncultivated (78.77), riparian (71.00) and paddy (69.25) habitats recorded the highest abundance, while mixed (68.88), grassland (53.74) and banana plantations (55.70) were among the samples with the lowest abundance values. The overall mean abundance was 66.22 individuals

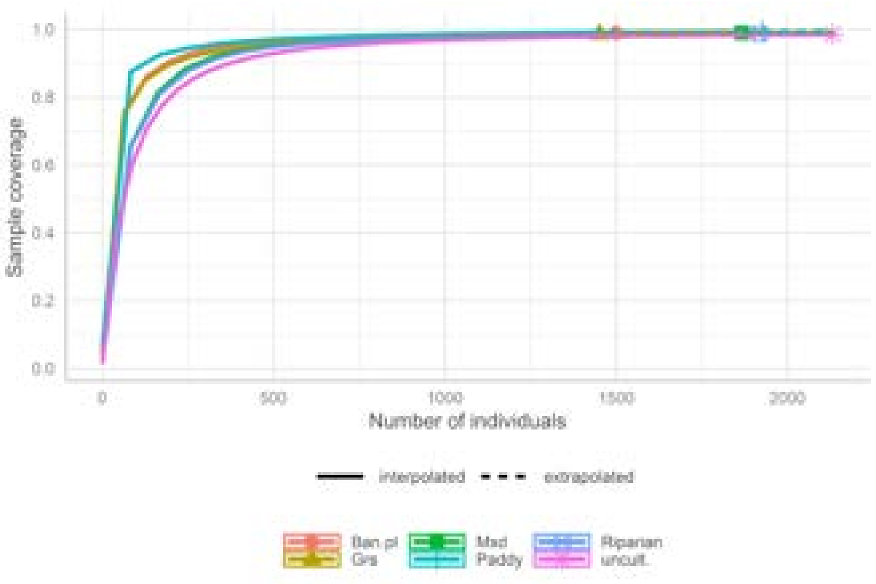

Figure 4.3.7: Sample completeness curve showing sample coverage for rarefied samples and extrapolated samples as a function of sample size for spider samples collected from paddy, grasslands, banana plantations, mixed crops, uncultivated and riparian habitats in the Muriyad Kol wetland landscape, the symbols represent the reference samples

(n=162). There was seasonal variation in the abundance of spiders. Monsoon reported the lowest (56.46, n=50) abundance among the three with pre-monsoon and Post-monsoon seasons averaging 70.38 (n=58) and 70.81 (n=54) individuals respectively. The site-wise abundance of spiders is provided in Fig. 4.3.8, and no visible changes in the variances among the different sites of habitats were found. The general pattern of abundance of spiders collected from different sampling sites at the Muriyad kol landscape is presented in Fig. 4.3.10.

The results of the type II Analysis of deviance performed on the generalized linear model (GLM) fit to the abundance of spiders revealed significant differences in spider abundances between seasons ($\chi^2 = 43.752$, Df $= 2$, $p < 0.001$) and habitats ($\chi^2 = 72.923$, Df $= 5$, $p < 0.001$), but also the interaction seasons and habitat ($\chi^2 = 21.006$, Df $= 10$, $p < 0.05$). The model validation indicated no problems (Figs 4.A.1A and 4.A.1B). The interaction plot of the effects and its interactions is given in Fig. 4.3.11 and the summary of GLM fitted to the abundances of spiders in Table 4.A.4 and graphically represented in a coefficient plot Fig. 4.3.12. The model showed that the abundances of spiders were negatively associated with both samples from banana plantations ($p < 0.05$) and interaction of grasslands and monsoon ($p < 0.01$). Although insignificant in the model, the abundances were negatively associated with grasslands to a certain degree. It was also positively

Table 4.3.2: Mean fitted values of abundance of spiders with 95% confidence intervals for the negative binomial GLM against seasons and habitat types of Muriyad Kol wetland landscape.

	Habitat					
Season	**Paddy**	**Grs**	**Ban.pl**	**Mxd**	**uncult**	**Riparian**
Pre-monsoon	71.76 [64.33, 80.05]	61.22 [53.47, 70.09]	58.22 [50.78, 66.74]	69.22 [60.64, 79.00]	80.44 [70.71, 91.50]	82.11 [72.21, 93.36]
Monsoon	63.60 [53.11, 76.15]	36.55 [31.40, 42.55]	46.33 [40.14, 53.48]	65.77 [57.55, 75.16]	69.88 [61.24, 79.75]	58.44 [50.98, 66.99]
Post-monsoon	68.77 [60.24, 78.51]	63.44 [55.46, 72.56]	62.55 [54.67, 71.57]	71.66 [62.84, 81.73]	86.00 [75.70,97.69]	72.44 [63.53, 82.59]

associated with uncultivated ($p < 0.05$) and riparian habitats ($p < 0.05$), although not significant.

The fitted mean abundances given by the model indicated the lowest values in the monsoon season among samples collected in the grasslands (36.55 [31.40,42.55] individuals) and banana plantations (46.33 [40.14, 53.48]) during the study period Table 4.3.2. Uncultivated plots with 86 [75.70, 97.69] individuals in the monsoon topped the list. Overall, both uncultivated and riparian habitat were indicated to be the groups with the largest abundances among the habitats Fig. 4.3.11.

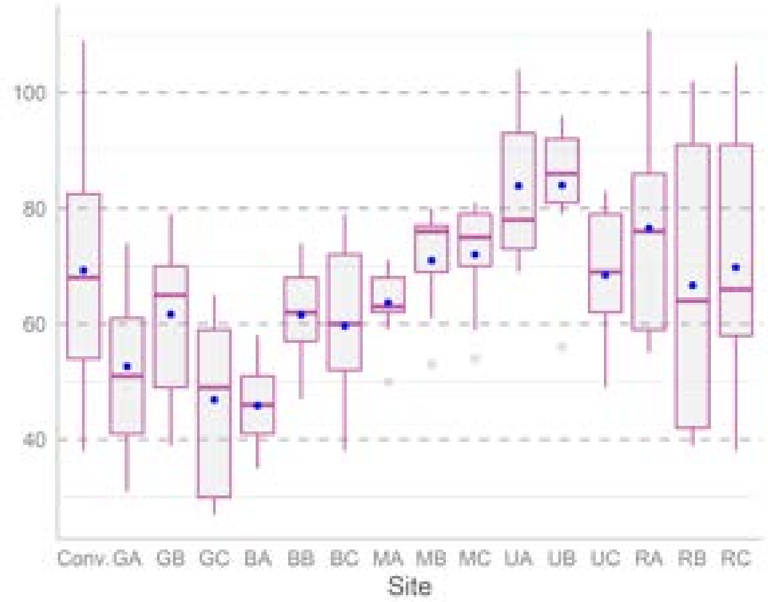

Figure 4.3.8: Abundance of spiders sampled from different collection sites at Muriyad Kol wetland landscape. Dots indicate mean.

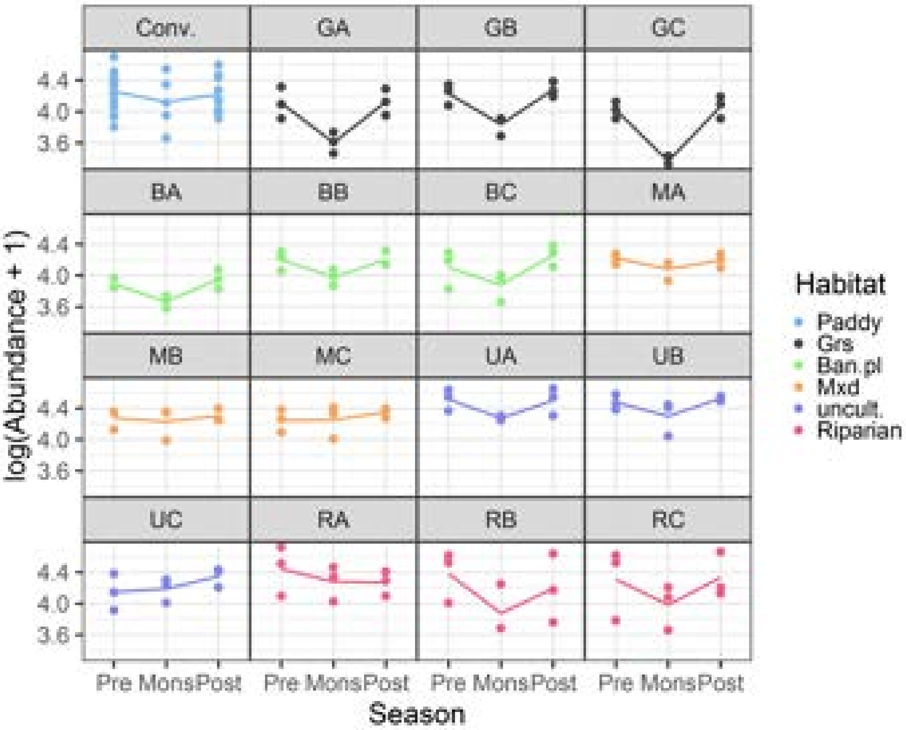

Figure 4.3.9: Abundance of spiders sampled from different collection sites during the three seasons at Muriyad Kol wetland landscape. Lines indicate mean.

Richness

The data revealed substantial variability in the distribution of observed Richness of spiders among the habitats and slightly among the seasons (Fig. 4.3.13). Uncultivated (55.18 species), mixed crops (47.52) and riparian (46.89) habitats reported the largest observed Richness, while banana plantations (27.37), grasslands (26.00) and paddy (22.77) were among the samples with the lowest Richness (Fig. 4.3.16). The overall mean Richness was 37.62 species (n=162). Seasonal variations in the abundances were evident from the data. Similar to abundances, the monsoon samples had the lowest (33.41 , n=50) mean Richness among the three seasons, with pre-monsoon and Post-monsoon seasons averaging 40.08 (n=58) and 38.89 (n=54) species respectively. The site-wise Richness of spiders is provided in Figs 4.3.14 and 4.3.15.

The results of the type II Analysis of deviance performed on the generalized linear model (GLM) fit to the Richness of spiders revealed significant differences in spider species richness between seasons ($\chi^2 = 25.73$, Df = 2, $p < 0.001$) and habitats ($\chi^2 = 501.85$, Df = 5, $p < 0.001$), but the interaction between seasons and habitat turned out not significant ($p = 0.16$). The model validation indicated

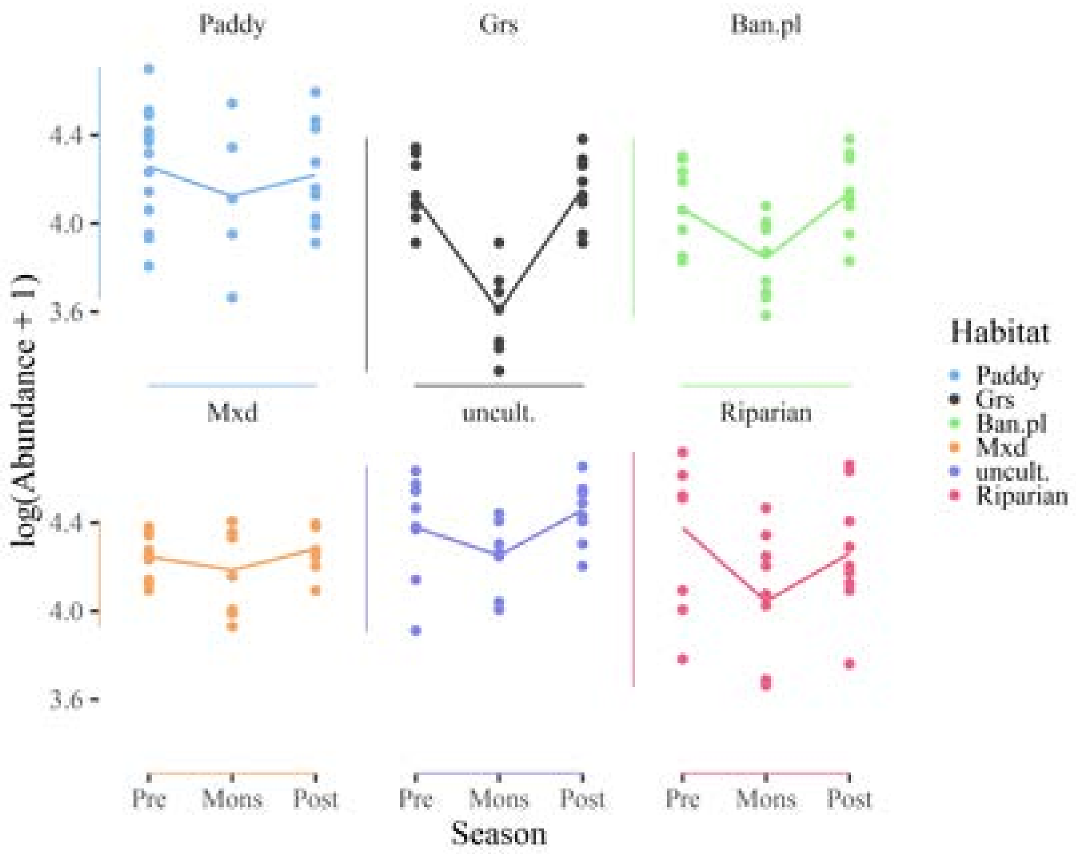

Figure 4.3.10: Abundance of spiders sampled from different habitats and seasons at Muriyad Kol wetland landscape. Lines indicate mean.

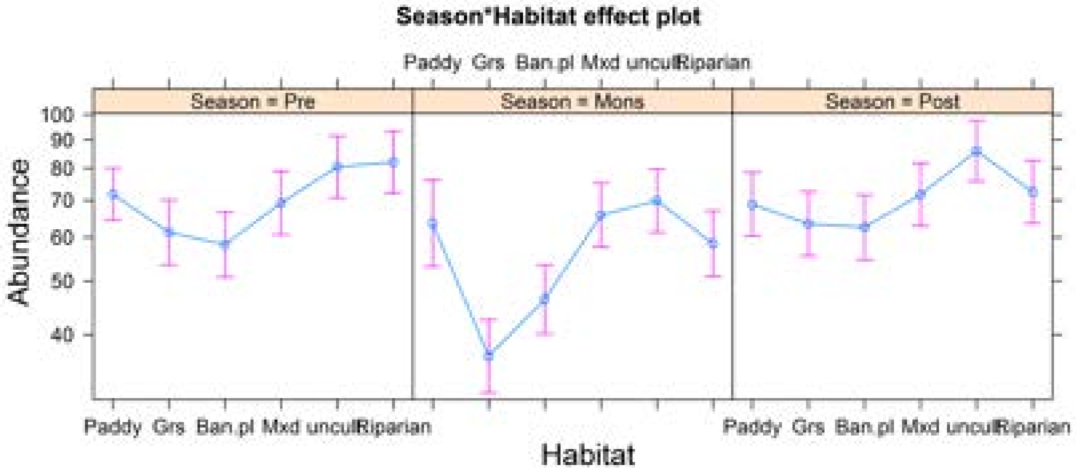

Figure 4.3.11: Effects displayed for the interaction between season and habitat type in the generalized linear model (with 95% confidence intervals) fit to abundances of spiders collected at Muriyad Kol wetland landscape.

no problems (Figs 4.A.2A and 4.A.2B). The interaction plot of the effects and its interaction is given in Fig. 4.3.17 and the summary of the glm fitted to the

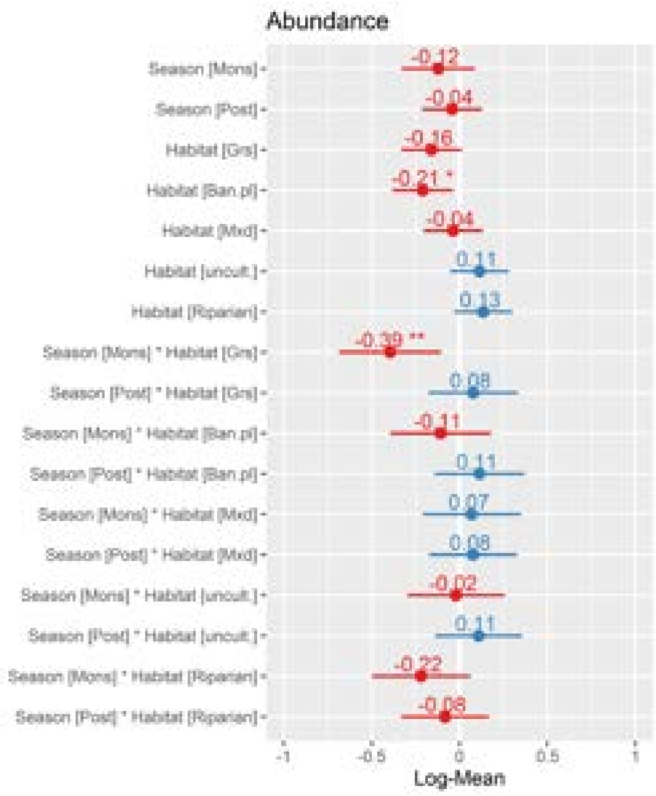

Figure 4.3.12: Coefficient plot of the generalized linear model (with 95% confidence intervals) fit to abundance of spiders against season and habitat collected at Muriyad Kol wetlands.

Richness of spiders in provided in Table 4.A.5 and graphically represented in a coefficient plot (Fig. 4.3.18).

The fitted mean Richness given by the model indicated that samples from groups such as Grasslands, paddy and banana plantations had an outcome of less than 35 species (Table 4.3.3). The largest fitted mean richness was predicted to be in uncultivated habitat, with Post-monsoon (58.77 [43.37, 65.66] species) indicating slightly larger values compared to other seasons. Heterogeneity and complex vegetational structure characteristic of uncultivated and riparian plots sampled in the study is reflected in the larger species richness as compared to less complex and monoculture habitats (Fig. 4.3.17).

Estimated Shannon diversity

The data revealed substantial variability in the distribution of estimated Shannon diversities (q=1) of spiders among the habitats (Fig. 4.3.20). It gives a hint of the distribution of typical species among the six habitats studiesd in the wetland. Uncultivated (123), mixed crops (98.46), riparian (97.13) habitats were among

Table 4.3.3: Mean fitted values of Richness of spiders with 95% confidence intervals for the negative binomial GLM against seasons and habitat types of Muriyad Kol wetland landscape.

[.01cm]	Habitat					
Season	**Paddy**	**Grs**	**Ban.pl**	**Mxd**	**uncult**	**Riparian**
Pre-monsoon	24.30 [21.44, 27.55]	29.66 [25.79, 34.11]	28.55 [24.78, 32.90]	28.55 [24.78, 54.37]	55.33 [42.96, 61.94]	55.33 [49.42, 61.22]
Monsoon	21.80 [17.64, 26.92]	20.66 [17.59, 24.27]	23.22 [19.91, 27.07]	65.77 [24.78, 51.24]	51.44 [40.29, 57.73]	39.33 [45.83, 44.62]
Post-monsoon	21.11 [17.99, 24.76]	27.66 [23.96, 31.93]	30.33 [26.40, 34.84]	48.77 [26.40, 54.85]	58.77 [43.37,65.66]	46.66 [52.61, 52.56]

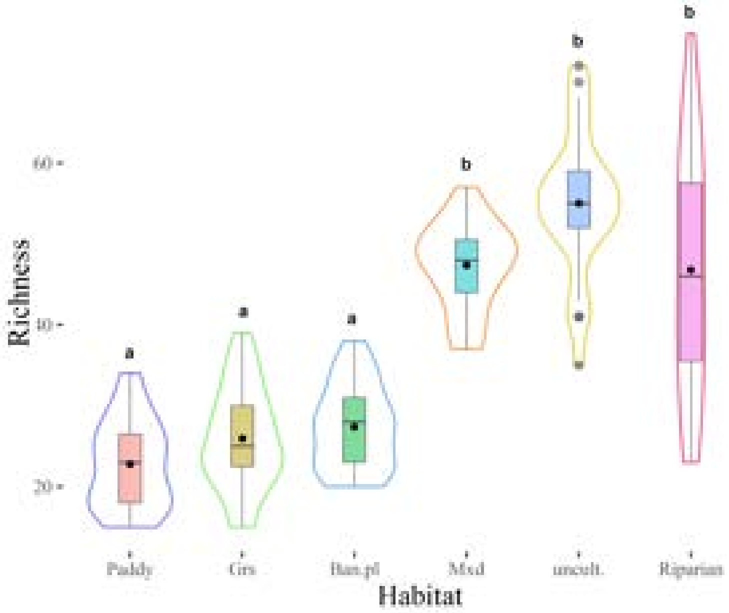

Figure 4.3.13: Observed Richness of spiders by habitat collected at Muriyad Kol wetlands

the groups with the largest mean estimated Shannon diversities, while banana plantation (34.69), grassland (33.72) and paddy (20.64) were among the groups with the lowest means (Figs 4.3.19 and 4.3.22). The overall mean estimated Shannon diversity was 67.94 species (n=162). The mean diversities among the seasons did not vary much, with pre-monsoon (69.57, n=58) leading, followed by monsoon (67.16, n= 50) and Post-monsoon (66.93, n=50) seasons.

The results of the type II Analysis of deviance performed on the generalized linear mixed model (GLMM) fit to the estimated Shannon diversity of spiders revealed significant differences in estimated Shannon diversity between habitats ($\chi^2 = 325.587$, Df $= 5$, $p < 0.001$) , but not between seasons ($\chi^2 = 1.818$, Df $= 2$, $p = 0.402$), and the interaction between seasons and habitat turned out not significant ($\chi^2 = 13.071$, Df $= 10$, p 0.219). The model validation indicated no problems (Figs 4.A.3A and 4.A.3B). The effect plot of habitat on the estimated

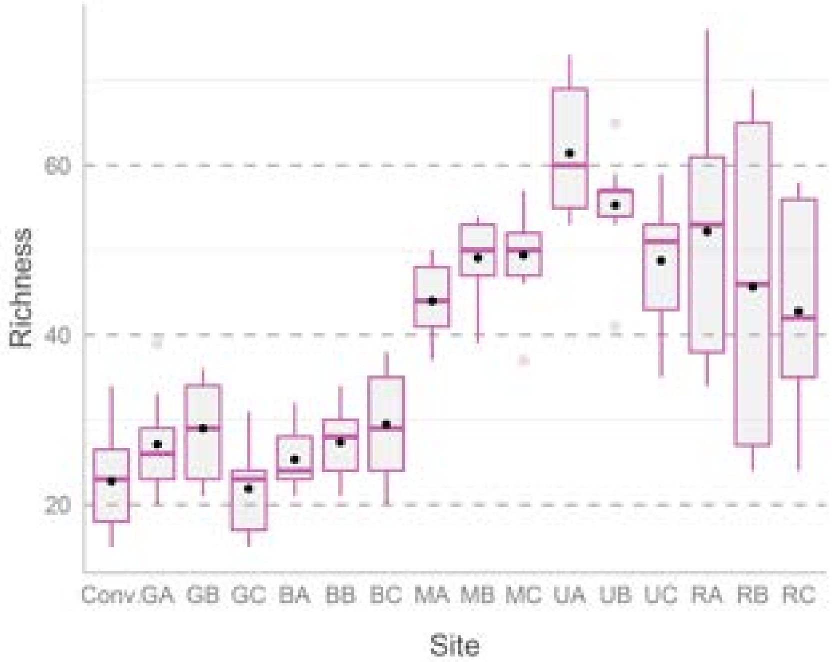

Figure 4.3.14: Observed Richness of spiders by collection site at Muriyad Kol wetlands

Shannon diversity of spiders is provided in Fig. 4.3.23. The random or group level effect of collection site explained 0.012 variance of the model. Figure 4.3.25 illustrates how much the intercept of the model shifts up or down in various collection sites relative to the fixed intercept. The sites belonging to uncultivated (UA) and riparian (RC and RA) habitats contributed to the differences among sites. Samples in the sites UA and RC have larger values compared to the others, and in contrast, the samples in RC have smaller values.

The summary of glm fitted to the estimated Shannon diversity of spiders against the habitat types is given in Table 4.A.6 and graphically represented in a coefficient plot (Fig. 4.3.23). Table 4.3.4 provides the mean fitted values of estimated Shannon diversities for the GLMM model fitted against habitat and seasons. The uncultivated and riparian plots with its complex vegetation structure and relatively less anthropogenic disturbance had the largest means fitted by the model.

4.3.4 Beta diversity

The Beta diversity (β) was significantly different among the habitat types ($F_{5,156}$= 3.666, p = 0.01). There was significant difference in the pair-wise comparisons of

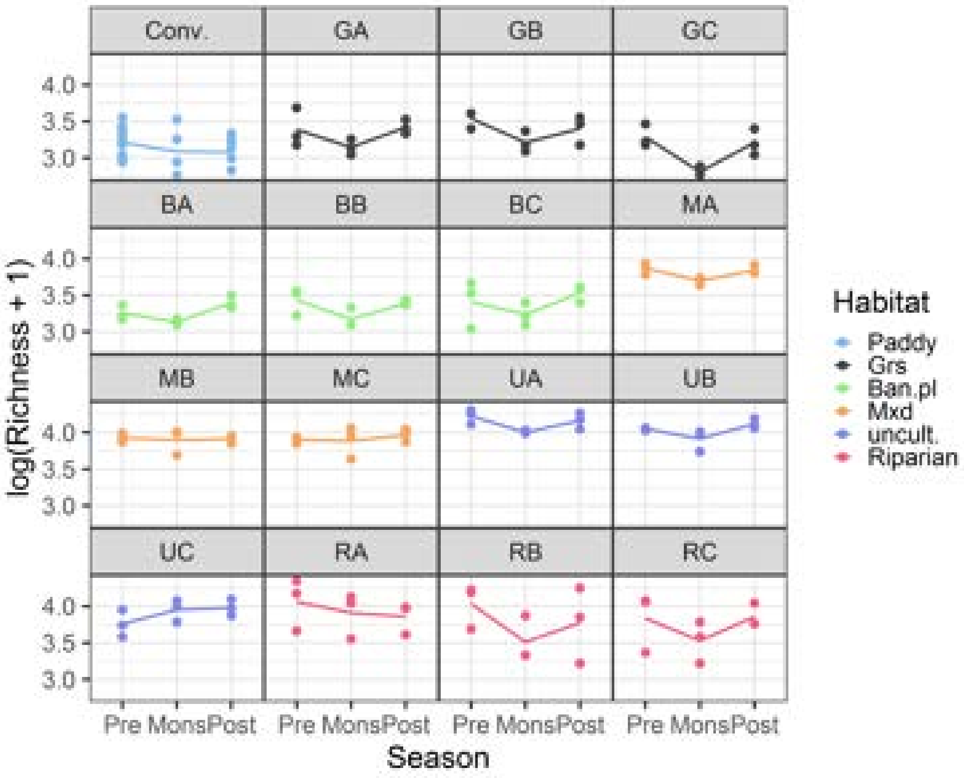

Figure 4.3.15: Observed Richness (log(Richness+1)) of spiders by collection site and season at Muriyad Kol wetlands

the dispersions between grasslands and paddy (p = 0.001), grassland and mixed (p = 0.025), uncultivated and mixed (p = 0.017) and uncultivated and paddy habitats ($p < 0.001$) (Fig. 4.3.27). The principal coordinates analysis plot (Fig. 4.3.26) shows greater spread of points around the centroids of the group in grasslands, riparian and paddy along both axes. Mixed crops, uncultivated and banana plantations appears to have greater spread in the axis 2. Axis 1 of the PCoA explained most (14.16%) of the variance while axis 2 explained only 4.14% of variances. The groups paddy and grassland appears to overlap and clustered situated far from the other clusters. The assemblages found in the groups are more similar and at

Table 4.3.4: Mean fitted values of estimated Shannon diversity of spiders with 95% confidence intervals for the negative binomial GLMM against seasons and habitat types of Muriyad Kol wetland landscape.

	Habitat					
Season	**Paddy**	**Grs**	**Ban.pl**	**Mxd**	**uncult**	**Riparian**
Pre-monsoon	21.36 [16.25, 28.08]	35.88 [28.84, 44.64]	35.34 [28.39, 43.99]	106.28 [87.09, 129.71]	108.42 [88.84, 132.33]	118.82 [87.32, 130.06]
Monsoon	19.36 [13.63, 27.51]	32.83 [24.19, 40.95]	30.25 [28.39, 37.82]	93.45 [76.47, 114.21]	137.55 [112.95, 167.51]	85.17 [69.58, 104.23]
Post-monsoon	20.26 [15.05, 27.28]	31.70 [30.53, 39.57]	37.93 [30.53, 47.11]	95.18 [77.90, 116.30]	118.82 [97.46,144.86]	95.56 [69.58, 116.76]

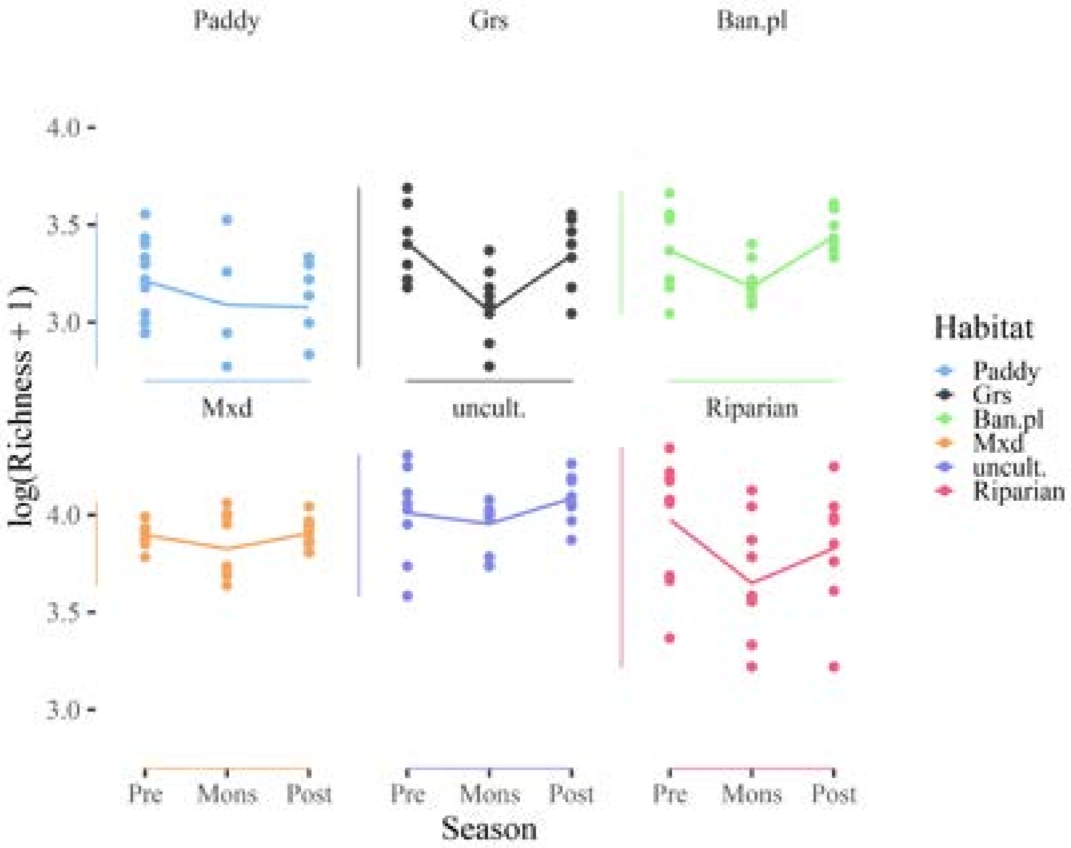

Figure 4.3.16: Observed Richness (log(Richness+1)) of spiders by habitat and season at Muriyad Kol wetlands

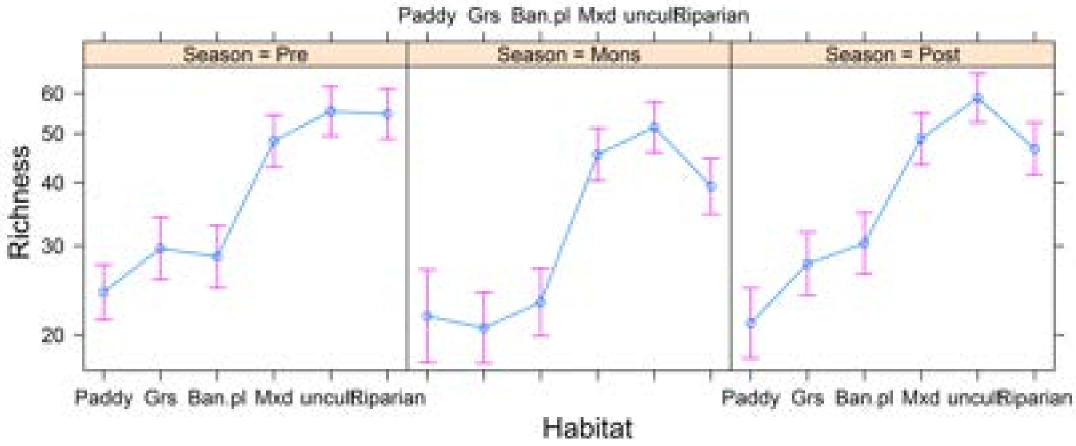

Figure 4.3.17: Effects displayed for the interaction between season and habitat type in the generalized linear model (with 95% confidence intervals) fit to observed Richness of spiders collected at Muriyad Kol wetlands.

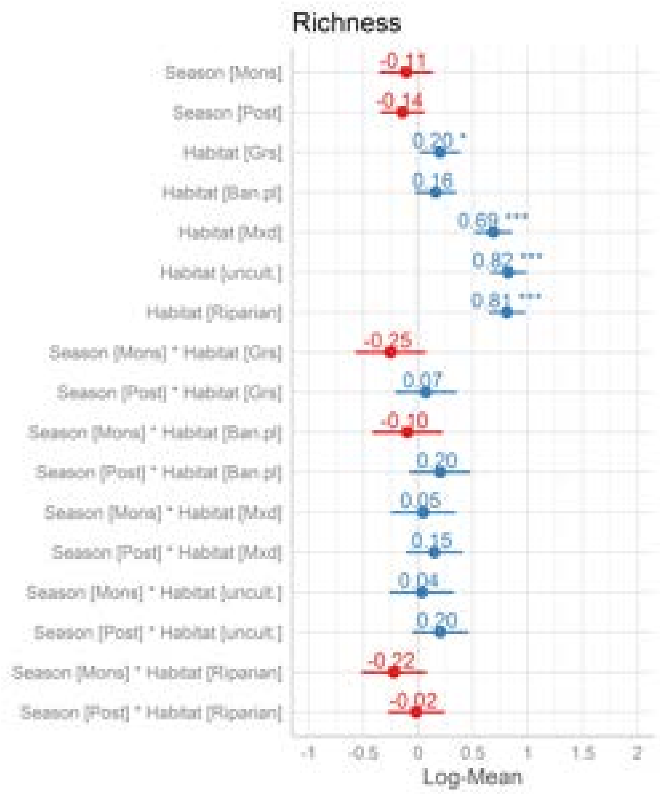

Figure 4.3.18: Coefficient plot of the generalized linear model (with 95% confidence intervals) fit to observed Richness of spiders against season and habitat collected at Muriyad Kol wetlands.

times overlap during different phases of the crop cycle. Riparian, uncultivated habitats and mixed crops formed a cluster far separated from the points belonging to banana plantations on the PCoA axis 2. The spider assemblages in the samples from the former group shows certain degree of similarity between them as the clusters of the riparian and mixed crops overlap with that of uncultivated habitats.

The multiple site Bray-Curtis dissimilarity (β_{BC}) of spider assemblages across the habitats (Paddy, grasslands, banana plantations, mixed crops, uncultivated plots and riparian) was 0.72. The abundance balanced variation (β_{BAL}) and abundance gradients (β_{GRA}) components were 0.69 and 0.034 respectively. Whereas, the incidence-based multiple site Sorensen dissimilarity (β_{SOR}) of spider assemblages across the habitats was 0.56. When partitioned into components, the replacement component (β_{SIM}, spatial turnover) was 0.38 and the nestedness-resultant component (β_{SNE}) was 0.18.

When the abundance-based indices were computed for 1000 samples of 10 plots, the mean value of total dissimilarity was (β_{BC}) = 0.84, with components (β_{BAL}) = 0.79 and (β_{GRA}) = 0.04. In the case of incidence-based indices, the mean value of

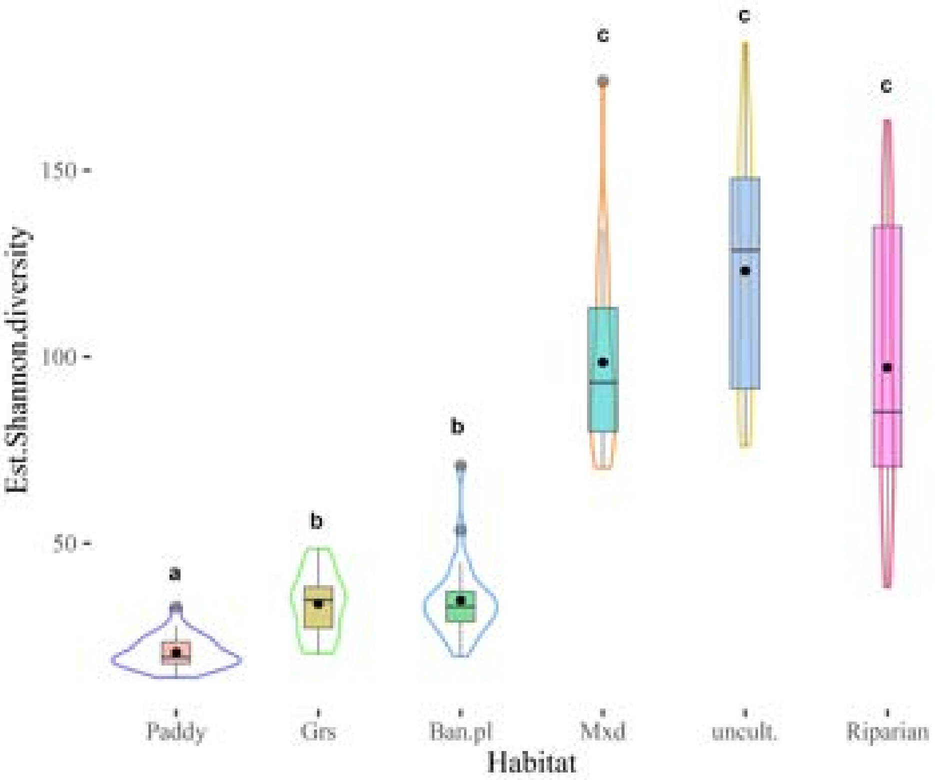

Figure 4.3.19: Estimated Shannon diversity of spiders by habitat collected at Muriyad Kol wetland landscape.

Figure 4.3.20: Estimated Shannon diversity of spiders by collection site at Muriyad Kol wetland landscape.

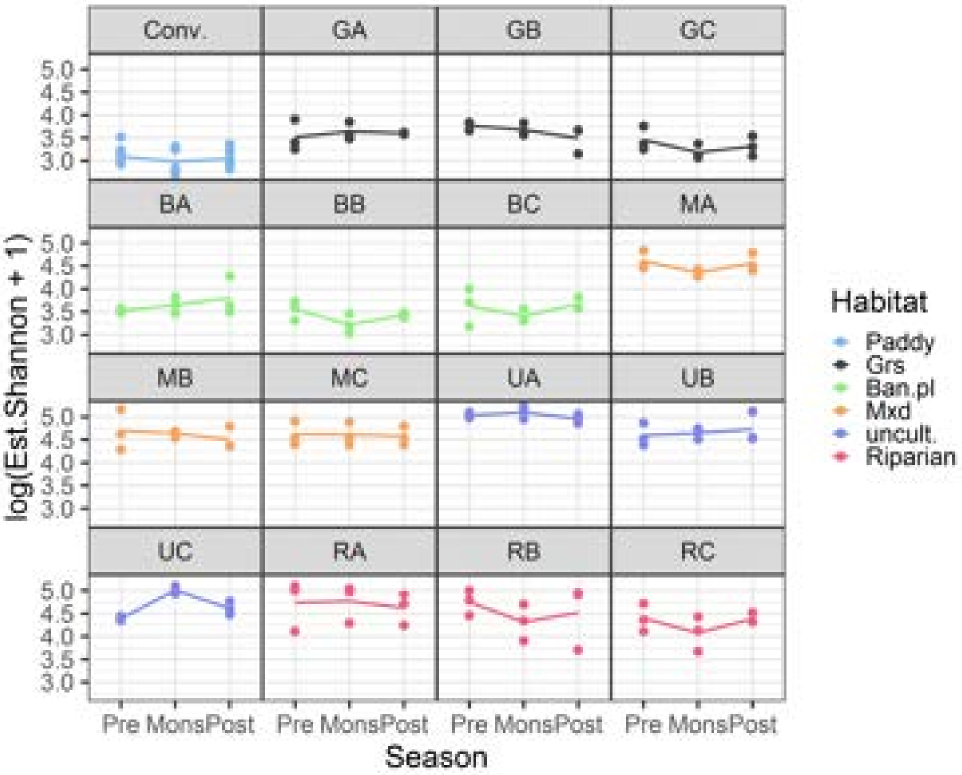

Figure 4.3.21: Estimated Shannon diversity (log(Est. Shannon diversity+1)) of spiders by collection site and season at Muriyad Kol wetland landscape.

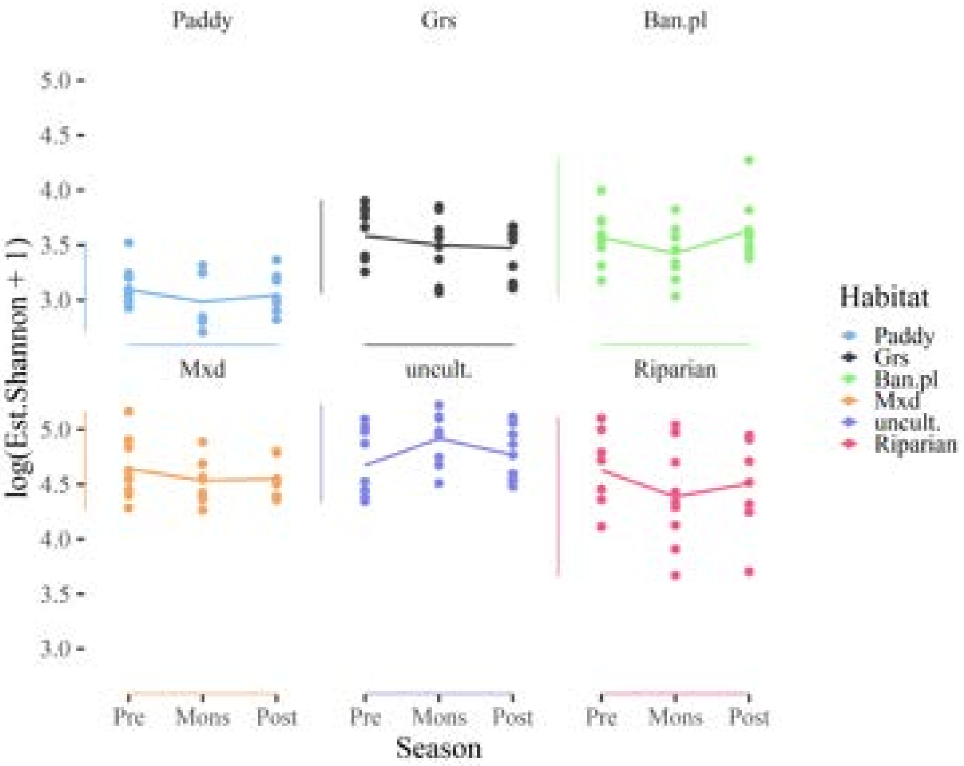

Figure 4.3.22: Estimated Shannon diversity (log(Est. Shannon diversity+1)) of spiders by habitat and season at Muriyad Kol wetland landscape.

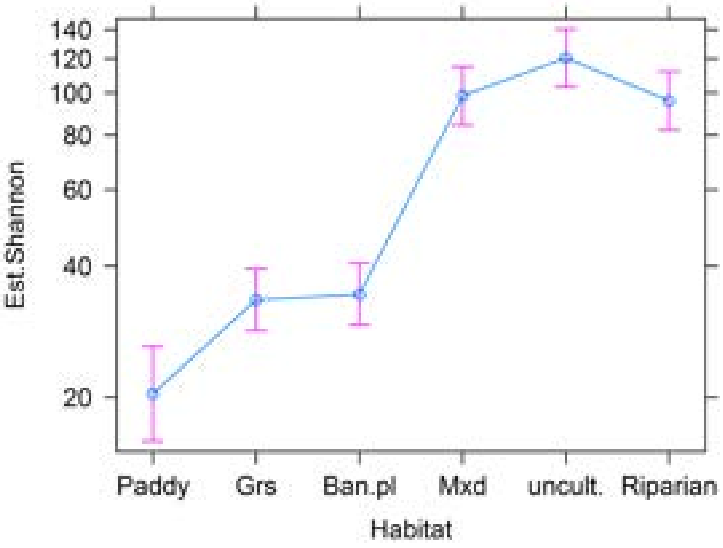

Figure 4.3.23: Effects displayed for the habitat type in the generalized linear mixed model (GLMM) (with 95% confidence intervals) fit to Estimated Shannon diversity of spiders collected at Muriyad Kol wetland landscape.

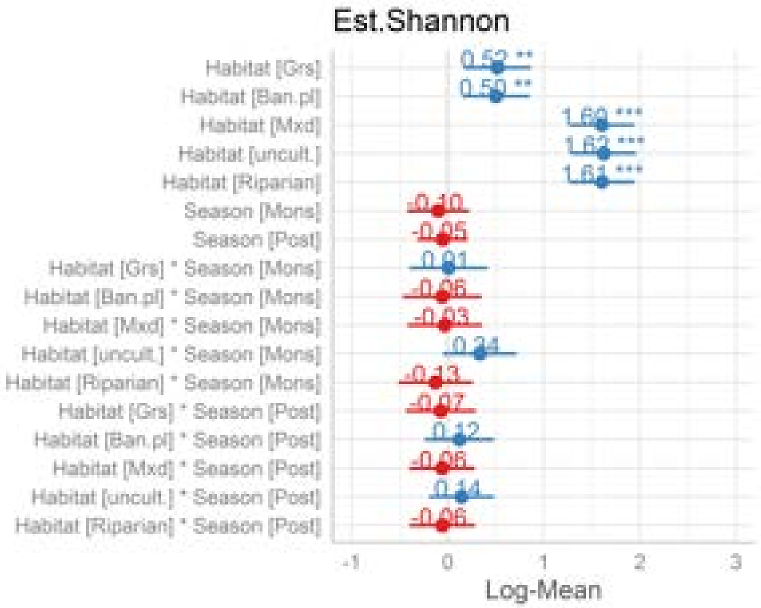

Figure 4.3.24: Coefficient plot of the generalized linear mixed model (with 95% confidence intervals) fit to estimated Shannon diversity of spiders collected at Muriyad Kol wetland landscape.

total dissimilarity was (β_{SOR}) = 0.81, with components (β_{SIM} = 0.73 and (β_{SNE}) = 0.08. When the variation of abundance was assessed, the dissimilarity was mostly related to balanced variation in abundance (substitution), while contribution of abundance gradients (subsets) was very low. Similarly, when the presence-absence data was assessed, the dissimilarity was mostly caused by species replacement (turnover) and there was little contribution of species nestedness (Fig. 4.3.28).

Seasonal turnover

The overall similarity based on the richness-based Sorensen and Jaccard index were 94.7% and 85.64% respectively. The pairwise similarity percentages using the relative abundance-based Horn ($q = 1$) between seasons among the habitats (Paddy, grasslands, banana plantations, mixed crops, uncultivated plots and riparian) were greater than 90% in all habitats (Table 4.3.5) and the overall similarity between seasons was greater than 97% when samples from all habitats were pooled. The estimated pairwise similarities were the largest ($> 94\%$) between post-monsoon and pre-monsoon among other pairs of seasons for all habitats.

The pairwise similarity percentage based on richness-based Sorensen index ($q = 0$) between seasons for the pooled samples from all habitats were greater than 94% for all pairs. For the samples from paddy fields, greater similarity

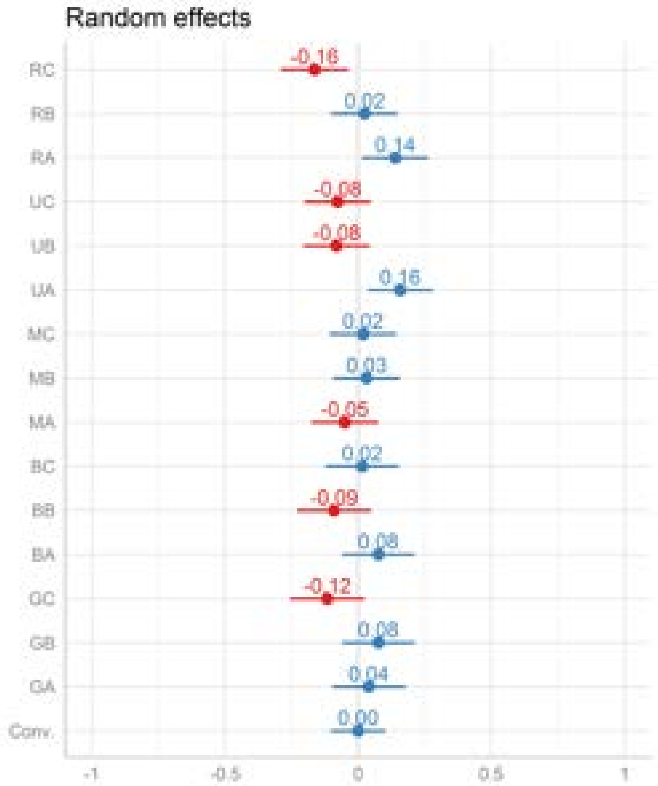

Figure 4.3.25: Coefficient plot of random effect for the generalized linear mixed model (with 95% confidence intervals)fit to Estimated Shannon diversity of spiders collectec

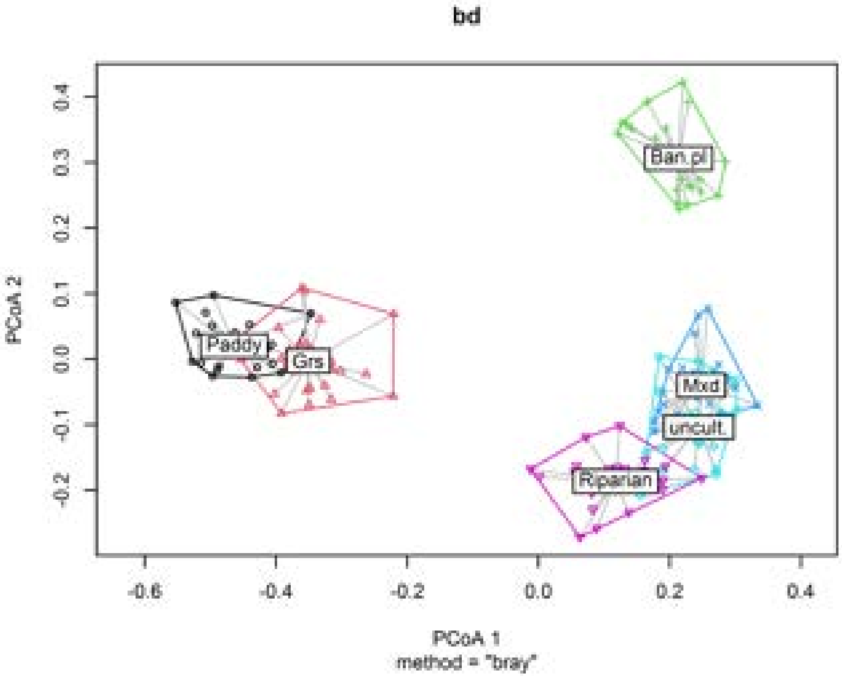

Figure 4.3.26: Principal coordinates analysis plot showing average dissimilarity (Bray-Curtis) from individual observations to their group centroids of spiders sampled at Muriyad Kol wetland landscape.

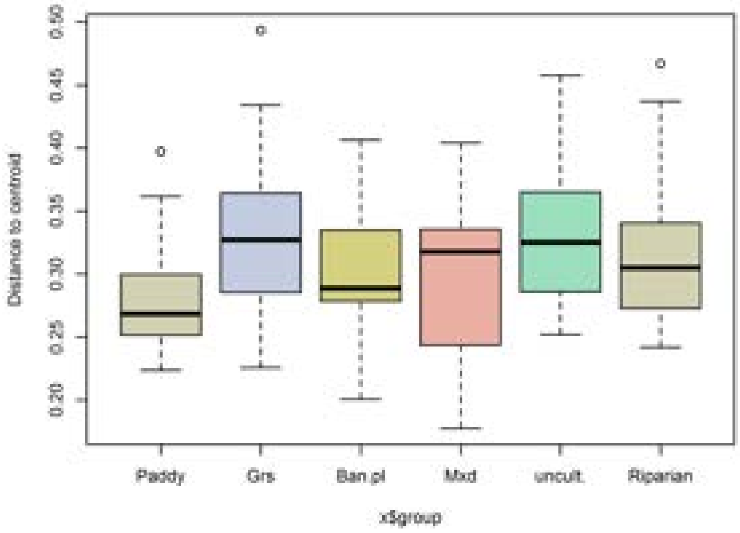

Figure 4.3.27: Boxplot plot of group-wise dispersion of dissimilarity from their cent

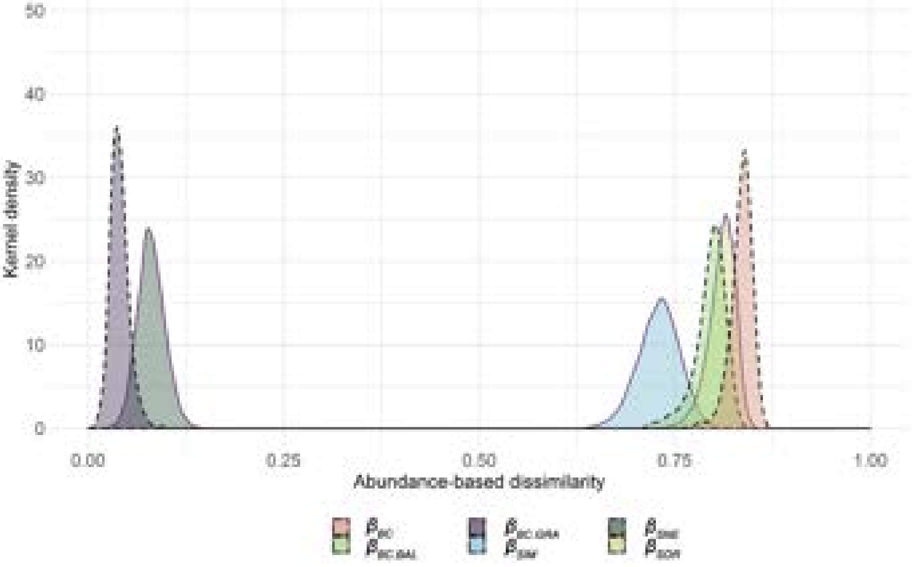

Figure 4.3.28: Density plots representing the distribution of abundance and incidence-based dissimilarity indices across 1000 samples of 10 subsampled plots across habitats. β_{BC}–total dissimilarity, $\beta_{BC.BAL}$–component of dissimilarity due to balanced variation in abundance, $\beta_{BC.GRA}$–component of dissimilarity due to abundance gradients, β_{SOR}–total dissimilarity, β_{SIM}–component of dissimilarity due to species replacement, β_{SNE}–component of dissimilarity due to nestedness. Abundance and incidence-based dissimilarities are bound by solid and dashed lines respectively.

was observed between pre-monsoon and post-monsoon (85.7%); percentage was

Table 4.3.5: Pairwise similarity percentage based on relative abundance-based Horn index (q=1) with a 95% confidence interval between seasons among the studied habitats of the Muriyad Kol wetland landscape.

	Pre-monsoon	Monsoon	Post-monsoon
Overall			
Pre-monsoon	100		
Monsoon	97 [96.10, 97.90]	100	
Post-monsoon	98 [97.40, 98.90]	97.53 [96.6, 98.40]	100
Paddy fields			
Pre-monsoon	100		
Monsoon	93.62 [87.9, 96.4]	100	
Post-monsoon	94.48 [90.4 , 1.000]	91.11 [88, 96.4]	100
Grasslands			
Pre-monsoon	100		
Monsoon	92.14 [92.2, 99.2]	100	
Post-monsoon	95.57 [92.4, 99]	92.17 [90.6 , 98.4]	100
Banana pl.			
Pre-monsoon	100		
Monsoon	95.67 [92.6, 99.7]	100	
Post-monsoon	95.7 [91.9, 100]	94.52 [93.6,99.9]	100
Mixed crops			
Pre-monsoon	100		
Monsoon	92.14 92.5, 99.8]	100	
Post-monsoon	95.57 [92.2, 99.9]	92.17 [93.6, 99.9]	100
Uncultivated			
Pre-monsoon	100		
Monsoon	92.14 [90.9, 98]	100	
Post-monsoon	95.57 [90.6, 99.1]	92.17 [90.2, 97.3]	100
Riparian			
Pre-monsoon	100		
Monsoon	95.50 [92, 99]	100	
Post-monsoon	94.46 [90.5, 98.5]	94.49 [90.5, 98.5]	100

similar between pre-monsoon–monsoon (72%), monsoon and post-monsoon (70.9%) (see Table 4.3.6). Post-monsoon and pre-monsoon samples coincided with the Mundakan and Puncha cropping seasons of paddy cultivation respectively, and the standing crops were under the influence of more or less same environmental conditions, except during the early Mundakan season when there was comparatively lower ambient temperature and high precipitation. The estimated similarities between pre-monsoon–monsoon and monsoon–post-monsoon were 72 [56.8, 87.2] and 70.9 [48.6, 93.2] percent respectively. The number of shared species observed in the pooled samples for pre-monsoon, monsoon and post-monsoon were 42 (observed

Table 4.3.6: Pairwise similarity percentage based on richness-based Sorensen index (q=0) with a 95% confidence interval between seasons among the habitats of the Muriyad Kol wetland landscape.

	Pre-monsoon	Monsoon	Post-monsoon
Overall			
Pre-monsoon	100		
Monsoon	94 [84.9, 100]	100	
Post-monsoon	95.3 [81.7, 100]	95.3 [86.9, 100]	100
Paddy fields			
Pre-monsoon	100		
Monsoon	72 [56.8, 87.2]	100	
Post-monsoon	85.7 [50, 100]	70.9 [48.6, 93.2]	100
Grasslands			
Pre-monsoon	100		
Monsoon	70.3 [52.3, 80.8]	100	
Post-monsoon	73.5 [50.1, 97]	63.6 [47.3, 79.9]	100
Banana pl.			
Pre-monsoon	100		
Monsoon	74 [53.3, 94.6]	100	
Post-monsoon	89.6 [67.9 , 100]	76.8 [57.6 , 96]	100
Mixed crops			
Pre-monsoon	100		
Monsoon	92.7 [73, 100]	100	
Post-monsoon	91.4 [67.7 , 100]	96.4 [79.1 , 100]	100
Uncultivated			
Pre-monsoon	100		
Monsoon	81.3 [69.3 , 93.2]	100	
Post-monsoon	76.9 [62.3, 91.6]	86.2 [72.4, 99.9]	100
Riparian			
Pre-monsoon	100		
Monsoon	79.1 [66.5, 91.7]	100	
Post-monsoon	81.3 [67.5, 95.1]	81 [64.9 , 97.1]	100

Richness = 65), 44 (48) and 36 (50) species respectively. The overall empirical similarities given by the Sorensen and Jaccard indices were 80.06 ±2.05 (±SE) and 57.24 ±2.87 percent respectively.

In the grasslands, the overall empirical similarities given by the Sorensen and Jaccard indices were 78.43 ±2.17 (±SE) and 54.79 ±2.88 percent respectively. Between seasons similarities in the Grassland samples was also the highest in Pre-monsoon and post-monsoon (73.5 [50.1, 97]%), followed by pre-monsoon–monsoon and monsoon–post-monsoon with 70.30 [52.3, 80.8] and 63.6 [47.3, 79.9] percent respectively. The number of shared species observed in the pooled samples for pre-monsoon, monsoon and post-monsoon in the grasslands were 49 (observed Richness = 80), 51 (60) and 43 (57) species respectively.

In the banana plantations, the overall empirical similarities given by the Sorensen and Jaccard indices were 85.93 ±1.94 (±SE) and 67.06 ±2.95 percent respectively. Between seasons percentage similarities were as follows: Pre-monsoon—post-monsoon (89.6 [67.9, 100]%) > monsoon—post-monsoon(76.8 [57.6, 96]) > pre-monsoon–monsoon (74 [53.3, 94.6]). The number of shared species observed in the pooled samples for pre-monsoon, monsoon and post-monsoon in the habitat were 56 (observed Richness = 69), 56 (69) and 53 (61) species respectively.

In the mixed cropped habitat, the overall empirical similarities given by the Sorensen and Jaccard indices were 89.05 ±1.51 (±SE) and 73.05 ±2.64 percent respectively. Interestingly, monsoon–post-monsoon had the greatest (96.4 [79.1, 100]%) pairwise similarity based on richness-based Sorensen index in the mixed cropped habitat. The similarities for pre-monsoon–monsoon and post-monsoon–pre-monsoon were estimated to be 92.7 [73, 100] and 91.4 [67.7, 100] percent respectively. The number of shared species observed in the pooled samples for pre-monsoon, monsoon and post-monsoon in the habitat were 90 (observed Richness = 108), 88 (105) and 92 (102) species respectively.

The overall empirical similarities in the uncultivated plots given by the Sorensen and Jaccard indices were 87.29 ±1.3 (±SE) and 69.59 ±2.11 percent respectively. Moreover, the pairwise similarity was also greater(86.2 [72.4, 99.9]%) to an extend between monsoon–post-monsoon compared to that between pre-monsoon–monsoon (81.3 [69.3 , 93.2]%) and post-monsoon–pre-monsoon (76.9 [62.3, 91.6]%). The number of shared species observed in the pooled samples for pre-monsoon, monsoon and post-monsoon in the uncultivated habitats were 120 (observed Richness = 145), 111 (139) and 112 (125) species respectively.

In the riparian habitat, the overall empirical similarities given by the Sorensen and Jaccard indices were 86.67 ±1.3 (±SE) and 68.42 ±2.15 percent respectively. The pairwise similarities were estimated to be 81.3 [67.5, 95.1], 81 [64.9 , 97.1] and 79.1 [66.5, 91.7] between Pre-monsoon–post-monsoon, monsoon–post-monsoon and pre-monsoon–monsoon respectively. The number of shared species observed in the pooled samples for pre-monsoon, monsoon and post-monsoon were 92 (observed Richness = 118), 87 (103) and 81 (94) species respectively.

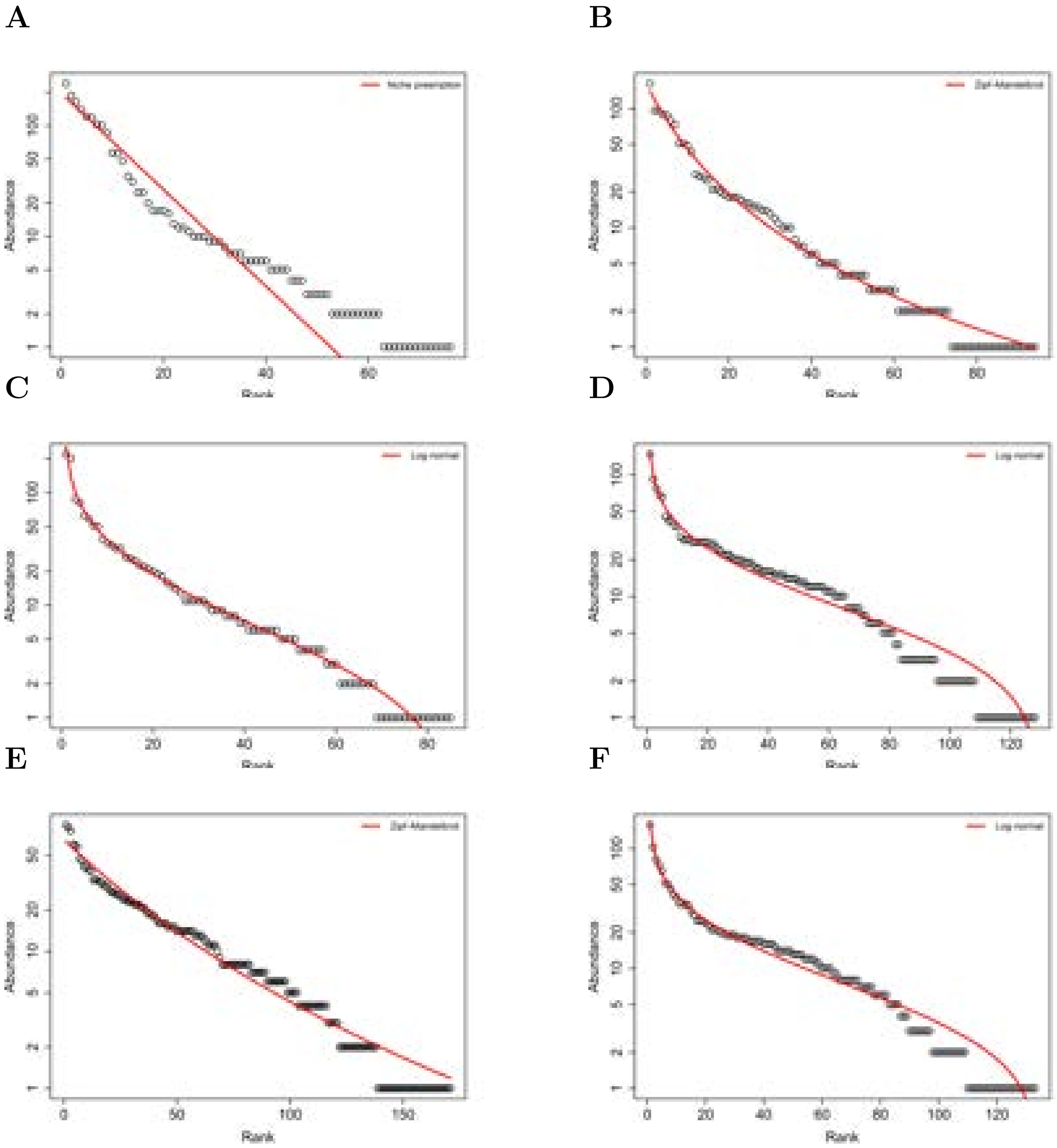

Figure 4.3.29: Rank abundance distribution (RAD) curves with the best models fitted (red line) for the spiders sampled from each habitat at Muriyad Kol wetland landscape. **A**. Paddy fields, **B**. Grasslands, **C**. Banana plantations, **D**. Mixed crops, **E**. Uncultivated plots, **F**. Riparian.

4.3.5 Community structure

The best fits for the Rank abundance distribution curves corresponded to Niche-Preemption (one RAD curve), Zipf-Mandelbrot (two RAD curves) and Log-normal (three RAD curves) (Fig. 4.3.29). The shape of rank abundance curves revealed differences in spider dominance and evenness from individual habitats, which indicates their relative success at resource partitioning and competition for prey and space. The paddy assemblages showed a niche preemption distribution with *Tetragnatha javana* (n=240), *Pardosa pseudoannulata* (188) and *Glenognatha dentata* (164) dominated the others. Here the most successful species, presumably with the highest competitive ability, takes major fraction of the resources and the second most successful takes a portion of the rest and so on. This is a straight line on the rank abundance curve. Other dominant species were *Argiope catenulata* (140), *Bianor kolensis* (121), *Tylorida striata* (118), *Tetragnatha keyserlingi* (103), *Oxyopes javanus* (101) and *Araneus ellipticus* (86).

Grassland and uncultivated land showed Zipf-Mandelbrot distribution. *Pardosa pseudoannulata* (161), *Araneus ellipticus* (96), *Oxyopes javanus* (98), *Bianor kolensis* (89), *Larinia phthisica* (88), *T. squamata* (79) and *Hippasa agelenoides* (73) held the top ranks in the grasslands. While, the dominant species in uncultivated plots were species such as *Tamigalesus munnaricus* (83), *Oxytate* sp. (80), *Pardosa pseudoannulata* (75), *Oxyopes javanus* (60) and *Castianeira zetes* (59). The log-normal distribution fitted best in banana plantations, mixed crops and riparian habitats. *Indopadilla insularis* (220) and *Pardosa pseudoannulata* (202) ranked highest in the banana plantations, followed by *Cyrtophora cicatrosa* (88), *Tamigalesus munnaricus* (82) and *Tylorida ventralis* (58). However, *Pardosa pseudoannulata* (147), *Indopadilla insularis* (220) maintained their ranks in the mixed cropped habitats, followed by *Oxytate* sp. (77), *Chalcotropis pennata* (68)and *Cheiracanthium danieli* (65). As for the riparian, *Pardosa pseudoannulata* (157) ranked highest in riparian habitats, followed by *Tylorida ventralis* (103), *Oxytate* sp (81), *Epidius parvati* (73), *O. javanus* (65) and *Tetragnatha viridorufa* (52).

4.4 Discussion

4.4.1 Diversity

The study showed that the overall diversity of spiders in the Muriyad Kol wetland landscape was greater than that reported in any previous work in different areas of the Vembanad-Kol wetlands (Malamel & Sudhikumar, 2020; Sebastian, Murugesan, et al., 2005; Sudhikumar, 2007). Families such as Araneidae, Lycosidae, Oxyopidae, Salticidae, Tetragnathidae, Theridiidae, Thomisidae and Corinnidae dominated the spider communities in the study area. The Mygalomorphae were represented by the families Halonoproctidae and Idiopidae. The lateritic nature of the surrounding wetland landscape may harbour many individuals of burrowing mygalomorphs.

Other hunters guild, which included the members of the foliage runners and stalkers, was the dominant group in the wetlands, followed by Orb weavers, Ground hunters, Space web weavers, Ambush hunters, Sensing web, Sheet web weavers and Specialists. In wetlands such as rice paddies and open grasslands, the number of orb weavers is greater because there is more space for attaching webs and there is more prey. They are mainly composed of Araneidae and Tetragnathidae. Large Orb weavers occupy the higher strata of grass, paddy or forb, while juveniles and other species such as *Tylorida striata* occupy the lower strata of vegetation. *P. pseudoannulata* was the single most dominant Ground hunter, especially in the wetland habitats such as paddy fields and grassland.

Invertebrates such as like spiders have attracted many studies in the agricultural landscapes to determine their role and see if they are numerous enough to control pests (Duffey, 2012). Like other landscape, spiders in the study area are an important component of the agroecosystem and services that are integral to the people dependent on it. The landscape was dominated by spiders from the Tetragnathidae, Salticidae, Araneidae, Lycosidae, and Thomisidae families. In mixed crops and banana plantations, the family Salticidae had the most spiders, followed by the similarly abundant families Lycosidae and Araneidae, and Theridiidae in the pooled data. Salticidae and Araneidae were the most abundant families in uncultivated plots. The dominant families in riparian areas were Tetragnathidae, Araneidae and Salticidae, all with similar abundance. Tetragnathidae spiders were most numerous in the paddy fields, followed by Araneidae, Salticidae, Lycosidae, Theridiidae and Oxyopidae. In contrast, individuals of Araneidae, Tetragnathidae, Salticidae and Lycosidae were almost equally abundant in the neighbouring grassland areas. When the agricultural fields are no longer cultivated, they turn into meadows. After three to four years, the spider fauna reaches its climax and maximum abundance, indicating that there may be a capacity limit in each specific habitat (Duffey, 2012).

Fragments of semi-natural habitats that are stable and free from disturbance are rare in the study area, and such areas are being converted to different land uses at a very rapid rate. The study has shown that these fragments have a greater abundance and diversity of spiders compared to other habitats in the landscape. The species richness of spiders in the uncultivated plots was estimated to be more than 200 species and the estimated diversities were also highest in this habitat according to different estimators. The grassland habitats which are close to the paddy fields were estimated to contain more than 100 species far greater than that estimated in the paddy fields. The diversities were also greater in the grasslands compared to the paddy fields. Natural or better preserved environments have higher spider diversity compared to nearby agroecosystems such as rice, wheat, maize, other cereals and soybean (Nyffeler & Benz, 1987). Areas on the edges of cultivated lands, with vegetation that is not only different from that of agroecosystems, but also more complex and less managed, could serve as refuges for spiders in times of disturbance, forcing them to disperse (Rodrigues & Mendonça, 2009).

Results of the study confirmed a marked habitat-wise and seasonal differentiation in the spider community. Spider abundance and species richness were significantly lower in the monsoon season, and this was even more pronounced in grassland habitats that are largely flooded during the season. The abundance of spiders was significantly influenced by the seasons in each habitat. Species richness, on the other hand, varied between samples collected in habitats and seasons. Estimated Shannon diversity differed between habitats, but seasons had no effect on it.

The effects of landscape change operate at a landscape level and examining species diversity at a local level fails to explain the total species richness of an agricultural landscape. So, α,β, γ diversities have an important role in studies in agricultural landscapes like Kol wetland. A decrease in total species richness could be attributed primarily to a decrease in species diversity between local communities (β diversity) (Hendrickx et al., 2007). Intensification of agriculture is inimical to wildlife including spiders due to various reasons such as decreasing proximity of the semi-natural habitat patches.

4.4.2 Beta diversity

The results suggest that beta diversity, measured as the degree of variation in species identities between habitats, shows significant differences between habitats. The pairwise comparisons showed that variation was significantly different between spider communities in grassland and paddy, grassland and mixed, uncultivated and mixed, and uncultivated and paddy habitats. β diversity through space (i.e. variability in species composition) is determined by factors related to species functional traits, geographic gradients and ecosystem characteristics (Korhonen et al., 2010). The choice of dissimilarity measure has been shown to have an extremely important influence on the observed patterns and the test of multivariate dispersions (Anderson et al., 2006). The multiple site dissimilarity analysis and its decomposition into components based on abundance and richness metrics revealed that a greater measure of dissimilarity was caused by the balanced variation and species replacement. Balanced variation in abundance means that the individuals of some species at one site are substituted by the same number of individuals of different species at another site or, in other words, the abundance of species changes from site to site with different signs for different species and the changes balance each other out (Baselga, 2013). Separating the components of incidence-based and abundance-based dissimilarities has proven useful in evaluating empirical patterns of species composition variation and their potential underlying determinants (Baselga, Gómez-Rodríguez, et al., 2012; Leprieur et al., 2011). The wetland landscape of the study area is a matrix of different habitats, including tiny fragments of semi-natural landscape structures that harbour diverse assemblages of spiders uniquely associated with the respective habitats. Distinguishing between components is important for developing conservation strategies and policy decisions at local and landscape levels. For example, if the component of nestedness is contributing more to overall dissimilarity, then this would preclude prioritising a small number of the richest sites, whereas if the component of species replacement contributes more and would require conservation efforts to be devoted to a large number of different sites, not necessarily the richest (Baselga, 2010).

Other aspect of β diversity is temporal turnover, or variation in species assemblages over time. Pairwise similarities based on the relative abundance-based index revealed high similarities between samples of different seasons in all habitats. However, when the richness-based index was used, the general seasonal response of spider communities was characterised by medium to high similarities between the three seasons. The highest similarities between seasons were observed in the samples from the mixed crop habitat. In the paddy fields, the post-monsoon and pre-monsoon samples had the highest similarity in spider species assemblages. The post-monsoon and pre-monsoon samples showed the greatest similarity in banana plantations and grasslands. Whereas, the monsoon and post-monsoon samples were the most similar in uncultivated plots. The results suggest that monsoon rains are the main driver responsible for these seasonal changes in spider communities in most wetland habitats.

4.4.3 Rank abundance distributions

The analysis of the rank abundance distributions showed that different structure of spider assemblages existed between habitats. Niche-Preemption distribution explained the abundance in the paddy fields assemblages. In Niche-preemption, the most successful species, presumably with the highest competitive ability, takes major fraction of the resources and the second most successful takes a portion of the remainder and so on.

Most of the tropical spider communities are generally fitted to the Log-Normal distribution, including understory and ground spider assemblages in forests (Campuzano et al., 2020; Coddington et al., 2009). The banana plantations, mixed crops, and riparian habitats were all fitted with log-normal distributions in this study. The log-normal model, which is frequently described for large, stable, and diverse communities, can be seen as the outcome of numerous factors acting simultaneously on the species (Whittaker, 1965; Wilson, 1991).

The Zipf-Mandelbrot model best explained the distribution of rank abundance distribution of spiders in grasslands and uncultivated habitats. In tiny, unstable and less diverse groups, this distribution model is usually linked to a number of factors acting sequentially (Magurran, 2004; Wilson, 1991). The uncultivated habitats in the study area are semi-natural, but due to their small size and fragmented character, the assemblages in this habitat are susceptible to being influenced by human activities on the adjacent properties. The spider communities in the grasslands, on the other hand, are influenced by the seasonal flooding during the monsoon season, which last for many weeks. The evolution of niche and habitat differentiation allows many species to exist as partial competitors in communities whose ranges largely and continuously overlap, forming the many intergrading communities of the landscape (Whittaker, 1965).

4.5 Conclusion

The results of the study show that spiders are abundant and diverse in the agricultural landscape of the Muriyad Kol wetlands. The region is a mosaic of a variety of natural and man-made habitats, with low-lying areas mostly dominated by rice fields and other crops. The study showed that habitat type, crops, and management practices influence spider abundance, diversity, and community structure of spiders. Paddy fields in the study area are highly productive ecosystems and as open canopy habitats, they are abundantly populated with spiders. The spider population was particularly high in the Mundakan and Puncha cropping seasons. The community of spiders in paddy fields showed variability in abundance depending on many factors such as the area, habitats surrounding the field, etc. However, greater abundance does not always mean greater diversity of spiders. In paddy fields, diversity was lower than in closed canopy habitats, with the exception of banana plantations. Paddy fields are characterised by a community dominated by a few highly successful spider species that use the majority of the resources. Sites belonging to riparian and uncultivated areas had greater diversity and abundance of spiders than sites in the other habitats. The most species-rich and diverse habitat was the uncultivated or semi-natural wooded sites in the study area that are intermediately disturbed and left unused for years. These highly fragmented and mostly tiny sites are highly susceptible to anthropogenic activities in surrounding areas.

Spider communities exhibited a significant degree of variation in species identities between habitats, as they support varied species functional traits due to different geographic gradients and ecosystem characteristics. Monsoon rains were found to be the driver responsible for seasonal changes in spider communities, explaining influences on local diversity and seasonal change within sites belonging to different habitats. Habitat-wise and seasonal differentiation of spider communities in the wetland landscape means that all biodiversity conservation efforts should focus on improving or mitigating the degradation of many habitats in the landscape. Traditional agricultural practices with minimal external inputs use natural defence mechanisms, use of polycultures, maintenance of vegetation complexity, etc. These practises provide stable populations of predators such as spiders, which are more resilient to crop management and support their greater diversity. Complex, heterogeneous landscapes with many semi-natural habitats and migration corridors support greater diversity of predatory arthropods. Promotion of environmentally friendly agriculture, integrated pest management, maintenance of natural vegetation on embankments and boundaries of cultivated areas, polycultures, and reduction in the use of inorganic fertilisers and weedicides can be considered as some of the positive steps towards conservation of spiders in wetlands. Intensification of agriculture in the region and reclamation of wetlands without a well thought out conservation plan, on the other hand, could spell disaster in the long run.

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Appendix

Table 4.A.1: Families and individuals of spiders sampled from different habitats.

Family	Paddy	Grassland	Banana pl.	Mixed crops	Uncultivated	Riparian
Araneidae	324	321	256	209	337	308
Clubionidae	10	14	50	29	12	20
Corinnidae	4	27	32	43	60	34
Ctenidae	0	0	1	0	0	1
Deinopidae	0	0	0	0	1	0
Eresidae	0	0	0	0	38	0
Gnaphosidae	0	10	13	34	32	18
Halonoproctidae	0	0	0	0	1	0
Hersiliidae	0	0	0	22	28	19
Idiopidae	0	0	0	0	4	0
Linyphiidae	79	30	11	18	43	5
Liocranidae	0	0	1	3	6	0
Lycosidae	219	263	267	223	136	212
Mimetidae	0	0	0	0	1	0
Miturgidae	17	30	20	67	59	46
Oecobiidae	3	0	1	0	3	0
Oonopidae	2	2	0	3	1	0
Oxyopidae	107	119	11	102	137	110
Palpimanidae	0	0	2	0	4	0
Philodromidae	7	3	2	17	26	10
Pholcidae	6	7	32	37	41	12
Pisauridae	0	0	0	0	2	36
Salticidae	223	184	549	518	486	305
Scytodidae	0	9	11	4	5	1
Sicariidae	0	1	0	1	1	0
Sparassidae	5	1	28	70	76	75
Tetragnathidae	676	287	78	102	141	324
Theraphosidae	0	0	1	1	8	0
Theridiidae	141	59	91	184	213	102
Theridiosomatidae	13	10	0	5	4	0
Thomisidae	34	73	19	123	160	212
Trachelidae	0	0	1	8	16	18
Uloboridae	0	0	27	33	39	45
Zodariidae	0	0	0	0	2	0
Total	**1870**	**1450**	**1504**	**1856**	**2123**	**1913**

Table 4.A.2: Families and species richness of spiders sampled from different habitats of Muriyad Kol wetland landscape.

Family	**Paddy**	**Grs**	**Ban.pl**	**Mxd**	**uncult.**	**Riparian**
Araneidae	13	17	17	23	29	30
Clubionidae	2	1	1	2	2	1
Corinnidae	1	2	1	2	2	1
Ctenidae	0	0	1	0	0	1
Deinopidae	0	0	0	0	1	0
Eresidae	0	0	0	0	1	0
Gnaphosidae	0	2	2	3	4	3
Halonoproctidae	0	0	0	0	1	0
Hersiliidae	0	0	0	1	1	1
Idiopidae	0	0	0	0	2	0
Linyphiidae	3	4	2	3	6	3
Liocranidae	0	0	1	1	1	0
Lycosidae	3	6	4	5	7	5
Mimetidae	0	0	0	0	1	0
Miturgidae	2	2	1	2	2	1
Oecobiidae	1	0	1	0	1	0
Oonopidae	1	2	0	1	1	0
Oxyopidae	5	5	1	6	6	6
Palpimanidae	0	0	1	0	1	0
Philodromidae	1	1	1	2	2	2
Pholcidae	1	1	1	5	3	2
Pisauridae	0	0	0	0	1	2
Salticidae	16	21	20	27	35	26
Scytodidae	0	2	2	2	1	1
Sicariidae	0	1	0	1	1	0
Sparassidae	2	1	2	3	4	5
Tetragnathidae	11	15	6	10	10	16
Theraphosidae	0	0	1	1	1	0
Theridiidae	7	5	12	15	25	15
Theridiosomatidae	1	1	0	1	1	0
Thomisidae	6	5	4	8	12	8
Trachelidae	0	0	1	1	1	1
Uloboridae	0	0	2	3	4	3
Zodariidae	0	0	0	0	1	0
Total	**76**	**94**	**85**	**128**	**171**	**153**

Table 4.A.3: Abundance of spiders species collected from different habitats of Muriyad Kol wetland landscape, including the shortened species names as given in the text.

Species name	**Shortened species name**	**Paddy**	**Grasslands**	**Banana plantations**	**Mixed crops**	**Uncult.**	**Riparian**	**Total**
Conothele sp.	*Con.sp1*	0	0	0	0	1	0	1
Heligmomerus maximus	*He.maximus*	0	0	0	0	1	0	1
Heligmomerus sp.	*He.sp1*	0	0	0	0	3	0	3
Annandaliella pectinifera	*A.pectinifera*	0	0	1	1	8	0	10
Anepsion maritatum	*An.maritatum*	0	1	51	19	33	28	132
Araneus ellipticus	*Ar.ellipticus*	86	96	0	1	1	35	219
Araneus inustus	*Ar.inustus*	2	7	0	2	4	1	16
Araneus viridisomus	*Ar.viridisomus*	0	0	0	2	12	8	22
Araneus mitificus	*Ar.mitificus*	0	0	0	6	8	3	17
Argiope aemula	*Arg.aemula*	6	0	2	0	0	1	9
Argiope anasuja	*Arg.anasuja*	25	0	6	16	15	17	79
Argiope catenulata	*Arg.catenulata*	140	51	0	3	1	0	195
Argiope pulchella	*Arg.pulchella*	2	5	1	12	15	10	45
Chorizopes sp.1	*C.sp1*	0	0	6	5	13	12	36
Cyclosa bifida	*Cy.bifida*	0	2	5	1	4	1	13
Cyclosa confraga	*Cy.confraga*	1	0	15	17	41	25	99
Cyclosa hexatuberculata	*Cy.hexatuberculata*	2	0	11	14	4	3	34
Cyrtophora cicatrosa	*Cyr.cicatrosa*	0	1	88	28	41	12	170
Cyrtophora citricola	*Cyr.citricola*	0	0	2	0	2	0	4
Cyrtophora unicolor	*Cyr.unicolor*	0	0	0	1	8	8	17
Cyrtarachne sundari	*Cyr.sundari*	0	0	0	0	7	2	9
Eriovixia laglaizei	*E.laglaizei*	0	12	22	19	27	17	97
Eriovixia excelsa	*E.excelsa*	0	0	4	1	4	1	10
Gasteracantha dalyi	*G.dalyi*	0	0	0	0	1	0	1
Gasteracantha geminata	*G.geminata*	0	0	1	13	14	13	41

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Table 4.A.3 – (Continued) Abundance of spiders species collected from different habitats.

Species name	Shortened species name	Paddy	Grasslands	Banana plantations	Mixed crops	Uncult	Riparian	Total
Herennia multipuncta	*H.multipuncta*	0	0	0	2	14	8	24
Larinia phthisica	*L.phthisica*	35	88	0	0	0	39	162
Larinia tabida	*L.tabida*	0	21	0	0	0	14	35
Neoscona bengalensis	*N.bengalensis*	0	1	4	11	7	4	27
Neoscona molemensis	*N.molemensis*	10	10	0	0	0	13	33
Neoscona mukerjei	*N.mukerjei*	0	4	36	27	26	18	111
Neoscona sp.	*N.sp1*	0	2	0	1	1	1	5
Neoscona theisi	*N.theisi*	10	15	1	6	3	3	38
Paravixia dehaani	*P.dehaani*	0	0	0	2	16	6	24
Poltys columnaris	*Po.columnaris*	0	0	0	0	2	3	5
Poltys nagpurensis	*Po.nagpurensis*	0	1	0	0	8	1	10
Araneid sp. 1	*Araneid.sp1*	4	0	1	0	0	0	5
Araneid sp. 2	*Araneid.sp2*	1	4	0	0	5	1	11
Clubiona sp1	*Cl.sp1*	9	14	50	28	11	20	132
Matidia sp	*M.sp1*	1	0	0	1	1	0	3
Castianeira zetes	*Ca.zetes*	4	25	32	42	59	34	196
Corinnomma severum	*Co.severum*	0	2	0	1	1	0	4
Ctenus cochinensis	*Ct.cochinensis*	0	0	1	0	0	1	2
Asianopis liukuensis	*As.liukuensis*	0	0	0	0	1	0	1
Cheiracanthium danieli	*Ch.danieli*	16	28	20	65	58	46	233
C. melanostomum	*Ch..melanostomum*	1	2	0	2	1	0	6
Stegodyphus sarasinorum	*S.sarasinorum*	0	0	0	0	38	0	38
Gnaphosa pauriensis	*Gn.pauriensis*	0	4	4	12	7	2	29
Gnaphosa sp. 1	*Gn.sp1*	0	0	0	5	2	0	7
Urozelotes patulusus	*U.patulusus*	0	0	0	0	1	2	3
Zelotes sp 1	*Z.sp1*	0	6	9	17	22	14	68
Hersilia savignyi	*Her.savignyi*	0	0	0	22	28	19	69

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Table 4.A.3 – (Continued) Abundance of spiders species collected from different habitats.

Species name	Shortened species name	Paddy	Grasslands	Banana plantations	Mixed crops	Uncult	Riparian	Total
Oedignatha sp 1	*O.sp1*	0	0	1	3	6	0	10
Erigone bifurca	*Er.bifurca*	17	5	0	3	4	1	30
Erigone sp.1	*Er.sp.1*	0	0	0	13	15	2	30
Atypena adelinae	*At.cirrifrons*	56	16	2	2	2	0	78
Atypena sp.1	*At.sp.1*	0	3	9	0	1	0	13
Nasoona crucifera	*Na.crucifera*	6	6	0	0	0	0	12
Neriene macella	*Ne.macella*	0	0	0	0	16	2	18
Hippasa agelenoides	*Hi.agelenoides*	0	73	5	0	2	12	92
Hippasa greenalliae	*Hi.greenalliae*	0	0	0	0	1	0	1
Lycosa sp.	*Ly.sp1*	20	10	21	12	8	7	78
Pardosa pseudoannulata	*Pa.pseudoannulata*	188	161	202	147	75	157	930
Pardosa sp. 1	*Pa.sp1*	11	16	0	2	14	6	49
Pardosa sp. 2	*Pa.sp2*	0	2	39	37	30	0	108
Wadicosa fidelis	*W.fidelis*	0	1	0	25	6	30	62
Mimetus sp.	*Mi.sp1*	0	0	0	0	1	0	1
Oecobius marathaus	*Oe.marathaus*	3	0	1	0	3	0	7
Oonopid sp1	*Oo.sp1*	2	1	0	3	1	0	7
Oonopid sp 2	*Oo.sp.2*	0	1	0	0	0	0	1
Hamadruas sikkimensis	*Ha.sikkimensis*	1	1	0	13	25	10	50
Hamataliwa hellia	*Ham.hellia*	2	4	0	16	8	2	32
Oxyopes birmanicus	*Ox.birmanicus*	1	17	0	20	17	16	71
Oxyopes javanus	*Ox.javanus*	101	96	11	42	60	65	375
Oxyopes shweta	*Ox.shweta*	2	1	0	10	19	9	41
Peucetia viridana	*Pe.viridana*	0	0	0	1	8	8	17
Artema atlanta	*Art.atlanta*	0	0	0	1	0	0	1
Crossopriza lyoni	*Cro.lyoni*	0	0	0	4	8	0	12
Pholcus phalangioides	*Ph.phalangioides*	0	0	0	1	0	0	1

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Table 4.A.3 – (Continued) Abundance of spiders species collected from different habitats.

Species name	Shortened species name	Paddy	Grasslands	Banana plantations	Mixed crops	Uncult	Riparian	Total
Pholcus sp. 1	*Ph.sp.1*	6	7	32	0	0	0	45
Smeringopus pallidus	*Sm.pallidus*	0	0	0	11	1	1	13
Psellonus planus	*Ps.planus*	7	0	0	3	19	4	33
Philodromid sp.	*Phi.sp.1*	0	3	2	14	7	6	32
Sarascelis sp.	*Sa.sp.1*	0	0	2	0	4	0	6
Perenethis venusta	*Per.venusta*	0	0	0	0	2	1	3
Pisaura sp.	*Pi.sp.1*	0	0	0	0	0	35	35
Asemonea tenuipes	*As.tenuipes*	0	1	19	29	24	14	87
Indopadilla insularis	*I.insularis*	0	0	220	92	46	21	379
Bianor angulosus	*B.angulosus*	31	15	0	0	0	6	52
Bianor kolensis sp. nov	*B.sp.1*	121	89	0	0	1	0	211
Brettus cingulatus	*Br.cingulatus*	0	0	13	22	20	15	70
Carrhotus viduus	*Car.viduus*	12	18	9	16	18	25	98
Chalcotropis pennata	*Cha.pennata*	0	0	63	68	33	13	177
Chinattus thamannae	*Chi.thamannae*	7	2	0	0	1	3	13
Chrysilla volupe	*Chrys.volupe*	0	1	0	0	2	2	5
Cocalus lacinia	*Coc.lacinia*	0	0	0	0	2	0	2
Curubis tetrica	*Cu.tetrica*	5	0	0	1	1	0	7
Epeus sp.	*Ep.* sp.	0	0	4	14	23	14	55
Epeus triangulopalpis	*Ep.triangulopalpis*	0	0	6	8	9	7	30
Epocilla aurantiaca	*Epo.aurantiaca*	1	0	0	3	7	2	13
Hyllus semicupreous	*Hy.semicupreous*	17	18	11	29	23	23	121
Hyllus kerala sp. nov.	*Hy. kerala*	0	0	0	0	5	0	5
Indomarengo chavarapater	*In.chavarapater*	0	1	1	0	6	1	9
Marengo sachintendulkar	*Ma.sachintendulkar*	0	1	2	1	1	0	5
Maripanthius sp.	*Maripanthius sp.*	8	4	0	0	0	0	12
Menemerus bivittatus	*Me.bivittatus*	0	0	0	8	12	7	27

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Table 4.A.3 – (Continued) Abundance of spiders species collected from different habitats.

Species name	Shortened species name	Paddy	Grasslands	Banana plantations	Mixed crops	Uncult	Riparian	Total
Myrmaplata plataleoides	*My.plataleoides*	1	14	34	29	33	19	130
Myrmarachne melanocephala	*My.melanocephala*	6	2	3	5	1	0	17
Myrmarachne sp.	*My.sp.1*	1	0	0	7	5	6	19
Phaeacius lancearius	*Pha.lancearius*	0	0	0	12	11	12	35
Phintella vittata	*Phi.vittata*	3	5	11	27	21	17	84
Phintelloides jesudasi	*Phint.jesudasi*	0	0	0	0	1	1	2
Piranthus planolancis	*Pi.planolancis*	0	0	0	1	1	0	2
Plexippus paykulli	*Pl.paykulli*	1	2	3	19	6	13	44
Plexippus petersi	*Pl.petersi*	0	1	0	2	1	0	4
Portia fimbriata	*Por.fimbriata*	0	2	16	16	14	16	64
Ptocasius sp.	*Pt.sp.1*	0	0	27	11	6	0	44
Rhene flavigera	*Rh.flavigera*	0	2	0	21	22	25	70
Siler semiglaucus	*Si.semiglaucus*	1	1	10	20	16	17	65
Stenaelurilus albus	*St.albus*	7	1	1	1	6	1	17
Stertinius aluva	*Ste.aluva*	0	0	0	0	2	0	2
Tamigalesus munnaricus	*T.munnaricus*	0	2	82	28	83	4	199
Tamigalesus noorae sp. nov.	*T. noorae*	0	0	0	0	1	0	1
Tamigalesus malabaricus sp. nov.	*T. malabaricus*	0	0	0	0	3	0	3
Telemonia dimidiata	*Te.dimidiata*	1	2	14	28	27	21	93
Thiania bhamoensis	*Thi. bhamoensis*	0	0	0	20	32	11	63
Scytodes fusca	*Sc.fusca*	0	5	6	3	0	0	14
S. thoracica	*Sc.thoracica*	0	4	5	1	5	1	16
Loxosceles rufescens	*Lo.rufescens*	0	1	0	1	1	0	3
Heteropoda sp.1	*Het.sp.1*	3	1	0	0	13	7	24
Heteropoda venatoria	*Het.venatoria*	2	0	23	10	0	2	37
Olios milleti	*Ol.milleti*	0	0	0	45	39	41	125
Pandercetes sp.	*Pan.sp1*	0	0	0	0	1	1	2

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Table 4.A.3 – (Continued) Abundance of spiders species collected from different habitats.

Species name	Shortened species name	Paddy	Grasslands	Banana plantations	Mixed crops	Uncult	Riparian	Total
Thelcticopis moolampilliensis	*Th.moolampilliensis*	0	0	5	15	23	24	67
Glenognatha dentata	*Gl.dentata*	164	27	0	2	4	0	197
Guizygiella nadleri	*Gu.nadleri*	3	3	0	0	2	1	9
Leucage decorata	*Le.decorata*	0	0	0	1	11	3	15
Tetragnatha cochinensis	*Tet.cochinensis*	6	3	0	0	0	7	16
Tetragnatha concordia sp. nov.	*Tet.sp1*	0	0	0	0	0	1	1
Tetragnatha hasselti	*Tet.hasselti*	2	1	0	1	0	0	4
Tetragnatha keyserlingi	*Tet.keyserlingi*	103	18	4	14	6	19	164
Tetragnatha viridorufa	*Tet.viridorufa*	0	21	4	28	30	52	135
Tetragnatha javana	*Tet.javana*	240	49	0	0	0	11	300
Tetragnatha mandibulata	*Tet.mandibulata*	17	3	7	15	22	20	84
Tetragnatha nitens	*Tet.nitens*	9	13	0	0	0	16	38
Tetragnatha serra	*Tet.serra*	0	3	0	0	0	1	4
Tetragnatha squamata	*Tet.squamata*	5	79	0	2	4	51	141
Tetragnatha ceylonica	*Tet.ceylonica*	0	0	2	12	0	1	15
Tetragnatha vermiformis	*Tet.vermiformis*	9	3	3	0	14	14	43
Tylorida ventralis	*Ty.ventralis*	0	20	58	24	47	103	252
Tylorida striata	*Ty.striata*	118	43	0	3	1	21	186
Tylorida sp.	*Ty.sp.*	0	1	0	0	0	3	4
Argyrodes flavescence	*Ay.flavescence*	5	0	8	12	18	10	53
Argyrodes gazedes	*Ay.gazedes*	0	0	1	2	2	2	7
Argyrodes kumadai	*Ay.kumadai*	0	0	6	18	14	8	46
Argyrodes bonadea	*Ay.bonadea*	2	0	0	1	1	1	5
Ariamnes flagellum	*Ari.flagellum*	0	0	1	8	8	2	19
Chrysso urbasae	*Chry.urbasae*	0	0	0	0	2	0	2
Coleosoma floridanum	*Col.floridanum*	57	19	11	15	26	8	136
Episinus affinis	*Epis.affinis*	0	0	0	0	5	0	5

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Table 4.A.3 – (Continued) Abundance of spiders species collected from different habitats.

Species name	**Shortened species name**	**Paddy**	**Grasslands**	**Banana plantations**	**Mixed crops**	**Uncult**	**Riparian**	**Total**
Euryopis episinoides	*Eu.episinoides*	3	1	1	6	8	2	21
Meotipa picturata	*Meo.picturata*	0	0	6	38	24	34	102
Meotipa multuma	*Meo.multuma*	25	8	0	0	2	0	35
Chrysso angula	*Chrysso angula*	0	0	0	0	2	0	2
Nesticodes rufipes	*Nes.rufipes*	0	0	0	2	8	0	10
Nihonhimea mundula	*Ni.mundula*	0	0	18	31	31	18	98
Molione trispinosa	*Mo.trispinosa*	0	0	0	0	6	0	6
Parasteatoda. sp.	*Par.sp1*	1	0	25	10	8	5	49
Phoroncidia septemaculeata	*Pho.septemaculeata*	0	0	0	6	8	5	19
Phycosoma labialis	*Phy.labialis*	48	26	7	0	4	1	86
Propostira quadrangulata	*Pr.quadrangulata*	0	0	0	3	6	3	12
Chikunia nigra	*Chr.angula*	0	0	1	0	13	0	14
Thwaitesia margaritifera	*Tw.margaritifera*	0	0	0	4	7	1	12
Theridion odisha	*Tr. odisha*	0	5	6	0	2	0	13
Theridion sp.1	*Tr. sp1*	0	0	0	0	1	2	3
Theridion sp.2	*Tr. sp2*	0	0	0	28	4	0	32
Theridiosoma sp.	*Td.sp1*	13	10	0	5	4	0	32
Amyciaea forticeps	*Am.forticeps*	0	0	8	7	21	16	52
Camaricus formosus	*Cam.formosus*	0	0	0	6	10	8	24
Epidius parvati	*Epi.parvati*	0	0	0	3	14	73	90
Indoxysticus minutus	*Ind.minutus*	5	6	1	3	7	5	27
Massuria sp.	*Mas.sp.*	1	0	0	0	3	0	4
Misumena mridulai	*Mis.mridulai*	4	0	0	3	2	1	10
Oxytate sp.	*Oxy.sp1*	0	1	8	77	80	81	247
Runcinia sp	*Ru.sp1*	12	51	0	0	1	9	73
Ozyptila sp.	*Oz.sp1*	0	0	0	0	1	0	1
Thomisus lobosus	*Tho.lobosus*	10	11	2	22	15	19	79

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Table 4.A.3 – (Continued) Abundance of spiders species collected from different habitats.

Species name	Shortened species name	Paddy	Grasslands	Banana plantations	Mixed crops	Uncult	Riparian	Total
Phrynarachne tuberosa	*Phr.tuberosa*	0	0	0	0	2	0	2
Thomisus projectus	*Tho.projectus*	2	4	0	2	4	0	12
Utivarachna fronto	*Ut.fronto*	0	0	1	8	16	18	43
Miagrammopes thwaitesi	*Mia.thwaitesi*	0	0	1	8	11	17	37
Miagrammopes extensus	*Mia.extensus*	0	0	0	0	1	0	1
Uloborus jabalpurensis	*Ul.jabalpurensis*	0	0	0	15	14	10	39
Zosis geniculata	*Zo.geniculata*	0	0	26	10	13	18	67
Tropizodium kalami	*Tro.kalami*	0	0	0	0	2	0	2

Table 4.A.4: Estimated regression parameters, standard errors, z-values and P-values for the negative binomial GLM fit to abundance of spiders sampled from different habitats of Muriyad Kol wetland, including the multiple comparisons of means using Tukey contrasts. Bold numbers indicate significance. Residual Df–162.53, Df 144.

	Estimate	**Std. Error**	**z value**	**P-value**
Effects				
Intercept	4.273	0.055	77.268	< **0.001**
SeasonMonsoon	-0.121	0.107	-1.133	0.257
SeasonPostmonsoon	-0.043	0.087	-0.490	0.624
HabitatGrs	-0.159	0.088	-1.806	0.071
HabitatBan.pl	-0.209	0.089	-2.363	**0.018**
HabitatMxd	-0.036	0.087	-0.416	0.677
Habitatuncult.	0.114	0.086	1.335	0.182
HabitatRiparian	0.135	0.085	1.577	0.115
SeasonMons:HabitatGrs	-0.395	0.148	-2.664	**0.008**
SeasonPost:HabitatGrs	0.078	0.130	0.603	0.547
SeasonMons:HabitatBan.pl	-0.108	0.146	-0.735	0.462
SeasonPost:HabitatBan.pl	0.114	0.130	0.878	0.380
SeasonMons:HabitatMxd	0.070	0.143	0.489	0.625
SeasonPost:HabitatMxd	0.077	0.128	0.603	0.547
SeasonMons:Habitatuncult	-0.020	0.142	-0.140	0.889
SeasonPost:Habitatuncult.	0.109	0.126	0.866	0.387
SeasonMons:HabitatRiparian	-0.219	0.143	-1.536	0.125
SeasonPost:HabitatRiparian	-0.083	0.127	-0.650	0.516
Linear hypotheses				
Grs -Paddy	-0.159	0.088	-1.806	1
Ban.pl-Paddy	-0.209	0.089	-2.362	0.273
Mxd -Paddy	-0.039	0.087	-0.453	1
Uncult.-Paddy	0.111	0.086	1.301	1
Riparian-Paddy	0.135	0.085	1.577	1
Ban.pl -Grs	-0.05	0.097	-0.516	1
Mxd -Grs	0.12	0.096	1.249	1
uncult. -Grs	0.27	0.095	2.858	0.064
Riparian -Grs	0.294	0.094	3.109	**0.028**
Mxd -Ban.pl	0.17	0.096	1.764	1
uncult. -Ban.pl	0.321	0.095	3.371	**0.011**
Riparian -Ban.pl	0.344	0.095	3.622	**0.004**

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Table 4.A.4 – continued from previous page

	Estimate	Std. Error	z value	P-value
uncult. -Mxd	0.151	0.094	1.612	1
Riparian -Mxd	0.174	0.093	1.864	0.935
Riparian -uncult.	0.023	0.092	0.253	1
Mons-Pre	-0.121	0.107	-1.133	0.772
Post-Pre	-0.043	0.087	-0.49	1
Post-Mons	0.078	0.113	0.692	1

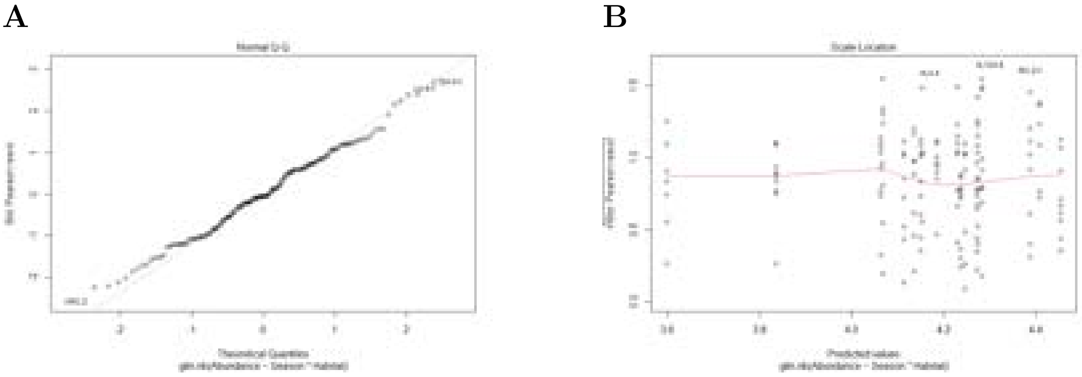

Figure 4.A.1: Diagnostic plots of negative binomial GLM to model the abundance of spiders sampled from different habitats of Muriyad Kol wetland. **A.** Normal Q-Q plot and **B.** Scale-Location plot.

Table 4.A.5: Estimated regression parameters, standard errors, z-values and P-values for the negative binomial GLM fit to richness of spiders sampled from different habitats of Muriyad Kol wetland, including the multiple comparisons of means using Tukey contrasts. Bold numbers indicate significance. Residual Df–156.68, Df 144.

	Estimate	Std. Error	z value	P-value
Effects				
Intercept	3.190	0.063	50.264	< 0.001
SeasonMonsoon	-0.108	0.124	-0.876	0.381
SeasonPostmonsoon	-0.140	0.102	-1.373	0.169
HabitatGrs	0.199	0.095	2.097	0.036
HabitatBan.pl	0.036	0.095	0.095	0.092
HabitatMxd	0.687	0.087	7.895	< 0.001
Habitatuncult.	0.822	0.085	9.636	< 0.001

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Table 4.A.5 – continued from previous page

	Estimate	Std. Error	z value	P-value
HabitatRiparian	0.810	0.085	9.478	< 0.001
SeasonMons:HabitatGrs	-0.252	0.164	-1.535	0.124
SeasonPost:HabitatGrs	0.071	0.144	0.494	0.621
SeasonMons:HabitatBan.pl	-0.097	0.163	-0.600	0.548
SeasonPost:HabitatBan.pl	0.201	0.143	1.403	0.160
SeasonMons:HabitatMxd	0.047	0.150	0.314	0.753
SeasonPost:HabitatMxd	0.150	0.132	1.131	0.258
SeasonMons:Habitatuncult	0.036	0.148	0.242	0.808
SeasonPost:Habitatuncult.	0.201	0.130	1.547	1.547
SeasonMons:HabitatRiparian	-0.220	0.151	-1.459	0.144
SeasonPost:HabitatRiparian	-0.017	0.132	-0.130	0.896
Linear hypotheses				
Grs -Paddy	0.199	0.095	2.101	0.534
Ban.pl-Paddy	0.161	0.096	1.685	1
Mxd -Paddy	0.683	0.087	7.855	0.001
Uncult.-Paddy	0.819	0.085	9.607	0.001
Riparian-Paddy	0.81	0.085	9.501	0.001
Ban.pl -Grs	-0.038	0.1	-0.38	1
Mxd -Grs	0.483	0.092	5.24	0.001
uncult. -Grs	0.619	0.091	6.831	0.001
Riparian -Grs	0.611	0.091	6.735	0.001
Mxd -Ban.pl	0.522	0.093	5.606	0.001
uncult. -Ban.pl	0.658	0.091	7.189	0.001
Riparian -Ban.pl	0.649	0.092	7.094	0.001
uncult. -Mxd	0.136	0.082	1.649	1
Riparian -Mxd	0.128	0.082	1.549	1
Riparian -uncult.	-0.008	0.081	-0.1	1
Mons-Pre	-0.109	0.124	-0.877	1
Post-Pre	-0.141	0.103	-1.375	0.507
Post-Mons	-0.032	0.134	-0.24	1

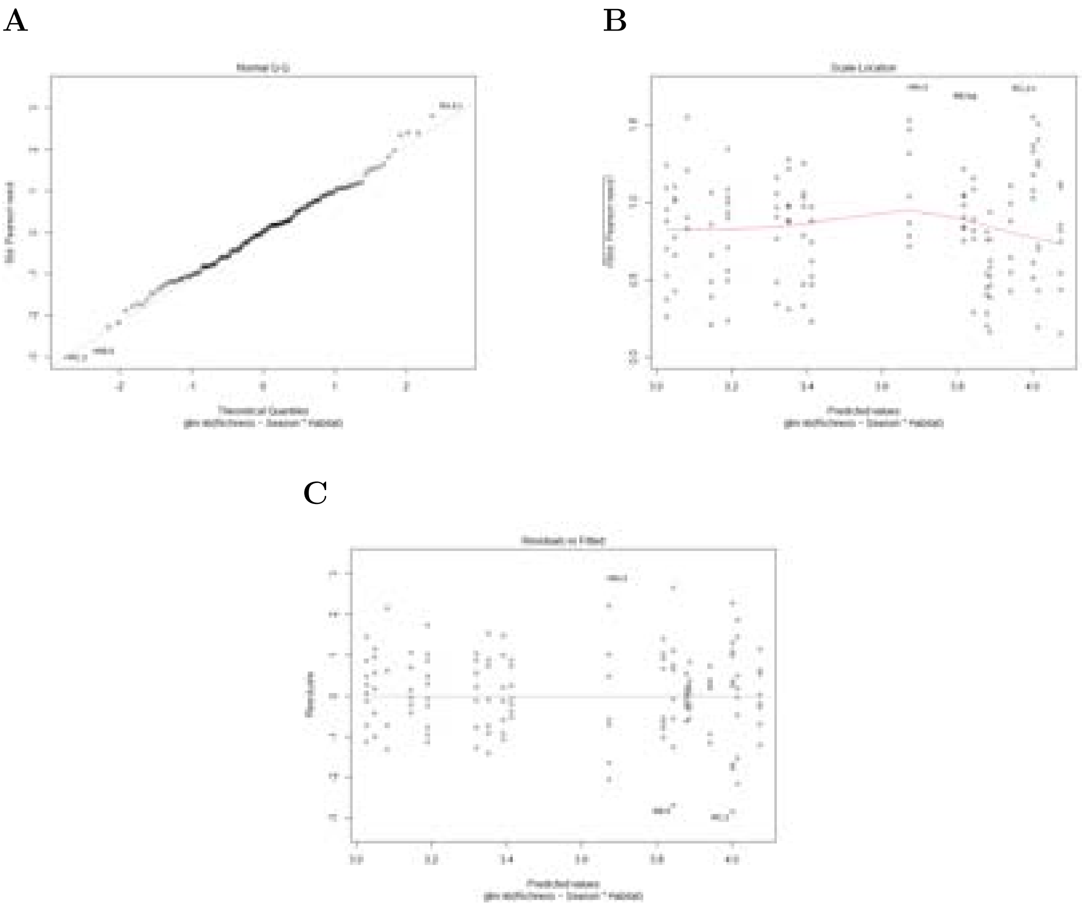

Figure 4.A.2: Diagnostic plots of negative binomial GLM to model the Richness of spiders sampled from different habitats of Muriyad Kol wetland. **A.**, Normal Q-Q plot. **B.**, Scale-Location plot. **C.** Residual plot.

Table 4.A.6: Estimated regression parameters, standard errors, z-values and P-values for the negative binomial GLM fit to estimated Shannon diversity of spiders sampled from different habitats of Muriyad Kol wetland, including the multiple comparisons of means using Tukey contrasts. Bold numbers indicate significance. Dispersion, χ^2 142.07, ratio 0.99.

	Estimate	**Std. Error**	**z value**	**P-value**
Effects				
Intercept	3.061	0.138	22.120	< 0.001
HabitatGrs	0.518	0.177	2.929	0.003
HabitatBan.pl	0.503	0.177	2.840	0.004
HabitatMxd	1.604	0.171	9.372	< 0.001
Habitatuncult.	1.624	0.171	9.487	< 0.001
HabitatRiparian	1.607	0.171	9.386	< 0.001

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Table 4.A.6 – continued from previous page

	Estimate	Std. Error	z value	P-value
SeasonMons	-0.098	0.171	-0.601	0.547
SeasonPost	-0.052	0.133	-0.395	0.692
SeasonMons:HabitatGrs	0.009	0.208	0.044	0.964
SeasonPost:HabitatGrs	-0.057	0.208	-0.275	0.783
SeasonMons:HabitatBan.pl	-0.030	0.197	-0.155	0.877
SeasonPost:HabitatBan.pl	0.336	0.196	1.708	0.087
SeasonMons:HabitatMxd	-0.126	0.197	-0.637	0.524
SeasonPost:HabitatMxd	-0.071	0.185	-0.385	0.700
SeasonMons:Habitatuncult	0.123	0.184	0.669	0.503
SeasonPost:Habitatuncult.	-0.057	0.173	-0.333	0.739
SeasonMons:HabitatRiparian	0.144	0.172	0.834	0.404
SeasonPost:HabitatRiparian	-0.056	0.173	-0.325	0.744
Linear hypotheses				
Grs -Paddy	0.509	0.168	3.032	0.036
Ban.pl-Paddy	0.493	0.168	2.938	0.05
Mxd -Paddy	1.594	0.161	9.874	0.001
Uncult.-Paddy	1.614	0.162	9.994	0.001
Riparian-Paddy	1.597	0.162	9.888	0.001
Ban.pl -Grs	-0.015	0.155	-0.099	1
Mxd -Grs	1.086	0.148	7.321	0.001
uncult. -Grs	1.106	0.148	7.457	0.001
Riparian -Grs	1.088	0.148	7.339	0.001
Mxd -Ban.pl	1.101	0.148	7.415	0.001
uncult. -Ban.pl	1.121	0.149	7.55	0.001
Riparian -Ban.pl	1.104	0.148	7.433	0.001
uncult. -Mxd	0.02	0.141	0.143	1
Riparian -Mxd	0.003	0.141	0.02	1
Riparian -uncult.	-0.017	0.141	-0.123	1

Table 4.A.9: Summary of generalised linear model fit to the relative abundance of individual spider guilds among different habitats of Muriyad Kol wetland landscape, including the multiple comparisons of means using Tukey contrasts.

	Estimate	Std. Error	z value	P-value
Space web weaver				
Effects				
(Intercept)	-2.46	0.086	-28.624	0.001

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Table 4.A.9 – continued from previous page

	Estimate	Std. Error	z value	P-value
HabitatGrs	-0.583	0.153	-3.826	0.001
HabitatBan.pl	0.044	0.127	0.347	0.729
HabitatMxd	0.473	0.112	4.222	0.001
Habitatuncult.	0.514	0.109	4.713	0.001
HabitatRiparian	-0.268	0.129	-2.073	0.038
Linear hypotheses				
Grs–Paddy	-0.583	0.153	-3.826	0.002
Ban.pl–Paddy	0.044	0.127	0.347	1
Mxd–Paddy	0.473	0.112	4.222	0.001
uncult.–Paddy	0.514	0.109	4.713	0.001
Riparian–Paddy	-0.268	0.129	-2.073	0.573
Ban.pl–Grs	0.628	0.157	3.991	0.001
Mxd–Grs	1.056	0.145	7.284	0.001
uncult.–Grs	1.097	0.143	7.687	0.001
Riparian–Grs	0.315	0.159	1.986	0.706
Mxd–Ban.pl	0.428	0.118	3.621	0.004
uncult.–Ban.pl	0.47	0.116	4.063	0.001
Riparian–Ban.pl	-0.312	0.135	-2.315	0.31
uncult.–Mxd	0.041	0.098	0.419	1
Riparian–Mxd	-0.741	0.12	-6.153	0.001
Riparian–uncult	-0.782	0.118	-6.645	0.001
Other hunters				
Effects				
(Intercept)	-1.174	0.054	-21.539	0.001
HabitatGrs	0.163	0.081	2.025	0.043
HabitatBan.pl	0.989	0.075	13.149	0.001
HabitatMxd	0.936	0.072	12.998	0.001
Habitatuncult.	0.779	0.071	10.997	0.001
HabitatRiparian	0.341	0.074	4.585	0.001
Linear hypotheses				
Grs - Paddy	0.163	0.081	2.025	0.643
Ban.pl - Paddy	0.989	0.075	13.149	0.001
Mxd - Paddy	0.936	0.072	12.998	0.001
uncult. - Paddy	0.779	0.071	10.997	0.001
Riparian - Paddy	0.341	0.074	4.585	0
Ban.pl - Grs	0.826	0.079	10.477	0.001

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Table 4.A.9 – continued from previous page

	Estimate	Std. Error	z value	P-value
Mxd - Grs	0.773	0.076	10.199	0.001
uncult. - Grs	0.616	0.075	8.248	0.001
Riparian - Grs	0.177	0.078	2.277	0.342
Mxd - Ban.pl	-0.053	0.07	-0.762	1
uncult. - Ban.pl	-0.21	0.069	-3.056	0.034
Riparian - Ban.pl	-0.648	0.072	-8.96	0.001
uncult. - Mxd	-0.157	0.065	-2.404	0.243
Riparian - Mxd	-0.595	0.069	-8.624	0.001
Riparian - uncult	-0.438	0.068	-6.464	0.001
Orb weavers				
Effects				
(Intercept)	0.171	0.046	3.675	0.001
HabitatGrs	-0.468	0.071	-6.634	0.001
HabitatBan.pl	-1.32	0.076	-17.32	0.001
HabitatMxd	-1.618	0.075	-21.438	0.001
Habitatuncult.	-1.236	0.069	-17.947	0.001
HabitatRiparian	-0.727	0.067	-10.862	0.001
Linear hypotheses				
Grs - Paddy	-0.468	0.071	-6.634	0.001
Ban.pl - Paddy	-1.32	0.076	-17.32	0.001
Mxd - Paddy	-1.618	0.075	-21.438	0.001
uncult. - Paddy	-1.236	0.069	-17.947	0.001
Riparian - Paddy	-0.727	0.067	-10.862	0.001
Ban.pl - Grs	-0.852	0.08	-10.59	0.001
Mxd - Grs	-1.15	0.08	-14.422	0.001
uncult. - Grs	-0.767	0.073	-10.442	0.001
Riparian - Grs	-0.259	0.072	-3.613	0.005
Mxd - Ban.pl	-0.298	0.085	-3.52	0.006
uncult. - Ban.pl	0.084	0.079	1.067	1
Riparian - Ban.pl	0.593	0.077	7.668	0.001
uncult. - Mxd	0.383	0.078	4.891	0.001
Riparian - Mxd	0.891	0.077	11.636	0.001
Riparian - uncult	0.508	0.07	7.258	0.001
Ground hunters				
Effects				
(Intercept)	-1.953	0.07	-27.833	0.001

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Table 4.A.9 – continued from previous page

	Estimate	Std. Error	z value	P-value
HabitatGrs	0.63	0.095	6.612	0.001
HabitatBan.pl	0.632	0.095	6.685	0.001
HabitatMxd	0.44	0.093	4.745	0.001
Habitatuncult.	0.106	0.095	1.116	0.265
HabitatRiparian	0.273	0.095	2.881	0.004
Linear hypotheses				
Grs - Paddy	0.63	0.095	6.612	0.001
Ban.pl - Paddy	0.632	0.095	6.685	0.001
Mxd - Paddy	0.44	0.093	4.745	0.001
uncult. - Paddy	0.106	0.095	1.116	1
Riparian - Paddy	0.273	0.095	2.881	0.059
Ban.pl - Grs	0.002	0.09	0.021	1
Mxd - Grs	-0.19	0.089	-2.141	0.484
uncult. - Grs	-0.523	0.091	-5.734	0.001
Riparian - Grs	-0.357	0.091	-3.935	0.001
Mxd - Ban.pl	-0.192	0.088	-2.183	0.435
uncult. - Ban.pl	-0.525	0.09	-5.805	0.001
Riparian - Ban.pl	-0.359	0.09	-3.991	0.001
uncult. - Mxd	-0.334	0.089	-3.763	0.003
Riparian - Mxd	-0.167	0.088	-1.898	0.865
Riparian - uncult	0.167	0.091	1.836	0.996
Ambush hunters				
Effects (Intercept)	-3.987	0.173	-23.037	0.001
HabitatGrs	1.065	0.21	5.063	0.001
HabitatBan.pl	-0.369	0.289	-1.278	0.201
HabitatMxd	1.364	0.197	6.942	0.001
Habitatuncult.	1.541	0.192	8.049	0.001
HabitatRiparian	1.938	0.188	10.317	0.001
Linear hypotheses				
Grs - Paddy	1.065	0.21	5.063	0.001
Ban.pl - Paddy	-0.369	0.289	-1.278	1
Mxd - Paddy	1.364	0.197	6.942	0.001
uncult. - Paddy	1.541	0.192	8.049	0.001
Riparian - Paddy	1.938	0.188	10.317	0.001
Ban.pl - Grs	-1.433	0.26	-5.514	0.001
Mxd - Grs	0.3	0.151	1.98	0.716

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Table 4.A.9 – continued from previous page

	Estimate	Std. Error	z value	P-value
uncult. - Grs	0.477	0.145	3.294	0.015
Riparian - Grs	0.873	0.14	6.244	0.001
Mxd - Ban.pl	1.733	0.249	6.961	0.001
uncult. - Ban.pl	1.91	0.245	7.796	0.001
Riparian - Ban.pl	2.307	0.242	9.526	0.001
uncult. - Mxd	0.177	0.124	1.431	1
Riparian - Mxd	0.574	0.118	4.855	0.001
Riparian - uncult	0.397	0.11	3.615	0.005

Table 4.A.10: Summary of generalised linear model fit to the relative species richness of Ambush hunters among different habitats of Muriyad Kol wetland landscape, including the multiple comparisons of means using Tukey contrasts.

	Estimate	Std. Error	z value	P-value
Space web weaver				
Effects				
(Intercept)	-2.164	0.133	-16.314	0.001
HabitatGrs	-0.447	0.2	-2.234	0.026
HabitatBan.pl	0.18	0.174	1.032	0.302
HabitatMxd	0.351	0.155	2.26	0.024
Habitatuncult.	0.322	0.153	2.107	0.035
HabitatRiparian	-0.315	0.169	-1.858	0.063
Linear hypotheses				
Grs - Paddy	-0.447	0.2	-2.234	0.383
Ban.pl - Paddy	0.18	0.174	1.032	1
Mxd - Paddy	0.351	0.155	2.26	0.358
uncult. - Paddy	0.322	0.153	2.107	0.527
Riparian - Paddy	-0.315	0.169	-1.858	0.948
Ban.pl - Grs	0.626	0.187	3.343	0.012
Mxd - Grs	0.797	0.17	4.693	0.001
uncult. - Grs	0.768	0.168	4.585	0.001
Riparian - Grs	0.132	0.183	0.721	1
Mxd - Ban.pl	0.171	0.139	1.233	1
uncult. - Ban.pl	0.142	0.136	1.045	1
Riparian - Ban.pl	-0.494	0.154	-3.203	0.02
uncult. - Mxd	-0.029	0.11	-0.263	1
Riparian - Mxd	-0.665	0.133	-5.018	0.001

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Table 4.A.10 – continued from previous page

	Estimate	Std. Error	z value	P-value
Riparian - uncult	-0.636	0.13	-4.91	0.001
Other hunters				
Effects				
(Intercept)	-0.789	0.087	-9.071	0.001
HabitatGrs	-0.006	0.119	-0.052	0.958
HabitatBan.pl	0.524	0.114	4.586	0.001
HabitatMxd	0.51	0.104	4.92	0.001
Habitatuncult.	0.391	0.102	3.835	0.001
HabitatRiparian	0.214	0.105	2.035	0.042
Linear hypotheses				
Grs - Paddy	-0.006	0.119	-0.052	1
Ban.pl - Paddy	0.524	0.114	4.586	0.001
Mxd - Paddy	0.51	0.104	4.92	0.001
uncult. - Paddy	0.391	0.102	3.835	0.002
Riparian - Paddy	0.214	0.105	2.035	0.627
Ban.pl - Grs	0.531	0.11	4.812	0.001
Mxd - Grs	0.517	0.099	5.206	0.001
uncult. - Grs	0.397	0.097	4.08	0.001
Riparian - Grs	0.22	0.1	2.188	0.431
Mxd - Ban.pl	-0.014	0.093	-0.151	1
uncult. - Ban.pl	-0.134	0.091	-1.469	1
Riparian - Ban.pl	-0.311	0.095	-3.287	0.015
uncult. - Mxd	-0.12	0.077	-1.548	1
Riparian - Mxd	-0.297	0.081	-3.647	0.004
Riparian - uncult	-0.177	0.079	-2.242	0.375
Orb weavers				
Effects				
(Intercept)	-0.245	0.081	-3.014	0.003
HabitatGrs	-0.121	0.112	-1.086	0.277
HabitatBan.pl	-0.719	0.116	-6.22	0.001
HabitatMxd	-0.924	0.105	-8.84	0.001
Habitatuncult.	-0.684	0.1	-6.869	0.001
HabitatRiparian	-0.322	0.1	-3.219	0.001
Linear hypotheses				
Grs - Paddy	-0.121	0.112	-1.086	1
Ban.pl - Paddy	-0.719	0.116	-6.22	0.001

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Table 4.A.10 – continued from previous page

	Estimate	Std. Error	z value	P-value
Mxd - Paddy	-0.924	0.105	-8.84	0.001
uncult. - Paddy	-0.684	0.1	-6.869	0.001
Riparian - Paddy	-0.322	0.1	-3.219	0.019
Ban.pl - Grs	-0.598	0.113	-5.311	0.001
Mxd - Grs	-0.803	0.101	-7.937	0.001
uncult. - Grs	-0.563	0.096	-5.861	0.001
Riparian - Grs	-0.201	0.097	-2.08	0.562
Mxd - Ban.pl	-0.205	0.105	-1.943	0.78
uncult. - Ban.pl	0.035	0.1	0.351	1
Riparian - Ban.pl	0.397	0.101	3.93	0.001
uncult. - Mxd	0.24	0.087	2.745	0.091
Riparian - Mxd	0.602	0.088	6.833	0.001
Riparian - uncult	0.362	0.082	4.404	0.001
Ground hunters				
Effects				
(Intercept)	-2.237	0.137	-16.379	0.001
HabitatGrs	0.49	0.173	2.831	0.005
HabitatBan.pl	0.458	0.172	2.659	0.008
HabitatMxd	0.393	0.159	2.471	0.013
Habitatuncult.	0.155	0.16	0.973	0.33
HabitatRiparian	0.169	0.163	1.038	0.299
Linear hypotheses				
Grs - Paddy	0.49	0.173	2.831	0.07
Ban.pl - Paddy	0.458	0.172	2.659	0.118
Mxd - Paddy	0.393	0.159	2.471	0.202
uncult. - Paddy	0.155	0.16	0.973	1
Riparian - Paddy	0.169	0.163	1.038	1
Ban.pl - Grs	-0.032	0.149	-0.217	1
Mxd - Grs	-0.097	0.134	-0.724	1
uncult. - Grs	-0.335	0.135	-2.485	0.194
Riparian - Grs	-0.321	0.139	-2.311	0.312
Mxd - Ban.pl	-0.065	0.133	-0.487	1
uncult. - Ban.pl	-0.302	0.133	-2.266	0.352
Riparian - Ban.pl	-0.288	0.137	-2.096	0.541
uncult. - Mxd	-0.238	0.116	-2.048	0.609
Riparian - Mxd	-0.224	0.121	-1.852	0.96

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Table 4.A.10 – continued from previous page

	Estimate	Std. Error	z value	P-value
Riparian - uncult	0.014	0.122	0.115	1
Ambush hunters				
Effects				
(Intercept)	-2.963	0.187	-15.881	0.001
HabitatGrs	0.26	0.243	1.069	0.285
HabitatBan.pl	-0.717	0.302	-2.375	0.018
HabitatMxd	0.128	0.223	0.574	0.566
Habitatuncult.	0.339	0.213	1.591	0.112
HabitatRiparian	0.633	0.211	2.994	0.003
Linear hypotheses				
Grs - Paddy	0.26	0.243	1.069	1
Ban.pl - Paddy	-0.717	0.302	-2.375	0.263
Mxd - Paddy	0.128	0.223	0.574	1
uncult. - Paddy	0.339	0.213	1.591	1
Riparian - Paddy	0.633	0.211	2.994	0.041
Ban.pl - Grs	-0.977	0.284	-3.44	0.009
Mxd - Grs	-0.132	0.198	-0.665	1
uncult. - Grs	0.08	0.187	0.426	1
Riparian - Grs	0.373	0.185	2.02	0.65
Mxd - Ban.pl	0.845	0.267	3.165	0.023
uncult. - Ban.pl	1.057	0.259	4.079	0.001
Riparian - Ban.pl	1.35	0.257	5.246	0.001
uncult. - Mxd	0.211	0.16	1.32	1
Riparian - Mxd	0.504	0.157	3.208	0.02
Riparian - uncult	0.293	0.143	2.049	0.607

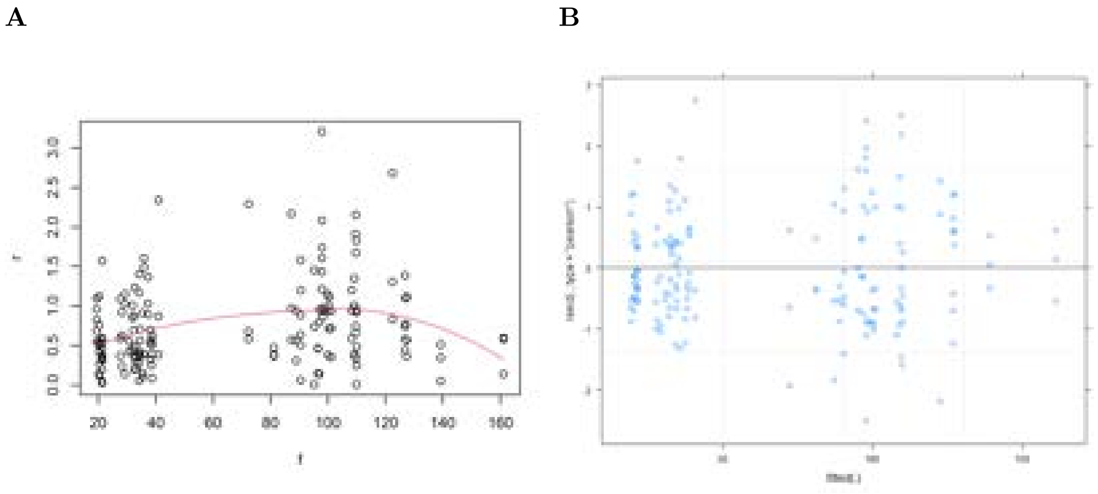

Figure 4.A.3: Diagnostic plots of Residuals and Pearson residuals to fitted values for generalized linear mixed model fit to estimated Shannon diversity of spiders collected from different habitats of Muriyad Kol wetlands.

Table 4.A.7: Abundance of guilds sampled from different habitats of Muriyad Kol wetland landscape

Guild	**Paddy**	**Grassland**	**Banana pl.**	**Mixed crops**	**Uncultivated**	**Riparian**
Ambush.hunters	34	74	19	124	162	212
Ground.hunters	232	305	316	331	277	292
Orb.Weavers	1013	618	361	349	521	677
Other.hunters	441	387	681	808	818	563
Sensing.web	3	0	2	23	44	19
Sheet.web	0	0	0	0	40	36
Space.webs	147	66	123	221	254	114
Specialists	0	0	2	0	7	0
Total	**1870**	**1450**	**1504**	**1856**	**2123**	**1913**

Table 4.A.8: Species richness of guilds sampled from different habitats of Muriyad Kol wetland landscape

Guild	**Paddy**	**Grassland**	**Banana**	**Mixed crops**	**Uncult.**	**Riparian**
Ambush.hunters	6	6	4	9	14	8
Ground.hunters	6	13	10	15	18	12
Orb.Weavers	25	33	25	37	44	49
Other.hunters	30	36	30	45	56	44
Sensing.web	1	0	2	2	6	1
Sheet.web	0	0	0	0	2	2
Space.webs	8	6	13	20	28	17
Specialists	0	0	1	0	3	0
Total	**76**	**94**	**85**	**128**	**171**	**133**

5 | Composition and Habitat Associations of Spiders

"There are no two species of indigenous spiders which occupy precisely the same position in nature's household."
–F. Dahl (1906) (cited by Wise 1993)

5.1 Introduction

5.1.1 Habitat heterogeneity and diversity

One of the fundamental principles of ecology is the associations between species and habitats. Understanding such associations accurately is important for conservation planing, policy and research, and it enables predicting which species are most likely to be effected if a particular habitat undergoes change (Redhead et al., 2016). Moreover, selecting appropriate indicator species for prioritising conservation sites or monitoring trends in habitat quality requires first assessing habitat relationships (Carignan & Villard, 2002).

Ecological studies on a landscape-scale that focuses on both local and regional mechanisms are important for understanding the factors driving community structure and species interactions (Holt, 1996; Levin, 2000). Comprehending the dynamics of species and communities in increasingly human-dominated landscapes requires understanding how landscape structure moderates their performance (Tscharntke et al., 2012). Processes acting at multiple spatial scales, typically much larger than the immediate local environment, influence population dynamics, community composition, and biotic interactions (Chase & Bengtsson, 2010).

According to the landscape species pool hypothesis, habitats with high structural heterogeneity and a wider area can be expected to include a greater proportion of the landscape's species pool. It will be important to compare different habitat types nested in different landscape contexts to see how local communities are selected from landscape-level species pools (Tscharntke et al., 2012). The current trend of drastic decline of semi-natural habitats in agricultural landscapes in densely populated state like Kerala, that potentially holds greater species richness, could constitute a severe danger to biodiversity. The richness of landscape-level species pools is threatened by continuous species losses in local communities inside habitat fragments.

Habitat heterogeneity have been shown to have a positive effect on species diversity in arthropods, birds, mammals, reptiles and amphibians (Tews et al., 2004). Small-scale architectural complexity also had significantly important role in groups such as arboreal arthropods, web spiders, grass hoppers and epigaeic beetles (Ávila et al., 2017, May; Halaj, 1996; Ross et al., 1998; Uetz, 1991). Keystone structures in the agricultural landscapes, in the form of distinct spatial structures providing resources, shelter or services crucial for other species, will maintain a high level of biodiversity whereas its removal will most likely lead to a breakdown in species diversity. The keystone structure concept, on the other hand, offers a way to incorporate biodiversity conservation into conventional land use (Tews et al., 2004).

5.1.2 Guild composition

Non-phylogenetic groups of species that share one or a number of resources are referred to as ecological guilds. In certain communities, they may have similar functional roles (Blondel, 2003; Cardoso, Pekár, et al., 2011). Guilds are useful in community comparison studies. Because it's impossible to study all the species in an ecosystem at the same time, guilds allow us to focus on specific groups with specific functional relationships. This is preferable to researching taxonomic groups, where different species may play different roles (Simberloff, 1991). Ecological guilds or functional groups studies can help researchers learn more about how assemblages respond to climate change, habitat disturbance, and management, among other things (Friedel, 1997). Spiders are considered to be a good indicator taxon to reflect ecological change, as they are indeed the main arthropod predators in many biomes and habitat types. The ability to describe spider diversity in terms of these groups allows researchers to gain a better understanding of how habitat differences may have influenced their life history strategies (Whitmore et al., 2002). Spiders can explore all parts of the crop, but they have certain niches because of their hunting behaviour. The classification of spiders into guilds is useful for studies of ecological change in all types of biomes and habitats (Cardoso, Pekár, et al., 2011). Their foraging strategy, prey range, vertical stratification, circadian activity, body size, and phenology are all used to classify them. The guild composition of a crop's spider fauna, as well as the level of damage by herbivores, may be determined by structural complexity (Young & Edwards, 1990). Sensing Web weavers, Sheet Web weavers, Space Web weavers, Orb Web weavers, Specialists, Ambush Hunters, Ground Hunters, and Other Hunters are the eight currently identified guilds (Cardoso, Pekár, et al., 2011).

5.1.3 Indicator species

The concept of indicator species has been frequently used in policies and regulations in order to monitor the ecological integrity of watersheds, lakes, semi-natural pastures, rangelands, and forests, as they provide a cost and time efficient mean to assess the impacts of environmental disturbances on an ecosystem (Cardoso, Rigal, et al., 2013, May 1; Carignan & Villard, 2002). A valuable indicator is supposed to posses some characteristics—provide early warning of natural responses to environmental impacts, directly indicate the cause of change rather than simply the existence of change, provide continuous assessment over a wide range and intensity of stresses, and are cost-effective to measure and can be accurately estimated by all personnel (Carignan & Villard, 2002). Indicators of ecological integrity can be found at many levels of organisation, including species, stands, landscapes, and ecosystems. Most indicator animals in agricultural landscapes are taxonomic or functional groups made up of several or more species, such as Lycosid spiders and predatory lady beetles (Tanaka, 2016). So, improving our understanding of the relationships between biodiversity and the delivery of ecosystem services is crucial for the development of sustainable agriculture.

Metrics of habitat association such as IndVal (Dufrene & Legendre, 1997) compare abundance or frequency of species between sites showing known differences in habitat. These rely on the location where the organism is recorded, accurately reflects the habitat with which it is associated. Spiders employ a wide range of foraging strategies and are differentially sensitive to changes in vegetation structure and disturbances (Barriga et al., 2010; Gibson et al., 1992; Uetz, 1991). But individuals, populations, and species are rarely restricted to only one type of habitat, and if the primary habitat is depleted or degraded, individuals, populations, and species may adapt their habitat affinities. Even where this does not occur, species may benefit from habitats other than the one that primarily determines their occurrence (Redhead et al., 2016). Also, the residence time of spiders is related to disturbance or web destruction, microhabitat features such as temperature or humidity, growth of the spider and a commensurate change in the structural requirements of web construction, and/or prey capture success (Bradley, 1993; Enders, 1977; Hodge, 1987; Lubin et al., 1993; Miyashita, 1994).

As in many tropical regions where intensification of agriculture is leading to severe environmental changes (Potapov et al., 2020), the Kol wetlands as well as most rice-growing areas in the state of Kerala are affected by the unnecessary and thoughtless use of pesticides and inorganic fertilizers. Unfortunately, rice agroecosystems in many areas of Kerala are in decline for a variety of reasons (Kumari, 2017). Over the decades, land use in Kol has changed significantly due to agriculture and infrastructure development. Due to lack of data, it is impossible to say how these changes are affecting the biodiversity of terrestrial arthropods such as spiders in the region.

The present study aims to elucidate the associations of spider assemblages to different habitats, namely paddy, grasslands, banana plantations, mixed crops, uncultivated land and riparian areas in the Muriyad Kol wetland landscape. In this study, I also present spiders that are potential indicators of these habitats in the wetland landscape. Future research on habitat-specific spider communities and their associations, as well as comparisons with other wetlands in the region, can benefit from this knowledge.

1. How does the species composition differ among different habitats in the wetland landscape?

2. How does the proportion of functional guilds differ among habitat types in the landscape?

5.2 Methodology

5.2.1 Statistical analysis

5.2.1.1 Sampling

This study uses the same dataset from the previous study (refer Chapter 4).

5.2.1.2 Species composition

Species composition was analysed using the Multivariate generalised linear model (MvGLM) using the mvabund package version 4.1.12 (Wang et al., 2021). It provides tools for model-based approach to the analysis of multivariate abundance data in ecology (Warton, 2011). Unlike univariate data ,which are routinely analysed by model based methods such as ANOVA, GLM and linear mixed models, multivariate data are mostly analysed by distance-based models. These methods including Correspondence Analysis (CA), Non-metric Multidimensional Scaling (NMDS) and Principal Coordinates Analysis (PCoA) (Jupke & Schäfer, 2020). Additionally, the confounding of location and dispersion effects are known to be plaguing distance-based methods (Warton et al., 2012). Even though there are a range of methods developed for detecting between-group effects, they fail to distinguish between location and dispersion effects. While methods were developed to find location effects (PERMANOVA, Anderson, 2001) and dispersion effects (Homogeneity of multivariate dispersions, Anderson, 2006), some additional undesirable properties were also reported (Warton et al., 2012). Even data transformation does not solve this problem and eventually mislead when one tries to identify taxa in which an effect is expressed. The data's statistical properties are taken into account when selecting a distance metrics. So, in the case of species abundances, it shows a quadratic mean-variance relationship (Routledge & Swartz, 1991; Yamamura, 1999). Appropriate distance metric for the data is selected depending on the properties of the data and the aim of study, because each metric extracts different information from the raw data. Model-based analysis is a good alternative to distance based approach as it accounts for mean-variance relationships and incorporates ecological assumptions (Jupke & Schäfer, 2020; Warton et al., 2012).

Multivariate generalized linear models take into account the marginal distributions and corresponding parameter, zero inflation, overdispersion, mean-variance relationships and correlation structure by specifying explicitly a statistical model of the process that generated the raw data. Additionally, a separate univariate GLM is fit to each taxon using the same predictors (Warton et al., 2012). Univariate GLMs can handle different residual distributions and mean-variance relationships (Warton, 2011). MvGLMs can effectively differentiate between the location (difference in mean) and dispersion (difference in mean–variance relationship) effects (Warton et al., 2012). Moreover, the GLM framework offers enhanced functionality than the similarity percentage method (SIMPER, Clarke, 1993). Fitting separate models to each taxon, then summing the test statistics, and using resampling to assess the significance of this multivariate test statistic, was used for testing the effect of differences in mean abundance between a set of multivariate samples (Warton, 2011). The 'sum-of-least ratio' statistics was used for testing the significance of the difference and p value calculated using 999 iterations via PIT-trap resampling.A pairwise likelihood ratio test of habitats was also performed, with adjustment for multiple comparisons via a free stepdown resampling procedure. The error distribution that explained the mean-variance relationships of abundances in the present study was negative binomial. Bayesian ordination (boral package, Hui, 2016; Hui, 2021) was used for model-based approach to unconstrained ordination, by fitting a pure latent variable model. The model used negative binomial distribution, additionally a site-level random effect was included to focus on community composition, and two latent variables to create a biplot analogous to non-metric multidimensional scaling (NMDS) plots. The package ggboral (Bedward, 2020) was employed to produce the biplots.

5.2.1.3 Guild composition

A guild can be defined as a group of species that exploit the same class of environmental resources in a similar way (Simberloff, 1991). The spider guilds were classified in the present study following Cardoso, Pekár, et al., 2011. GLMs with Binomial errors were used to compare the proportion of each hunting guild among habitats based on abundance and species richness, with habitat modelled as the factor. Space Web Weavers, Other Hunters, Ground Hunters, Ambush Hunters, and Orb Weavers each had their own GLMs computed. Sensing Web weavers, Sheet Web weavers, and Specialists were not modelled because of their low abundance and species richness, or because the groups contained too many zeros. To account for the multiple testing of the relative abundance and richness data, the confidence intervals were given a Bonferonni correction. (Dunn & Smyth, 2018). However, because the number of individuals and species were not evenly distributed among the five guilds, the confidence intervals used to determine statistical significance using the Bonferonni correction were not set to equal, but rather to the proportion of the data set that each guild composed. The confidence intervals to infer significance for the multiple models fit to relative abundance of spiders were: Ambush Hunters < 0.002, Space Web weavers < 0.004, Other Hunters < 0.017, Ground Hunters < 0.008 and Orb Weavers < 0.016; for the relative richness based multiple GLMs: Ambush Hunters < 0.003, Space Web weavers < 0.007, Other Hunters < 0.015, Ground Hunters < 0.004 and Orb Weavers < 0.016. A pairwise Tukey HSD test was conducted using ’glht’ function in the multicomp package version 1.4-18 (Hothorn et al., 2008).

5.2.1.4 Indicator species

Species diversity is a questionable measure when habitats of different productivity levels are compared even when the sampling efforts have been equal across sites. Representativeness or representative diversity is considered a more satisfactory criterion (Cousins, 1991; Webb, 1989). Indicator values measure the uniqueness of occurrences of species within a given vegetation type (Dufrene & Legendre, 1997). The ’indval’ function of the labdsv package version 2.0.1 (Roberts, 2019) was used to find indicator species and species assemblages characterizing groups of sites. The indicator value of species is defined as the product of the relative frequency and relative average abundance in clusters. The values lie between 0 and 1, a value of 1 represents a perfect indicator when all the individuals of a species are found in a single group of sites and occurs in all sites of that group (Dufrene & Legendre, 1997). The Monte Carlo randomisation approach with 4999 iterations is used to assess the relevance of each species’ indicator values. As a means of characterising spider habitat utilisation, this indicator values reflect species associations with each habitat category. In practise, the indicator value is a property of any single species that can be used to reduce the length of species lists that are regarded too extensive for practical purposes like monitoring or mapping (De Cáceres et al., 2012). The importance of an indicator variable’s rank order within a generally large species list is more essential in these circumstances than its magnitude (Wildi & Feldmeyer-Christe, 2013).

5.3 Results

5.3.1 Species composition

The results of the Multivariate generalised linear model (MvGLM) showed that there were significant differences in the species composition of spiders in the different habitats (LRT = 8460, P < 0.001). The model validation indicated no problems (Fig. 5.A.1). The residual vs. fitted value plots of the MvGLM showed no significant patterns and suggested the linearity of the relationship (Chapter 5). Pairwise analysis of deviance for the fit showed significant differences between habitats for all pairs ($p < 0.001$) in all pairs. Samples belonging to Grasslands and Paddy fields were significantly different from each other ($p < 0.001$), but

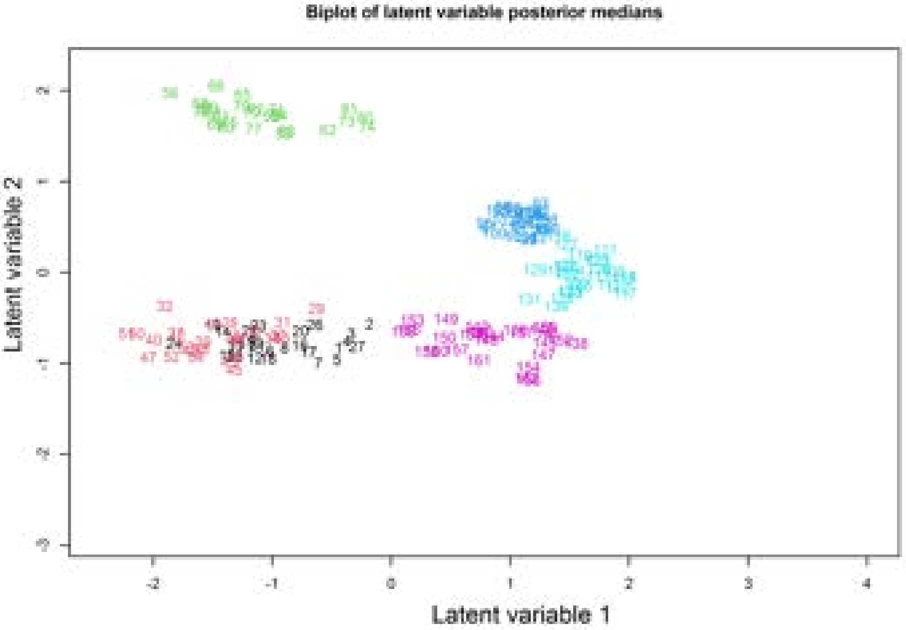

Figure 5.3.1: Unconstrained ordination of 162 spider samples based on the latent-variable method of the multivariate GLM model. The colours correspond to each of the six habitats studied and the numbers indicate the order of the samples: 1–27 Paddy fields, 28–54 Grasslands, 55–81 Banana plantations, 82–108 Mixed crops, 109–135 Uncultivated plots, 136–162 Riparian.

their assemblages were closer in species composition Fig. 5.3.1. Yet, there was considerable overalap in the clusters. There was greater separation in samples of Banana plantations from others in the biplot. As can be seen from the biplot, the samples representing Riparian habitats are closer to the sites belonging to Uncultivated and Grassland. The samples representing the Riparian, Uncultivated and Mixed crop habitats are close to each other, but without significant overlap. The biplot also shows that the samples within Mixed Crops and Uncultivated are similar in terms of species composition, as the points in both appear as clusters. The samples are more or less scattered in other groups. The Paddy and Grasslands samples are widely separated within the clusters, indicating differences in the species composition of the samples.

Table 5.3.1: Generalized Linear Model manyglm results (Deviation test statistic, p-value) of abundance of spiders ($p < 0.05$) sampled from six habitats at Muriyad Kol wetlands. Residual Df–156, Df–161. Full names of species as in Table 4.A.3

Species	**Test statistics**	**P-value**	**Species**	**Test statistics**	**P-value**
A.pectinifera	19.075	0.033	*Ep.tener*	59.397	0.001
An.maritatum	114.081	0.001	*Ep.triangulopalpis*	24.999	0.004
Ar.ellipticus	142.31	0.001	*Me.bivittatus*	38.931	0.001
Ar.viridisomus	38.513	0.001	*My.plataleoides*	51.946	0.001

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Table 5.3.1 – continued from previous page

Species	**Test statistics**	**P-value**	**Species**	**Test statistics**	**P-value**
Ar.mitificus	25.941	0.003	*My.* sp1	21.036	0.018
Arg.anasuja	41.464	0.001	*Pha.lancearius*	48.578	0.001
Arg.catenulata	155.802	0.001	*Phi.vittata*	34.253	0.001
Arg.pulchella	24.457	0.005	*Pl.paykulli*	34.109	0.001
C. sp1	32.013	0.001	*Por.fimbriata*	39.843	0.001
Cy.confraga	84.944	0.001	*Pt.* sp1	75.225	0.001
Cy.hexatuberculata	29.149	0.001	*Rh.flavigera*	83.649	0.001
Cyr.cicatrosa	159.097	0.001	*Si.semiglaucus*	41.191	0.001
Cyr.unicolor	31.133	0.001	*T.munnaricus*	78.178	0.001
Cyr.sundari	21.355	0.015	*Te.dimidiata*	59.319	0.001
E.laglaizei	41.944	0.001	*Salticid.sp1*	27.726	0.001
G.geminata	49.682	0.001	*Sc.fusca*	20.232	0.019
H.multipuncta	41.037	0.001	*Het.* sp.1	33.981	0.001
L.phthisica	160.47	0.001	*Het.venatoria*	60.417	0.001
L.tabida	69.452	0.001	*Ol.milleti*	172.872	0.001
N.bengalensis	20.957	0.018	*Th.moolampilliensis*	70.782	0.001
N.molemensis	46.279	0.001	*Gl.dentata*	163.371	0.001
N.mukerjei	72.808	0.001	*Le.decorata*	31.856	0.001
N.theisi	20.531	0.018	*Tet.cochinensis*	20.823	0.018
P.dehaani	46.454	0.001	*Tet.keyserlingi*	97.059	0.001
Po.nagpurensis	23.054	0.007	*Tet.viridorufa*	99.648	0.001
Cl. sp1	47.147	0.001	*Tet.javana*	223.614	0.001
Ca.zetes	62.096	0.001	*Tet.mandibulata*	23.879	0.006
Ch.danieli	55.848	0.001	*Tet.nitens*	52.427	0.001
S.sarasinorum	36.07	0.001	*Tet.squamata*	113.861	0.001
Gn.pauriensis	20.453	0.018	*Tet.ceylonica*	34.921	0.001
Z. sp1	36.893	0.001	*Tet.vermiformis*	31.149	0.001
Her.savignyi	97.445	0.001	*Ty.ventralis*	149.224	0.001
At..cirrifrons	101.214	0.001	*Ty.striata*	138.512	0.001
Na.crucifera	23.513	0.006	*Ay.flavescence*	28.184	0.001
Ne.macella	41.519	0.001	*Ay.kumadai*	45.296	0.001
At sp.1	25.669	0.003	*Ari.flagellum*	25.513	0.004
Er. sp.1	53.587	0.001	*Col.floridanum*	51.468	0.001
Hi.agelenoides	101.91	0.001	*Meo.picturata*	112.321	0.001
Pa.pseudoannulata	58.39	0.001	*Meo.multuma*	36.807	0.001
Pa. sp1	28.765	0.001	*Nes.flavipes*	24.79	0.004
Pa. sp2	127.165	0.001	*Ni.mundula*	83.896	0.001
W.fidelis	92.771	0.001	*Mo.trispinosa*	21.501	0.014
Ha.sikkimensis	61.658	0.001	*Par.* sp1	47.147	0.001
Ham.hellia	31.495	0.001	*Pho.septemaculeata*	23.202	0.006
Ox.birmanicus	50.34	0.001	*Phy.labialis*	70.023	0.001
Ox.javanus	95.583	0.001	*Chr.angula*	32.284	0.001
Ox.shweta	42.674	0.001	*Tw.margaritifera*	21.697	0.014
Pe.viridana	31.133	0.001	*Tr.odisha*	19.895	0.021
Cro.lyoni	27.178	0.003	*Tr.sp1*	83.128	0.001
Ph. sp1	62.012	0.001	*Td.sp1*	28.067	0.001
Ph. sp2	78.736	0.001	*Am.forticeps*	52.52	0.001
Sm.pallidus	32.651	0.001	*Cam.formosus*	34.282	0.001
Ps.planus	19.964	0.021	*Epi.parvati*	123.63	0.001
Phi. sp1	24.867	0.004	*Oxy.* sp1	207.464	0.001
Pi. sp1	70.874	0.001	*Ru.* sp1	107.936	0.001
As.tenuipes	68.33	0.001	*Tho.lobosus*	23.439	0.006
I.insularis	296.445	0.001	*Ut.fronto*	56.675	0.001
B.angulosus	60.195	0.001	*Mia.thwaitesi*	47.736	0.001

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Table 5.3.1 – continued from previous page

Species	Test statistics	P-value	Species	Test statistics	P-value
B.kolensis	233.73	0.001	*Ul.jabalpurensis*	53.982	0.001
Br.cingulatus	59.822	0.001	*Zo.geniculata*	59.271	0.001
Cha.pennata	167.697	0.001			

Many species showed significant associations with different habitats (Fig. 5.3.2 and table 5.3.1). The plates showing the contrast of species abundances with significant associations with different habitats given by the MvGLM is provided in Appendix 5.A.2. *Araneus ellipticus* was not only associated with Paddy fields and Grasslands, but also Riparian habitat (Dev = 142.31, $p < 0.001$). Abundance of *Argiope anasuja* (Dev = 41.464, $p < 0.001$) was greater in Paddy fields, but their abundance decreased in the Grasslands and Riparian habitat. Similarly, *Argiope catenulata* (Dev = 155.802, $p < 0.001$) were dominant in the Paddy fields and Grasslands. Another araneid that dominated these habitats was *Larinia phthisica* (Dev = 160.47, $p < 0.001$) and its abundance was also greater in the Riparian habitat. Linyphiids such as *Erigone bifurca, Atypena cirrifrons* and *Nasoona crucifera* (Dev = 101.214, $p < 0.001$; Dev = 101.214, $p < 0.001$; Dev = 23.513, p 0.006, respectively) had greater abundance in the Paddy fields. Among the Tetragnathids, *Tetragnatha cochinensis, T. javana T. mandibulata, T. nitens* and *T.keyserlingi* (Dev = 20.823, p 0.018; Dev = 223.614, $p < 0.001$; Dev = 23.879, p 0.006; Dev = 52.427, $p < 0.001$; Dev = 97.059, $p < 0.001$, respectively) showed significant association with Paddy fields. Some of these spiders such as *T. javana* and *T. mandibulata* were abundant in Grasslands. Salticids such as *Bianor angulosus* and *Bianor kolensis* (Dev = 60.195, $p < 0.001$; Dev = 233.73, $p < 0.001$, respectively) were abundant in Grasslands and Paddy fields. Also, *Meotipa multuma* and *Phycosoma labialis* (Dev = 36.807, $p < 0.001$; Dev = 70.023, $p < 0.001$, respectively) were among the most abundant Theridiids in these habitats.

Pardosa pseudoannulata was one of the most dominant species in many habitats in the study (Dev = 58.39, $p < 0.001$) and was most abundant in the paddy habitat. Others such as riparian, grasslands, banana plantations and uncultivated also had greater number of *P. pseudoannulata* in the samples. *Hippasa agelenoides, Tylorida ventralis* and *Runcinia* sp. (Dev = 101.91, $p < 0.001$; Dev = 149.224, $p < 0.001$; Dev = 107.936, $p < 0.001$ respectively) were abundant in grasslands. *Indopadilla insularis, Chalcotropis pennata, Cyrtophora cicatrosa, Cyrtophora citricola* and *Tamigalesus munnaricus* (Dev = 296.445, $p < 0.001$; Dev = 167.697, $p < 0.001$; Dev = 31.133, $p < 0.001$; Dev = 159.097, $p < 0.001$; Dev = 78.178, $p < 0.001$, respectively) were found to be associated with the banana plantations. *I. insularis*

Figure 5.3.2: Unconstrained ordination of the latent variables and their corresponding coefficients from the multivariate GLM fitted model on the abundance of spiders in the different habitats of the Muriyad Kol wetland landscape. The colours correspond to each of the six habitats studied and the numbers indicate the order of the samples: 1–27 Paddy fields, 28–54 Grasslands, 55–81 Banana plantations, 82–108 Mixed crops, 109–135 Uncultivated plots, 136–162 Riparian.

and *C. pennata* were also associated with Mixed crops habitat. Abundance of species like *Neoscona bengalensis, Meotipa picturata, Phintella vittata, Plexippus paykulli* and *Philodromus* sp. (Dev = 20.957 , p 0.018; Dev = 112.321, $p < 0.001$; Dev = 34.253, $p < 0.001$; Dev = 34.109, $p < 0.001$; Dev = 70.874, $p < 0.001$, respectively) increased in Mixed crops habitat. The abundance of *Castianeira zetes* (Dev = 62.096, $p < 0.001$) was greater in Uncultivated semi-natural habitats compared to banana plantations and mixed crops. *Cyclosa* spp. were abundant in the habitat, and *Cyrtarachne sundari* (Dev = 21.355, p 0.015) was found only in uncultivated and riparian habitats. *Tylorida ventralis* (Dev = 149.224, $p < 0.001$) numbers were higher in riparian than grasslands and banana plantations. *Tamigalesus munnaricus* was one of the dominant species in uncultivated semi-natural habitats.

5.3.2 Guild composition

Of the eighth guilds of spiders identified in the study, the most dominant was Other Hunters (3698 individuals, 35.51%), immediately followed by Orb Weavers (3539, 33.02%), Ground Hunters (1753, 16.35%), Space Web weavers (925, 8.63%, Ambush Hunters (625, 5.83%), Sensing Web (91, 0.85%), Sheet Web weavers (76, 0.71%) and Specialists (9. 0.08%).

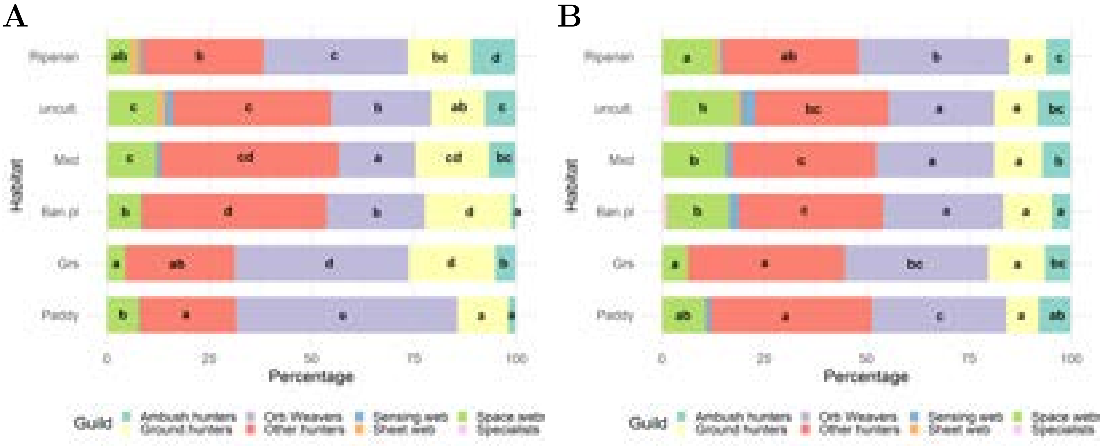

Figure 5.3.3: Guild composition of spiders in different habitats of Muriayd Kol wetland landscape. **A**, The relative abundance of individual spider guilds. **B**, The relative species richness of individual spider guilds. The letters indicate significance of post hoc Tukey test within each guild; where letters are different this indicates a significant difference (p < 0.05) in a guild's proportional abundance among the habitat types

The results of the type II Analysis of deviance performed on binomial GLMs fit to the relative abundance of Space Web weavers showed significant differences among the habitats (χ^2 = 112.92, Df = 5, $p < 0.001$), which is less than the Bonferroni corrected P values. The pairwise comparison of proportions of abundance of individual guilds is given in Fig. 5.3.3A. Habitats such as uncultivated and Mixed crop had greater proportion of abundances compared to other (GLM estimate= 0.514, $p < 0.001$ and GLM estimate= 0.473, $p < 0.001$ respectively) (Table 4.A.9 and Figs 5.3.3A).

The results of the type II Analysis of deviance performed on binomial GLMs fit to the relative abundance of Other Hunters showed significant differences among the habitats (χ^2 = 334.88, Df = 5, $p < 0.001$). The difference was driven by greater proportions in habitats such as banana plantation (GLM estimate= 0.989, $p < 0.001$), mixed crop (GLM estimate= 0.936 , $p < 0.001$) and uncultivated (GLM estimate= 0.779, $p < 0.001$) compared to other (Table 4.A.9 and Figs 5.3.3A).

The proportion of Orb Weavers was significantly different among habitats (χ^2 = 709.94, Df = 5, $p < 0.001$). The difference was driven by greater proportions in paddy fields (GLM estimate=0.171, $p < 0.001$) than grasslands (GLM estimate= -0.468, $p < 0.001$) (Table 4.A.9 and Figs 5.3.3A). Except for uncultivated and banana plantation, pairwise comparisons of habitats revealed significant differences in proportions of Orb Weavers in all pairs. The proportion of both Ground Hunters and Ambush Hunters were also significantly different among habitats (χ^2 = 82.292, Df = 5, $p < 0.001$; χ^2 = 258.86, Df = 5, $p < 0.001$ respectively). For ground Hunters, the difference was mostly driven by the greater proportion of individuals in banana plantation and grassland habitats (GLM estimate= 0.632, $p < 0.001$; GLM estimate= 0.63, $p < 0.001$ respectively) than other habitats. The Bonferroni adjusted Tukey test showed that the relative abundance of Ground Hunters among habitats such as riparian, uncultivated, mixed crops did not differ significantly. The proportion of Ambush Hunters associated with paddy was significantly lower than other habitats (GLM estimate= 0.63, $p < 0.001$). However, the association in banana plantations was not significant, although negatively associated with the intercept. The pairwise analysis showed that there were no significant difference in the relative abundance of Ambush Hunters between uncultivated and mixed crops, mixed and grasslands and paddy and banana plantations.

Sensing Web weavers were found in small numbers in uncultivated (44 individuals), mixed crops (23) and riparian (19) habitats, with only very few individuals found in paddy fields (3) and banana plantations (2). Sheet web weavers were found in relatively small abundance only in habitats with semi-natural conditions, such as uncultivated and riparian. Very few individuals of Specialists were found in uncultivated (7) and banana plantations (2).

The results of the type II Analysis of deviance performed on binomial GLMs fit to the relative species richness of Space Web weavers showed significant differences among the habitats ($\chi^2 = 51.432$, Df = 5, $p < 0.001$). The difference was driven by greater proportion in mixed crops and uncultivated (GLM estimate= 0.351, $p < 0.024$; GLM estimate= 0.322, $p < 0.035$) than other habitats, and significant lower proportions in grasslands (GLM estimate= 0.447, $p < 0.026$). The pairwise comparison showed significantly greater proportions of relative species richness of Space Web weavers among banana plantation, mixed crops and uncultivated than grassslands.

Similary, the proportions of Other Hunters and Ground Hunters were significantly different among habitats ($\chi^2 = 54.446$, Df = 5, $p < 0.001$; $\chi^2 = 16.806$, Df = 5, $p < 0.004$, respectively). For Other Hunters, it was driven by a greater proportion in banana plantation and mixed crops (GLM estimate= 0.52, $p < 0.001$; GLM estimate= 0.51, $p < 0.001$, respectively) than uncultivated (GLM estimate= 0.39, $p < 0.001$), followed by riparian (GLM estimate= 0.21, $p < 0.042$). The pairwise Bonferroni adjusted Tukey test showed that there was no significant difference in the proportion of relative species richness of Other Hunters between grassland and paddy habitat. However, it differed significantly from banana plantation, mixed crops and uncultivated habitats. The difference in the proprotion of Ground Hunters were driven by greater proportions in grasslands, bananna plantations and mixed crops (GLM estimate= 0.49, $p < 0.005$; GLM estimate= 0.46, $p < 0.008$; GLM estimate= 0.39, $p < 0.013$, respectively). The pairwise comparisons did not show any significant differences in the proportion of relative species richness of Ground Hunters between habitats (see Appendix Table 4.A.10).

The proportions of Orb weavers and Ambush Hunters were significantly different among habitats ($\chi^2 = 131.59$, Df = 5, $p < 0.001$; $\chi^2 = 40.095$, Df = 5, $p < 0.001$, respectively). In the case of Orb Weavers, the difference was driven by proportions in banana plantation, mixed crop, and uncultivated habitats (GLM estimate= 0.719, p 0.003; GLM estimate= 0.95, $p < 0.001$; GLM estimate= 0.68, $p < 0.001$, respectively). The relative species richness was significantly negatively associated in all habitats. However, paddy fields and riparian habitats (GLM estimate= 0.24, p 0.003; GLM estimate= 0.32, $p < 0.001$) had higher proportion relative species richness of Orb Weavers compared to others. For Ambush Hunters, the difference was driven by greater proportion in riparian (GLM estimate= 0.63, p 0.003); the proportion of species richness of the guild was negatively associated with banana plantation (GLM estimate= 0.72, p 0.018).

5.3.3 Indicator species

Table 5.3.2: Indicator values for spiders in relation to habitat types of Muriyad Kol wetlands. Indicator species analysis produces an indicator value between 0 and 1, with values closest to 1 signifying a good indicator (always present in a particular habitat).

Species	Paddy	Grassland	Banana	Mixed crops	Uncult. Plots	Riparian
He. sp1	.	.	.	.	0.11	.
A.pectinifera	.	.	.	.	0.18	.
An.maritatum	.	.	0.34	0.09	0.21	0.18
Ar.ellipticus	0.36	0.41	.	.	.	0.07
Ar.inustus	.	0.08	.	.	.	.
Ar.viridisomus	.	.	.	.	0.24	0.11
Ar.mitificus	.	.	.	0.08	0.12	.
Arg.aemula	0.1	.	.	.	.	.
Arg.anasuja	0.19	.	.	0.11	0.09	0.12
Arg.catenulata	0.69	0.19	.	.	.	.
Arg.pulchella	.	.	.	0.12	0.17	0.08
C. sp1	.	.	.	.	0.12	0.12
Cy.bifida	.	.	0.07	.	0.05	.
Cy.confraga	.	.	0.06	0.1	0.35	0.16
Cy.hexatuberculata	.	.	0.12	0.18	.	.
Cyr.cicatrosa	.	.	0.52	0.13	0.18	.
Cyr.unicolor	.	.	.	.	0.14	0.14
Cyr.sundari	.	.	.	.	0.17	.
E.laglaizei	.	0.05	0.15	0.12	0.21	0.09
E.excelsa	.	.	0.06	.	0.06	.
G.geminata	.	.	.	0.12	0.18	0.15
H.multipuncta	.	.	.	.	0.24	0.09
L.phthisica	0.14	0.52	.	.	.	0.18
L.tabida	.	0.31	.	.	.	0.16
N.bengalensis	.	.	.	0.15	0.07	.
N.molemensis	0.11	0.11	.	.	.	0.18
N.mukerjei	.	.	0.25	0.16	0.18	0.1
N.theisi	0.08	0.16	.	.	.	.
P.dehaani	.	.	.	.	0.37	0.06
Po.columnaris	.	.	.	.	.	0.07
Po.nagpurensis	.	.	.	.	0.24	.
Araneid. sp1	0.12	.	.	.	.	.
Araneid. sp2	.	0.05	.	.	0.08	.
Cl. sp1	.	.	0.34	0.16	.	0.1
Ca.zetes	.	0.09	0.13	0.21	0.3	0.15
Ch.danieli	.	0.08	0.05	0.28	0.24	0.18
S.sarasinorum	.	.	.	.	0.33	.
Gn.pauriensis	.	.	.	0.18	0.06	.
Gn. sp1	.	.	.	0.13	.	.
Z. sp1	.	.	.	0.14	0.16	0.1

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Table5.3.2 – (Continued) Indicator values for spiders in relation to habitat types.

Species	**Paddy**	**Grassland**	**Banana**	**Mixed crops**	**Uncult. Plots**	**Riparian**
Her.savignyi	.	.	.	0.2	0.3	0.17
O. sp1	.	.	.	.	0.13	.
Er.bifurca	0.15	.	.	.	.	.
At..cirrifrons	0.64	0.09	.	.	.	.
Na.crucifera	0.07	0.11	.	.	.	.
Ne.macella	.	.	.	.	0.36	.
At. sp.1	.	.	0.21	.	.	.
*Er.*sp2	.	.	.	0.18	0.24	.
Lin. sp4	.	.	.	.	0.15	.
Hi.agelenoides	.	0.62	.	.	.	0.06
Ly. sp1	0.13	.	0.15	0.07	.	.
Pa.pseudoannulata	0.2	0.17	0.22	0.16	0.07	0.17
Pa. sp1	0.06	0.11	.	.	0.13	.
Pa. sp2	.	.	0.29	0.3	0.22	.
W.fidelis	.	.	.	0.27	.	0.38
Ha.sikkimensis	.	.	.	0.12	0.37	0.07
Ham.hellia	.	.	.	0.28	0.07	.
Ox.birmanicus	.	0.12	.	0.17	0.13	0.13
Ox.javanus	0.25	0.25	.	0.1	0.15	0.15
Ox.shweta	.	.	.	0.09	0.33	0.07
Pe.viridana	.	.	.	.	0.14	0.14
Cro.lyoni	.	.	.	0.05	0.17	.
Ph. sp1	.	.	0.47	.	.	.
Ph. sp2	.	.	.	0.14	0.38	0.05
Sm.pallidus	.	.	.	0.34	.	.
Ps.planus	0.05	.	.	.	0.15	.
Phi. sp1	.	.	.	0.21	0.06	.
Sa. sp1	.	.	.	.	0.1	.
Pi. sp1	.	.	.	.	.	0.59
As.tenuipes	.	.	0.12	0.26	0.19	0.07
I.insularis	.	.	0.58	0.24	0.11	.
B.angulosus	0.31	0.12	.	.	.	.
B. sp1	0.57	0.41	.	.	.	.
Br.cingulatus	.	.	0.09	0.23	0.2	0.12
Car.viduus	.	0.1	.	0.08	0.1	0.17
Cha.pennata	.	.	0.33	0.38	0.15	.
Chi.thamannae	0.12	.	.	.	.	.
Coc.lacinia	.	.	.	.	0.07	.
Cu.tetrica	0.13	.	.	.	.	.
Ep. sp.	.	.	.	0.12	0.26	0.13
Ep.triangulopalpis	.	.	.	0.08	0.1	0.05
Epo.aurantiaca	.	.	.	.	0.14	.
Hy.semicupreous	0.08	0.08	.	0.19	0.15	0.13
In.chavarapater	.	.	.	.	0.15	.
Me.bivittatus	.	.	.	0.09	0.18	0.07
My.plataleoides	.	.	0.22	0.17	0.24	0.1
My.melanocephala	0.07	.	.	0.05	.	.
My. sp1	.	.	.	0.1	0.05	0.07
Pha.lancearius	.	.	.	0.15	0.13	0.14
Phi.vittata	.	.	0.05	0.23	0.19	0.12
Pl.paykulli	.	.	.	0.26	.	0.14
Por.fimbriata	.	.	0.13	0.14	0.11	0.15
Pt. sp1	.	.	0.45	0.08	.	.
Rh.flavigera	.	.	.	0.2	0.22	0.26

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Table5.3.2 – (Continued) Indicator values for spiders in relation to habitat types.

Species	**Paddy**	**Grassland**	**Banana**	**Mixed crops**	**Uncult. Plots**	**Riparian**
Si.semiglaucus	.	.	0.05	0.18	0.15	0.15
St.albus	0.05	.	.	.	0.05	.
Ste.aluva	.	.	.	.	0.07	.
T.munnaricus	.	.	0.27	0.09	0.19	.
Te.dimidiata	.	.	0.07	0.22	0.26	0.16
Maripanthus sp.	0.2	0.05	.	.	.	.
Thi. bhamoensis	.	.	.	.	0.05	0.07
Sc.fusca	.	0.05	0.1	.	.	.
Sc.thoracica	.	.	0.05	.	0.06	.
Het. sp.1	.	.	.	.	0.26	0.08
Het.venatoria	.	.	0.39	0.1	.	.
Ol.milleti	.	.	.	0.36	0.3	0.32
Th.moolampilliensis	.	.	.	0.12	0.25	0.28
Gl.dentata	0.8	0.07	.	.	.	.
Le.decorata	.	.	.	.	0.3	.
Tet.cochinensis	0.06	.	.	.	.	0.1
Tet.keyserlingi	0.58	.	.	.	.	0.07
Tet.viridorufa	.	0.08	.	0.17	0.18	0.39
Tet.javana	0.8	0.13	.	.	.	.
Tet.mandibulata	0.1	.	.	0.09	0.15	0.16
Tet.nitens	0.05	0.14	.	.	.	0.22
Tet.serra	.	0.08	.	.	.	.
Tet.squamata	.	0.46	.	.	.	0.28
Tet.ceylonica	.	.	.	0.36	.	.
Tet.vermiformis	0.05	.	.	.	0.16	0.16
Ty.ventralis	.	.	0.22	0.07	0.18	0.38
Ty.striata	0.59	0.16	.	.	.	0.05
Ty. sp.	.	.	.	.	.	0.08
Ay.flavescence	.	.	.	0.1	0.18	0.06
Ay.kumadai	.	.	.	0.23	0.11	0.05
Ari.flagellum	.	.	.	0.12	0.12	.
Chry.urbasae	.	.	.	.	0.07	.
Col.floridanum	0.34	0.08	.	0.05	0.13	.
Epis.affinis	.	.	.	.	0.19	.
Eu.episinoides	.	.	.	0.06	0.11	.
Meo.picturata	.	.	.	0.34	0.16	0.3
Meo.multuma	0.26	.	.	.	.	.
Ay. bonadea	.	.	.	.	0.07	.
Nes.flavipes	.	.	.	.	0.21	.
Ni.mundula	.	.	0.08	0.27	0.19	0.1
Mo.trispinosa	.	.	.	.	0.22	.
Par. sp1	.	.	0.32	0.06	.	.
Pho.septemaculeata	.	.	.	0.06	0.09	.
Phy.labialis	0.37	0.19	.	.	.	.
Pr.quadrangulata	.	.	.	.	0.11	.
Chr.angula	.	.	.	.	0.31	.
Tw.margaritifera	.	.	.	0.05	0.15	.
Tr.odisha	.	0.06	0.1	.	.	.
Tr. sp2	.	.	.	0.65	.	.
Tr. sp3	.	.	.	.	0.11	.
Td. sp1	0.14	0.08	.	.	.	.
Am.forticeps	.	.	0.05	.	0.28	0.16
Cam.formosus	.	.	.	0.06	0.15	0.1
Epi.parvati	.	.	.	.	.	0.81

Continued on next page

Table5.3.2 – (Continued) Indicator values for spiders in relation to habitat types.

Species	Paddy	Grassland	Banana	Mixed crops	Uncult. Plots	Riparian
Ind.minutus	.	.	.	.	0.07	.
Mas. sp.	.	.	.	.	0.08	.
Oxy. sp1	.	.	.	0.3	0.31	0.33
Ru. sp1	0.06	0.62	.	.	.	.
Tho.lobosus	0.05	0.05	.	0.2	0.11	0.17
Phr.tuberosa	.	.	.	.	0.07	.
Ut.fronto	.	.	.	0.06	0.19	0.28
Mia.thwaitesi	.	.	.	0.06	0.12	0.29
Ul.jabalpurensis	.	.	.	0.17	0.17	0.07
Zo.geniculata	.	.	0.24	.	0.08	0.14
Tro.kalami	.	.	.	.	0.07	.

Table 5.3.3: Spider species associated with habitat types of Muriyad Kol wetlands and its indicator values. Indicator species analysis produces an indicator value between 0 and 1, with values closest to 1 signifying a good indicator (always present in a particular habitat). $***$ indicates P value <0.001

Species	Family	Guild	Habitat	Indicator value
Argiope catenulata	Araneidae	Orb Weavers	Paddy	0.691***
Cyrtophora cicatrosa	Araneidae	Orb Weavers	Banana pl.	0.518***
Larinia phthisica	Araneidae	Orb Weavers	Grasslands	0.523***
Atypena cirrifrons	Linyphiidae	Other hunters	Paddy	0.638***
Hippasa agelenoides	Lycosidae	Ground hunters	Grasslands	0.617***
Pisaura sp.	Pisauridae	Sheet web	Riparian	0.593***
Indopadilla insularis	Salticidae	Other hunters	Banana pl.	0.58***
Bianor kolensis sp. nov.	Salticidae	Other hunters	Paddy	0.573***
Glenognatha dentata	Tetragnathidae	Orb Weavers	Paddy	0.802***
Tetragnatha keyserlingi	Tetragnathidae	Orb Weavers	Paddy	0.582***
Tetragnatha javana	Tetragnathidae	Orb Weavers	Paddy	0.8***
Tylorida striata	Tetragnathidae	Orb Weavers	Paddy	0.587***
Theridiid sp.2	Theridiidae	Space webs	Mixed crops	0.648***
Epidius parvati	Thomisidae	Ambush hunters	Riparian	0.811***
Runcinia sp	Thomisidae	Ambush hunters	Grasslands	0.621***

The indicator species analysis provided a compact list of species with significant associations with habitats (Table 5.3.2). There was an indication that most species with an indicator value > 0.1 was associated with uncultivated plots (82 species), followed by mixed crops (51), riparian (46), paddy (24), banana (23) and grassland (20) habitats. Indicator species with greatest significant associations with their habitats is provided in Table 5.A.1. A breakdown of the list showed that most species was associated with uncultivated plots (50 species), followed by mixed crops (25), paddy (20), banana plantations (14), riparian (13), and grasslands (8). However, only 15 species were found to have an indicator value greater than 0.5 among habitats (Table 5.3.3). Of these, 7 species were associated with Paddy fields, 3 species with grasslands, 2 species each with banana plantations and riparian areas, and one species with Mixed crop habitats. Among those species associated with paddy fields, five belonged to Orb weavers and the rest belonged to the Other hunter guild. One species each from Orb Weavers, Ground Hunters and Ambush hunter guilds was associated with the grasslands. While, one species each from Orb weaver and Other Hunters guilds were found in banana plantations. The indicator species in the riparian habitat belonged to the Sheet web and Ambush hunter guilds. In the mixed crops, however, the species was a Space web weaver. None of the significantly associated species in the analysis had indicator value greater than 0.5 for the uncultivated plots. *Glenognatha dentata* (0.80, indicator value) prefers the lower layers of the rice plant, especially between tillers, and grasses in the field in rice fields. It is found throughout the cropping season in the Muriyad Kol wetland. *Larinia phthisica* (0.523) and also *L. tabida* are often found in grasslands and prefer especially the upper layers of grasses and other vegetation. *Tetragnatha* species are good indicators for paddy fields, due to its body size and preference of adults for upper strata of paddy fields. *T. keyserlingi* (0.58)and *T. javana* (0.8) were identified as indicators in the analysis. Jumping spiders of the genus *Bianor* were common in the paddy fields, especially *B. kolensis* sp. nov. (0.57) and *B. angulosus* (< 0.5). Another jumping spider, *Indopadilla insularis* (0.58), is frequently found in foliages, especially common in banana plantations. *Runcinia* sp. (0.62) is abundant in grasslands and forage on low vegetation. In uncultivated, semi-natural habitats, there was no species with an indicator value of more than 0.5. However, species such as *Cyclosa confraga, Paravixia dehaani, Hamadruas sikkimensis, Neriene macella* and *Herennia multipuncta* had an indicator value of more than 0.4 in the uncultivated plots.

5.4 Discussion

5.4.1 Species composition

The results suggest that different habitats in the Muriyad Kol wetland support distinct species assemblages. Habitat heterogeneity may be the driving factor that led to different species composition in these habitats. However, the effects of habitat heterogeneity may vary considerably depending on what is perceived as a habitat by the species group studied. Structural attributes of the vegetation that constitute habitat heterogeneity for one group may be perceived as habitat fragmentation by another taxonomic group (Økland, 1996). At a regional scale, vegetation structure served as a primary habitat cue for spider assemblage. Spider assemblages choose habitats based on vegetation structure first, then microclimate.

Changes in vegetation structure are expected to aid changes in arthropod diversity and abundance. Because spiders rely heavily on arthropod prey, changes in the prey base are likely to limit the spider assemblage from the bottom up. (Billeter et al., 2007). The results suggest that the spider assemblages in the paddy fields and grasslands were distinct but had some degree of overlap. A similar pattern was also observed in the species composition of uncultivated mixed crop and riparian habitats. However, the banana plantations had a very different spider community composition compared to the other groups.

The grassland habitat in the study area serves as a refuge for predators such as spiders between croping seasons. Diverse natural or semi-natural habitats adjacent to cereal fields, as well as more complex landscape structure with comparatively undisturbed habitats, e.g. fallow fields, field margins or hedgerows, may provide refuges or source habitats for various species (Bianchi et al., 2006). Neighbouring habitats such as homegarden polycultures and banana monocultures were found to have little effect on rice spiders in the highlands of Wayanad, but increasing the proportion of fallow fields had a positive effect on ground web spiders such as Erigoninae (Betz & Tscharntke, 2017). Homegarden polycultures, mixed crops and banana monocultures are dominated by woody plants and may be inhabited by a spider assemblage that prefers woody habitats and does not spillover into open habitats such as the rice fields (Entling et al., 2007).

The results confirm that the uncultivated or unmanaged plots in the study area have a different composition of spiders than the open habitats such as paddy fields and grasslands. But as the results in the previous chapters show, there is also a greater abundance and diversity of spiders here compared to the other habitats in the landscape. Spider species in arable fields benefit from non-agricultural habitats in the surrounding landscape, but some arable species tend to decline when the landscape becomes too dominated by non-crop habitats. However, species richness of arable spiders has been shown to depend on heterogeneous landscapes with a high proportion of non-crop habitats (Schmidt et al., 2008). The integration of rice paddies into rice heterogeneous landscapes probably strengthens the biological control of pest species in rice fields by supporting high populations of spiders between cropping seasons (Radermacher et al., 2020).

5.4.2 Guild composition

The spider communities in the rice agroecosystem of the study area were composed of spiders belonging to the eight guilds. The paddy fields and grasslands in the study area were dominated by Orb weavers and Other hunters. A similar pattern of guild composition occurs in rice fields of the Kuttanad region of Vembanad-Kol wetland (Sudhikumar, 2007), and low-land and highland paddy fields of central Kerala (Sebastian et al., 2005). Orb weavers such as *Tetragnatha* species that erect horizontal webs on the canopy of vegetation in the habitats, require an open vegetation architecture so that they have plenty of substrates to attach their large webs (Hatley & Macmahon, 1980). Other Orb weavers like *Argiope* species create vertical webs at the sub canopy level in between hills of paddy plants. While species such as *Tylorida striata* forage with horizontal web in the lower strata of the plant. So there exists a clear and distinct niche differentiation and vertical stratification among the spiders of the same guild in a homogeneous paddy field. Guilds are most useful when species co-occur in space and time, and each hunting behaviour is best suited to a certain type of habitat structure (Hatley & Macmahon, 1980; Hawkins & MacMahon, 1989). In habitats such as riparian, Orb weavers and Other hunters were present in almost equal proportions in the community. Other hunters, on the other hand, formed a major proportion of the spider communities in banana plantations, mixed crop and uncultivated plots. Previous works have shown that Orb weavers dominated the semi-natural habitats of Kumarakom and Pathiramanal, followed by Other hunters and Space web weavers, Ground hunters and Ambushers (Jobi & Samson, 2014; Malamel & Sudhikumar, 2020). Predator guild distributions could be determined by natural variation in architecture and associated insect faunas of different plant species. The structure of a plant community is a key factor in the organisation of spider communities (Hatley & Macmahon, 1980). The guild and taxonomic compositions of predators potentially vary depending on the surrounding landscape and this has different consequences for pest control services (Baba et al., 2018). Also, shifts in spiders' guild composition can also be used to monitor the habitat change, to assess microclimate complexity (Brown, 2003; Downes et al., 1998).

The proportion of space web weavers were the highest in the mixed crop and uncultivated plots, which may be due to greater diversity of niches within the habitat ranging from shady areas, crevices in trees and barks, and thick undergrowth. Increase in canopy cover has a positive influence on spider guilds, and individual guilds exhibit different responses to increase in heterogeneity of the habitat (Baba et al., 2018). The most common explanation for observed patterns of spider guild structure are effects of the host-crop, including its structural diversity, micro-environment, or the level of disturbance (Luczak, 1979; Young & Edwards, 1990).

5.4.3 Indicator species

Indicator analysis has helped transform the long list of spiders into a more manageable list, which is particularly important for future monitoring and mapping purposes, especially for lay people and those with little taxonomic knowledge. For most practical purposes, it is always more desirable to have a short list of indicator species than a long checklist of all species in a habitat. This is because it has the potential to encourage local farmers, naturalists, and enthusiasts to engage in long-term monitoring efforts to conserve biodiversity and to help develop and disseminate environmentally friendly farming practices. The indicator species identified in this study could be used for future monitoring of spider populations and their dynamics in different crops and management practices in the study area. It is important to consider different non-crop habitats separately because some of them might be more important in an agricultural landscape than others, and their effects on various groups of organisms might be different. The advantage of indicator species analysis is that when any of the indicator species is found in a newly surveyed site, the site can be assigned to the site group used in the study. The more indicator species are found in the newly surveyed site, the higher the confidence (De Cáceres et al., 2012). However, in this study, all non-crop habitats were considered as a single group to simplify the study.

Spider communities have been known to contribute a higher percentage of significant positive indicator species for biological control than ground or rove beetle communities (Birkhofer et al., 2018, August 1). The semi-natural characteristics and the comparatively lower degree of disturbance in the uncultivated plots explain the greater number of indicator species. A non-crop canopy, dense vegetation, the presence of litter and dense undergrowth could have a positive effect on the number of indicator species. In contrast, open-habitats such as grasslands and paddy fields in the study area harboured fewer indicator species, accounting for only a quarter of the species found in the uncultivated plots. The dominant Tetragnathidae species appear to have considerable potential as biological indicators for rapid biodiversity assessment for distinguishing wetland habitats such as paddy fields, grasslands and riparian from other habitats. Because of similar habitat characteristics like vegetation density and canopy cover, habitats like mixed crops, uncultivated plots, and riparian share many indicator species, according to the analysis.

Indicator species analysis identify species that indicate different environmental conditions and anthropogenic stress levels in local habitats (Maelfait & Hendrickx, 1998). But abundant and functionally important species in many cases provide ecosystem services and this relationship is therefore crucial for the development of sustainable agriculture (Bastian, 2013; Duru et al., 2015). Exploring the relationship between ecosystem services such as provision of biological control, biodiversity of threatened species and crop yield on the one hand, and multiple taxon like spiders, beetles, flies, birds and certain plants, that reflect major trophic groups including predators, herbivores and autotrophs on the other, adds value to any future study. The abundance of individual species in local communities and the level of ecosystem services could therefore facilitate the management of ecosystem services by species conservation and provide better predictions of ecosystem service levels (Mokany et al., 2008). However, studies with multiple taxa are better suited to investigate the complex relationship between community changes and associated functions (Birkhofer et al., 2018, August 1). But any set of indicator species identified in such analysis is most likely valid for a given region and a follow-up research to assess the viability of potential indicators for future community monitoring projects is desirable. Once completed, these studies would prevent future tedious experiments and surveys to assess species diversity and pest management potential in the agricultural landscape.

5.5 Conclusion

The results of the study indicate that the species composition was different among various habitats in the wetland landscape. The study also shows that the sites belonging to paddy fields and grasslands had significantly different species composition, although they shared many of the species in their assemblages. Many species were found to be significantly associated with different habitats and a biplot of all these species with their habitat was produced in the study. It is believed that habitat heterogeneity may be the driving factor responsible for these differences in species composition. Studies on the composition of spider guilds also showed significant differences in their proportions between habitats, both in terms of relative abundance and relative species richness. Most of the observed patterns of spider guild composition are thought to be effects of host-crop characteristics such as vegetation structure, microenvironment, degree of disturbance, etc. In addition, as heterogeneity increases, individual guilds might respond differently. Knowledge of spider guild composition can be used as a tool to monitor habitat health and changes in that habitat.

The study also provided a reduced list of indicator species for each habitat that will be useful for future ecosystem monitoring or can be tested with additional sampling. Some species that are strongly associated with the habitats also had higher indicator values. Further research using indicator species in differently managed crop fields could help authorities and stakeholders easily access and monitor farmers' and companies' compliance with environmental regulations. Such monitoring will be more reliable if multiple taxa such as spiders, beetles, birds, flies, plants, etc. are included.

The study observed that the presence of fallow fields near to paddy fields serves as a refuge for spiders between cropping seasons. Similarly, the maintenance and preservation of natural or semi-natural habitats adjacent to crop fields may also serve as source habitat for various species. Given the current precarious situation in which the world is facing a drastic loss of biodiversity, policy makers and stakeholders are challenged to formulate strategies that encourage farmers to maintain complex landscape structures with comparatively undisturbed habitats on medium to large holdings. In addition, conserving distinct spatial structures or keystone structures in conventional agricultural landscapes, such as paddy fields in Kol wetlands, could be a way to encorporate biodiversity conversation. These structures not only support arthropod predators but also provide shelter and services crucial for other species such as birds, reptiles and various other animal and plant species. If no concrete steps are taken to protect fragments of semi-natural habitats, the continuous loss of species in local communities would lead to a drastic decline in richness of landscape level species pool. Future ecological research in such ecosystems should focus on mechanisms at both local and regional scales to understand the influences of factors such as climate change, habitat destruction, disturbance, management, etc. on community structure and species interactions.

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Appendix

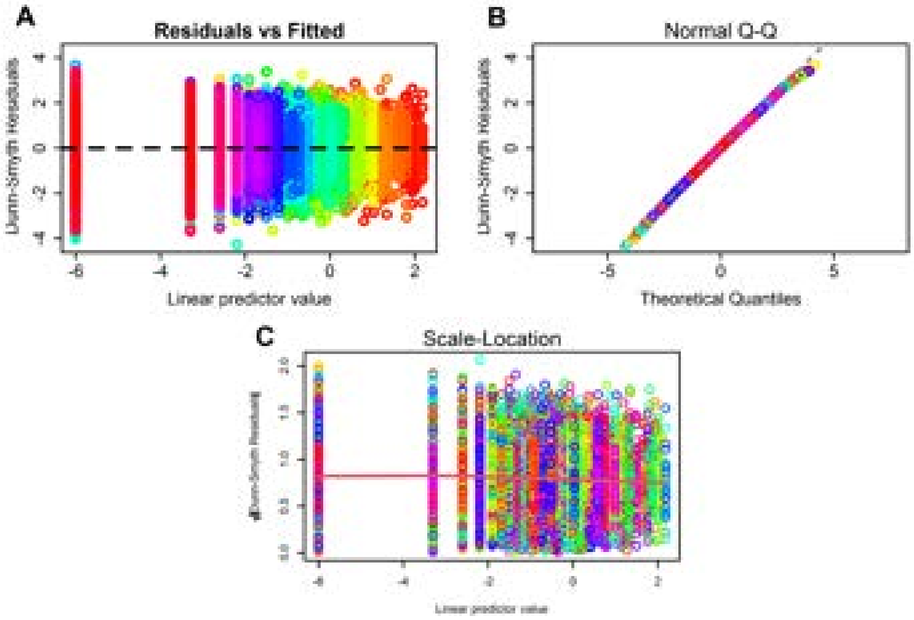

Figure 5.A.1: Diagnostic plots of multivariate GLM fit to abundances of spider assemblages in different habitats of Muriyad Kol wetland landscape: **A**, Residual vs. fits plot to check the quadratic mean–variance assumption of negative binomial regression (with different species coded in different colours). **B**, Normal Q-Q plot. **C**, Scale location plot.

Table 5.A.1: Spider species with maximum indicator values, associated habitat types and p–values. Indicator species analysis produces an indicator value between 0 and 1, with values closest to 1 signifying a good indicator (always present in a particular habitat). OW–Orb weaver, SW–Sheet web weavers, GH–Ground Hunters, S–Specialists, OH–Other Hunters, AH–Ambush Hunters.

Species	**Family**	**Guild**	**Habitat**	**Indicator value**	**P-value**
Heligmomerus sp.	Idiopidae	SW	Uncultivated	0.111	*0.032*
Annandaliella pectinifera	Theraphosidae	SW	Uncultivated	0.178	*0.001*
Anepsion maritatum	Araneidae	OW	Banana pl.	0.343	*0.001*
Araneus ellipticus	Araneidae	OW	Grasslands	0.406	*0.001*
Araneus viridisomus	Araneidae	OW	Uncultivated	0.242	*0.001*
Araneus mitificus	Araneidae	OW	Uncultivated	0.122	*0.027*
Argiope aemula	Araneidae	OW	Paddy	0.099	*0.026*
Argiope anasuja	Araneidae	OW	Paddy	0.188	*0.012*
Argiope catenulata	Araneidae	OW	Paddy	0.691	*0.001*
Argiope pulchella	Araneidae	OW	Uncultivated	0.173	*0.006*
Chorizopes sp.1	Araneidae	OW	Riparian	0.123	*0.045*

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Table5.A.1 – (Continued) Spiders associated with habitats types and their indicator values.

Species	**Family**	**Guild**	**Habitat**	**Indicator value**	***P-value***
Cyclosa confraga	Araneidae	OW	Uncultivated	0.353	*0.001*
Cyclosa hexatuberculata	Araneidae	OW	Mixed crops	0.183	*0.002*
Cyrtophora cicatrosa	Araneidae	OW	Banana pl.	0.518	*0.001*
Cyrtophora unicolor	Araneidae	OW	Uncultivated	0.139	*0.009*
Cyrtarachne sundari	Araneidae	OW	Uncultivated	0.173	*0.004*
Eriovixia laglaizei	Araneidae	OW	Uncultivated	0.206	*0.006*
Gasteracantha geminata	Araneidae	OW	Uncultivated	0.177	*0.007*
Herennia multipuncta	Araneidae	OW	Uncultivated	0.238	*0.001*
Larinia phthisica	Araneidae	OW	Grasslands	0.523	*0.001*
Larinia tabida	Araneidae	OW	Grasslands	0.311	*0.001*
Neoscona bengalensis	Araneidae	OW	Mixed crops	0.151	*0.011*
Neoscona molemensis	Araneidae	OW	Riparian	0.175	*0.004*
Neoscona mukerjei	Araneidae	OW	Banana pl.	0.252	*0.002*
Neoscona theisi	Araneidae	OW	Grasslands	0.161	*0.005*
Paravixia dehaani	Araneidae	OW	Uncultivated	0.37	*0.001*
Poltys nagpurensis	Araneidae	OW	Uncultivated	0.237	*0.001*
Araneid sp1	Araneidae	OW	Paddy	0.119	*0.018*
Clubiona sp1	Clubionidae	OH	Banana pl.	0.337	*0.001*
Castianeira zetes	Corinnidae	GH	Uncultivated	0.301	*0.001*
Cheiracanthium danieli	Miturgidae	OH	Mixed crops	0.279	*0.001*
Stegodyphus sarasinorum	Eresidae	SW	Uncultivated	0.333	*0.001*
Gnaphosa pauriensis	Gnaphosidae	GH	Mixed crops	0.184	*0.004*
Gnaphosa sp.	Gnaphosidae	GH	Mixed crops	0.132	*0.012*
Zelotes sp.	Gnaphosidae	GH	Uncultivated	0.156	*0.038*
Hersilia savignyi	Hersiliidae	SW	Uncultivated	0.301	*0.001*
Oedignatha sp.	Liocranidae	GH	Uncultivated	0.133	*0.006*
Erigone bifurca	Linyphiidae	OH	Paddy	0.147	*0.007*
Atypena cirrifrons	Linyphiidae	OH	Paddy	0.638	*0.001*
Nasoona crucifera	Linyphiidae	OH	Grasslands	0.111	*0.009*
Neriene macella	Linyphiidae	OH	Uncultivated	0.362	*0.001*
Atypena sp.	Linyphiidae	OH	Banana pl.	0.205	*0.001*
Erigone sp.	Linyphiidae	OH	Uncultivated	0.241	*0.001*
Linyphiid sp.	Linyphiidae	OH	Uncultivated	0.148	*0.007*
Hippasa agelenoides	Lycosidae	GH	Grasslands	0.617	*0.001*
Pardosa pseudoannulata	Lycosidae	GH	Banana pl.	0.217	*0.003*
Pardosa sp.1	Lycosidae	GH	Uncultivated	0.127	*0.047*
Pardosa sp.2	Lycosidae	GH	Mixed crops	0.305	*0.001*
Wadicosa fidelis	Lycosidae	GH	Riparian	0.376	*0.001*
Hamadruas sikkimensis	Oxyopidae	OH	Uncultivated	0.37	*0.001*
Hamataliwa hellia	Oxyopidae	OH	Mixed crops	0.278	*0.001*
Oxyopes birmanicus	Oxyopidae	OH	Mixed crops	0.167	*0.028*
Oxyopes javanus	Oxyopidae	OH	Paddy	0.249	*0.002*
Oxyopes shweta	Oxyopidae	OH	Uncultivated	0.326	*0.001*
Peucetia viridana	Oxyopidae	OH	Uncultivated	0.139	*0.014*
Crossopriza lyoni	Pholcidae	SW	Uncultivated	0.173	*0.003*
Pholcus sp.1	Pholcidae	SW	Banana pl.	0.474	*0.001*
Pholcid sp.2	Pholcidae	SW	Uncultivated	0.376	*0.001*
Smeringopus pallidus	Pholcidae	SW	Mixed crops	0.345	*0.001*
Psellonus planus	Philodromidae	GH	Uncultivated	0.149	*0.005*
Philodromid sp.	Philodromidae	GH	Mixed crops	0.211	*0.001*
Sarascelis sp.	Palpimanidae	S	Uncultivated	0.099	*0.043*
Pisaura sp.	Pisauridae	SW	Riparian	0.593	*0.001*
Asemonea tenuipes	Salticidae	OH	Mixed crops	0.259	*0.001*
Indopadilla insularis	Salticidae	OH	Banana pl.	0.58	*0.001*

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Table5.A.1 – (Continued) Spiders associated with habitats types and their indicator values.

Species	**Family**	**Guild**	**Habitat**	**Indicator value**	***P-value***
Bianor angulosus	Salticidae	OH	Paddy	0.309	*0.001*
Bianor kolensis	Salticidae	OH	Paddy	0.573	*0.001*
Brettus cingulatus	Salticidae	OH	Mixed crops	0.233	*0.001*
Chalcotropis pennata	Salticidae	OH	Mixed crops	0.384	*0.001*
Chinattus thamannae	Salticidae	OH	Paddy	0.12	*0.018*
Curubis tetrica	Salticidae	OH	Paddy	0.132	*0.009*
Epeus sp.	Salticidae	OH	Uncultivated	0.263	*0.001*
Epocilla aurantiaca	Salticidae	OH	Uncultivated	0.14	*0.01*
Indomarengo chavarapater	Salticidae	OH	Uncultivated	0.148	*0.003*
Menemerus bivittatus	Salticidae	OH	Uncultivated	0.181	*0.003*
Myrmaplata plataleoides	Salticidae	OH	Uncultivated	0.235	*0.001*
Phaeacius lancearius	Salticidae	OH	Mixed crops	0.152	*0.016*
Phintella vittata	Salticidae	OH	Mixed crops	0.226	*0.002*
Plexippus paykulli	Salticidae	OH	Mixed crops	0.256	*0.001*
Ptocasius sp.	Salticidae	OH	Banana pl.	0.455	*0.001*
Rhene flavigera	Salticidae	OH	Riparian	0.265	*0.001*
Siler semiglaucus	Salticidae	OH	Mixed crops	0.182	*0.011*
Tamigalesus munnaricus	Salticidae	OH	Banana pl.	0.275	*0.001*
Telemonia dimidiata	Salticidae	OH	Uncultivated	0.258	*0.001*
Chrysilla volupe	Salticidae	OH	Paddy	0.198	*0.001*
Heteropoda sp.1	Sparassidae	OH	Uncultivated	0.261	*0.001*
Heteropoda venatoria	Sparassidae	OH	Banana pl.	0.391	*0.001*
Olios milleti	Sparassidae	OH	Mixed crops	0.36	*0.001*
Thelcticopis moolampilliensis	Sparassidae	OH	Riparian	0.279	*0.001*
Glenognatha dentata	Tetragnathidae	OW	Paddy	0.802	*0.001*
Leucage decorata	Tetragnathidae	OW	Uncultivated	0.299	*0.001*
Tetragnatha keyserlingi	Tetragnathidae	OW	Paddy	0.582	*0.001*
Tetragnatha viridorufa	Tetragnathidae	OW	Riparian	0.385	*0.001*
Tetragnatha javana	Tetragnathidae	OW	Paddy	0.8	*0.001*
Tetragnatha nitens	Tetragnathidae	OW	Riparian	0.218	*0.001*
Tetragnatha squamata	Tetragnathidae	OW	Grasslands	0.457	*0.001*
Tetragnatha ceylonica	Tetragnathidae	OW	Mixed crops	0.356	*0.001*
Tetragnatha vermiformis	Tetragnathidae	OW	Uncultivated	0.157	*0.01*
Tylorida ventralis	Tetragnathidae	OW	Riparian	0.378	*0.001*
Tylorida striata	Tetragnathidae	OW	Paddy	0.587	*0.001*
Argyrodes flavescence	Theridiidae	SW	Uncultivated	0.176	*0.01*
Argyrodes kumadai	Theridiidae	SW	Mixed crops	0.232	*0.001*
Ariamnes flagellum	Theridiidae	SW	Mixed crops	0.125	*0.024*
Coleosoma floridanum	Theridiidae	SW	Paddy	0.342	*0.001*
Episinus affinis	Theridiidae	SW	Uncultivated	0.185	*0.001*
Euryopis episinoides	Theridiidae	SW	Uncultivated	0.113	*0.042*
Meotipa picturata	Theridiidae	SW	Mixed crops	0.345	*0.001*
Meotipa multuma	Theridiidae	SW	Paddy	0.265	*0.001*
Nesticodes flavipes	Theridiidae	SW	Uncultivated	0.207	*0.001*
Nihonhimea mundula	Theridiidae	SW	Mixed crops	0.269	*0.001*
Molione trispinosa	Theridiidae	SW	Uncultivated	0.222	*0.001*
Parasteatoda sp.	Theridiidae	SW	Banana pl.	0.321	*0.001*
Phycosoma labialis	Theridiidae	SW	Paddy	0.372	*0.001*
Propostira quadrangulata	Theridiidae	SW	Uncultivated	0.111	*0.035*
Chrysso angula	Theridiidae	SW	Uncultivated	0.31	*0.001*
Thwaitesia margaritifera	Theridiidae	SW	Uncultivated	0.151	*0.008*
Theridion odisha	Theridiidae	SW	Banana pl.	0.103	*0.032*
Theridiid sp.1	Theridiidae	SW	Mixed crops	0.648	*0.001*
Theridiid sp.2	Theridiidae	SW	Uncultivated	0.111	*0.027*

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Table5.A.1 – **(Continued) Spiders associated with habitats types and their indicator values.**

Species	**Family**	**Guild**	**Habitat**	**Indicator value**	***P-value***
Theridiosoma sp.	Theridiosomatidae	OW	Paddy	0.135	*0.028*
Amyciaea forticeps	Thomisidae	AH	Uncultivated	0.284	*0.001*
Camaricus formosus	Thomisidae	AH	Uncultivated	0.154	*0.009*
Epidius parvati	Thomisidae	AH	Riparian	0.811	*0.001*
Oxytate sp.	Thomisidae	AH	Riparian	0.328	*0.001*
Runcinia sp.	Thomisidae	AH	Grasslands	0.621	*0.001*
Thomisus lobosus	Thomisidae	AH	Mixed crops	0.196	*0.008*
Utivarachna fronto	Trachelidae	GH	Riparian	0.279	*0.001*
Miagrammopes thwaitesi	Uloboridae	OW	Riparian	0.289	*0.001*
Uloborus jabalpurensis	Uloboridae	OW	Uncultivated	0.173	*0.007*
Zosis geniculata	Uloboridae	OW	Banana pl.	0.244	*0.001*

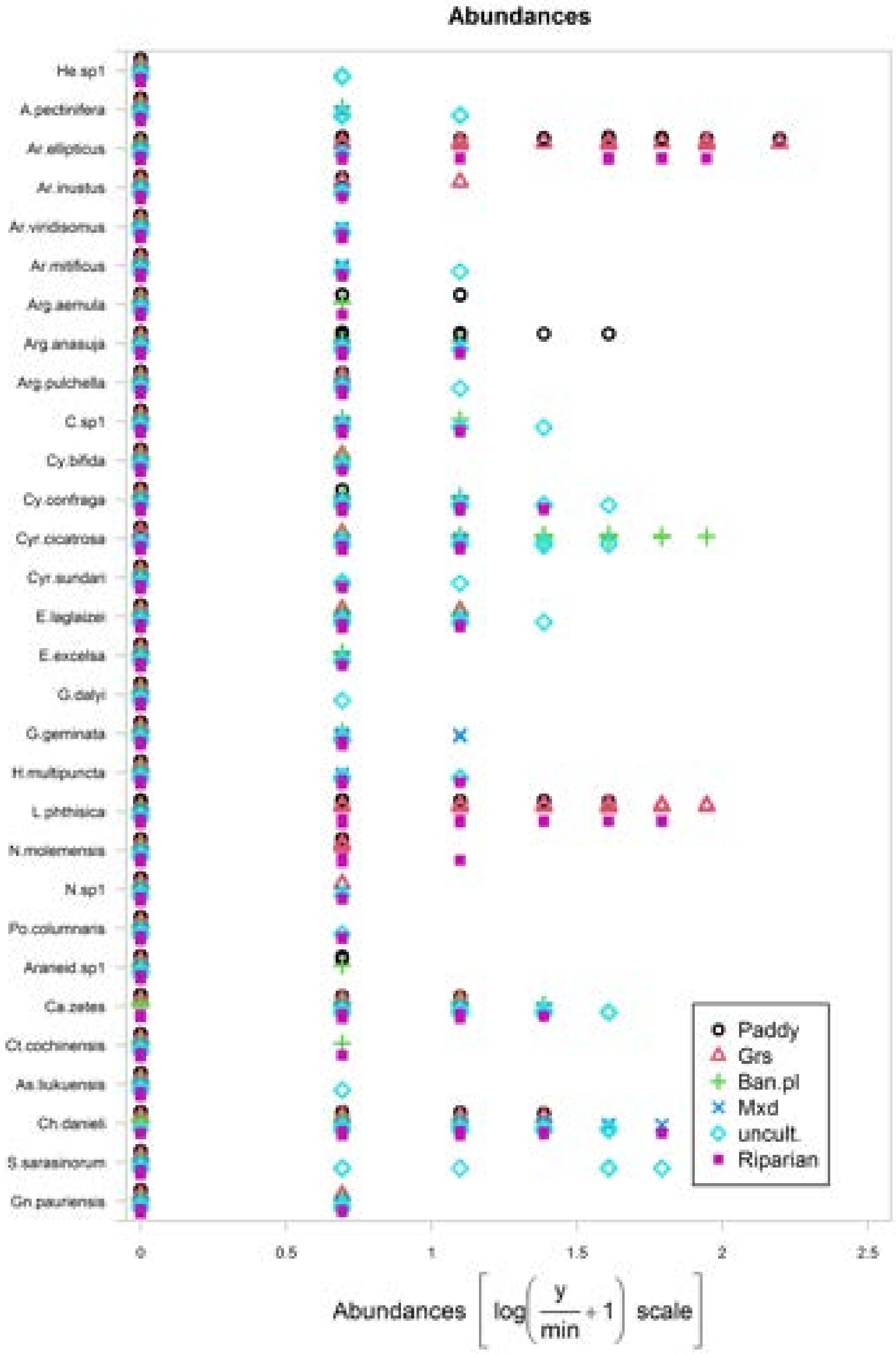

Figure 5.A.2: Contrast of spider abundances with significant association ($p < 0.05$) against habitat given by the multivariate GLM of spiders sampled at Muriyad Kol wetlands.

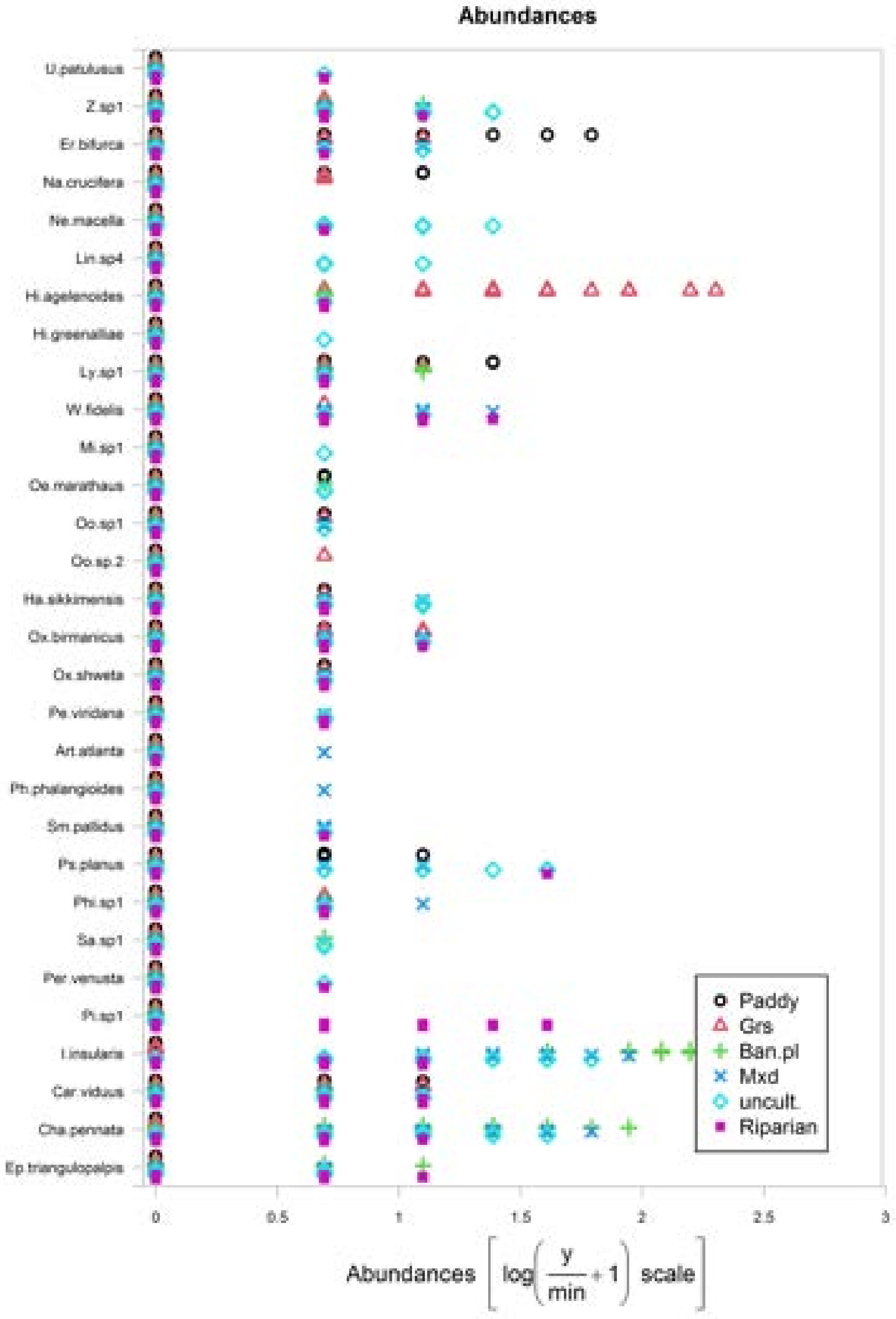

Figure 5.A.3: (Continued) Contrast of spider abundances with significant association ($p < 0.05$) against habitat given by the multivariate GLM of spiders sampled at Muriyad Kol wetlands.

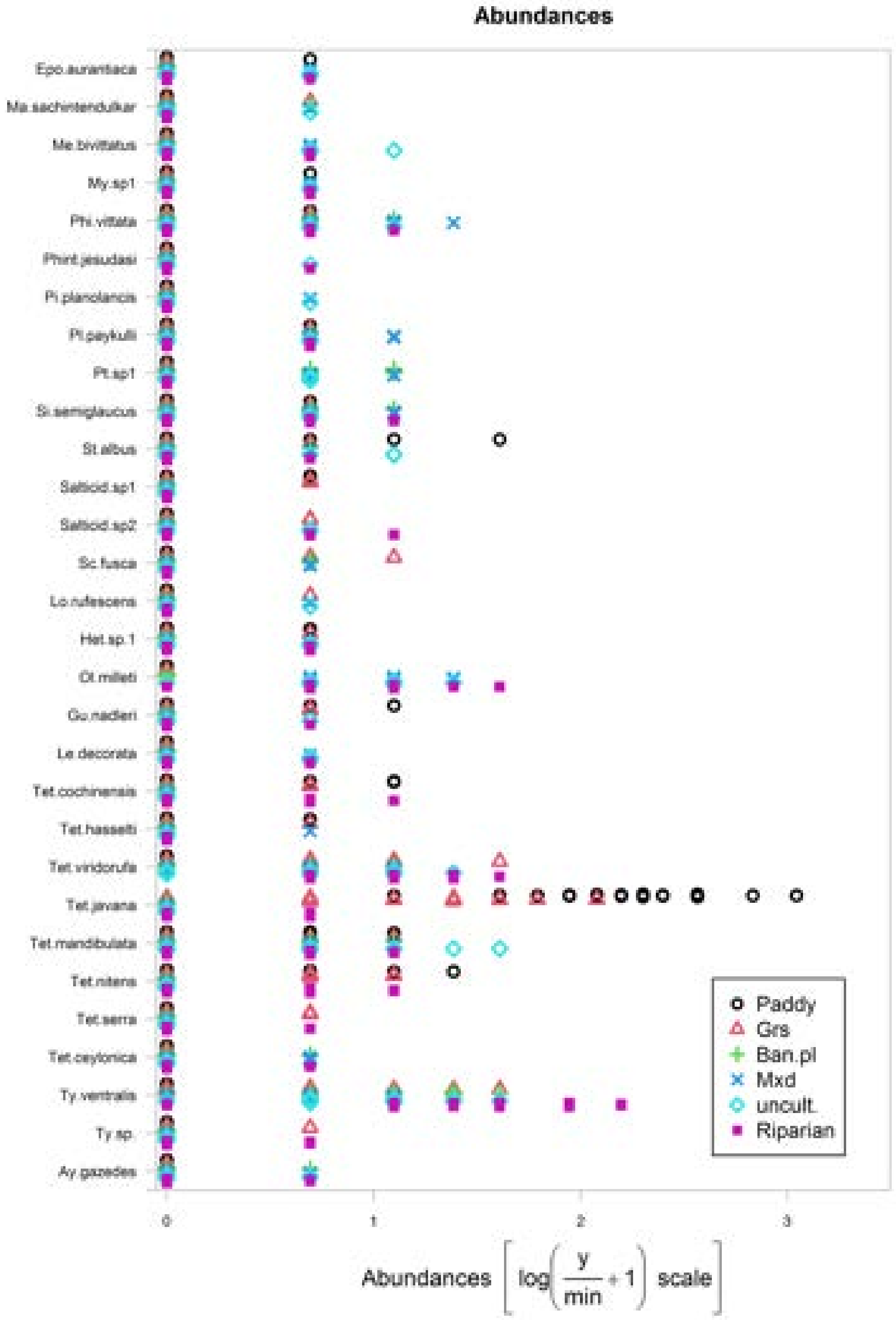

Figure 5.A.4: (Continued) Contrast of spider abundances with significant association ($p < 0.05$) against habitat given by the multivariate GLM of spiders sampled at Muriyad Kol wetlands.

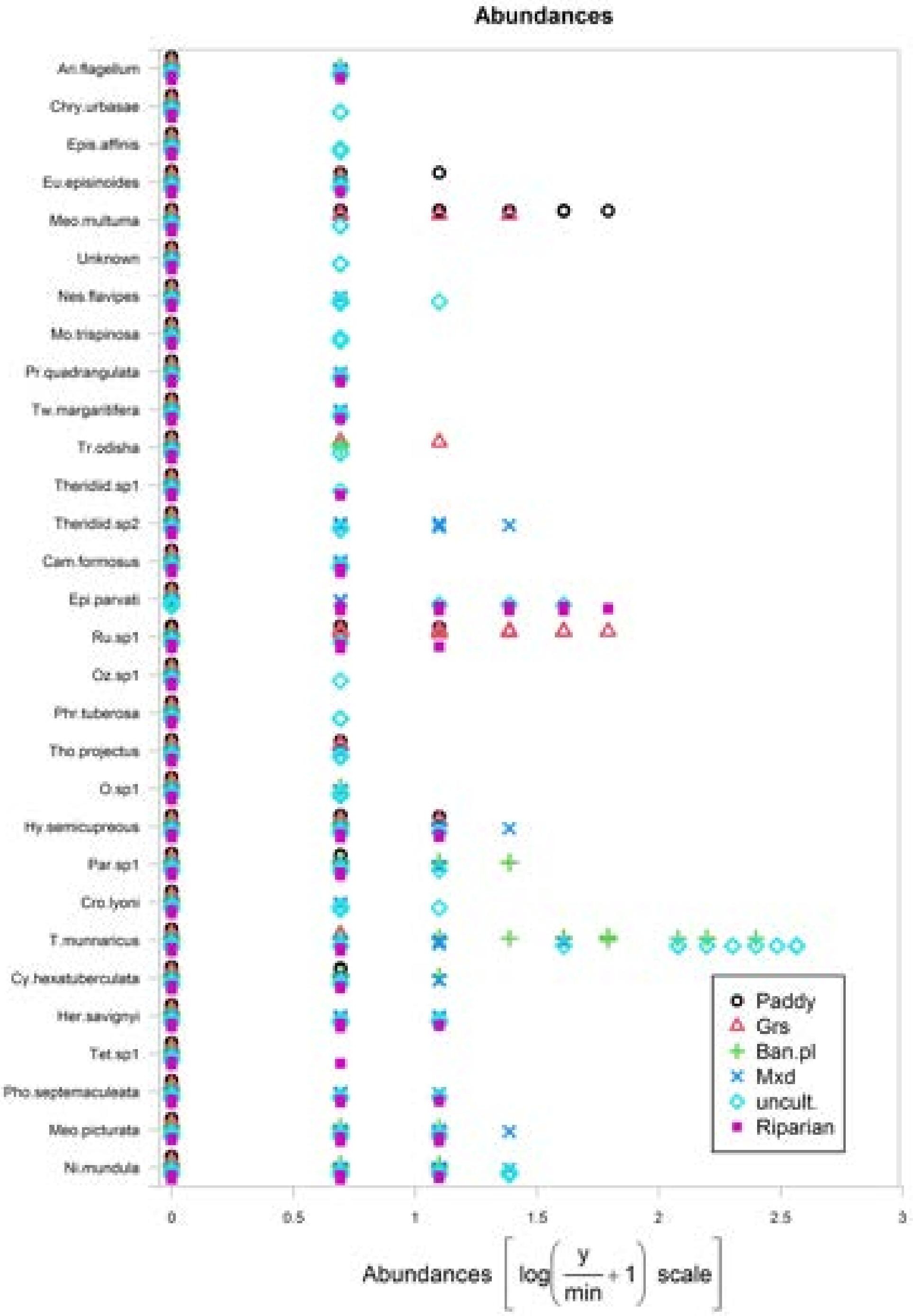

Figure 5.A.5: (Continued) Contrast of spider abundances with significant association ($p < 0.05$) against habitat given by the multivariate GLM of spiders sampled at Muriyad Kol wetlands.

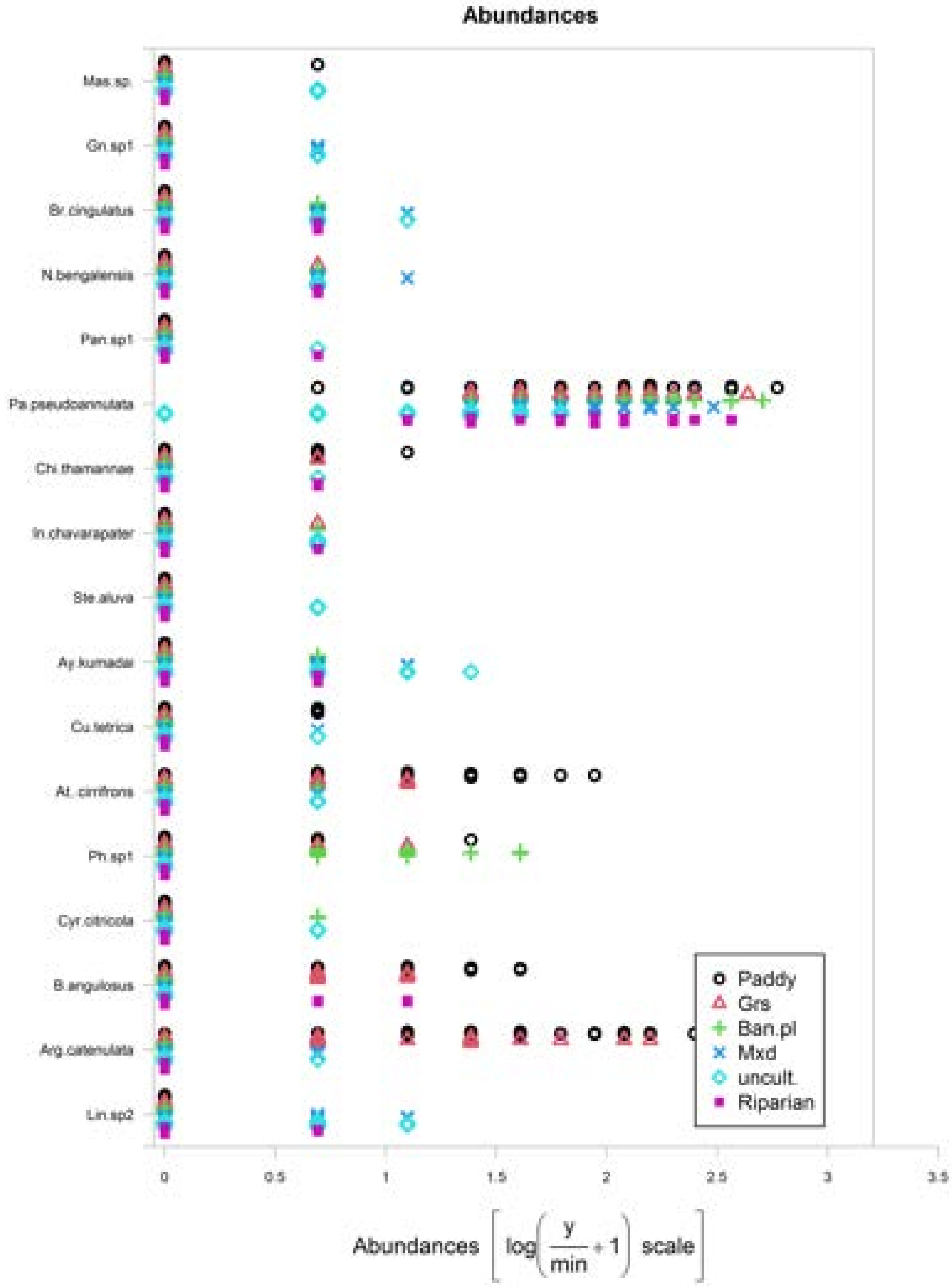

Figure 5.A.6: (Continued) Contrast of spider abundances with significant association ($p < 0.05$) against habitat given by the multivariate GLM of spiders sampled at Muriyad Kol wetlands.

6 Paddy Field Spiders: Turnover, Temporal Dynamics and Vertical Stratification

“We should preserve every scrap of biodiversity as priceless while we learn to use it and come to understand what it means to humanity.”
–E. O. Wilson

6.1 Introduction

Paddy receives special attention as the dominating crop in the wetlands. It represents an agricultural ecosystem of unrivalled ecological complexity, and even so as the arthropod species richness in many fields surpasses that of most temperate systems. In many rice-producing countries across the world, introduction of green revolution necessitated the use of a wide range of insecticides and herbicides in paddy fields to enhance yields, but at the expense of farmers health and biodiversity (Aronson et al., 2012; Mencher, 1991). But, widespread outbreaks of the brown plant hopper (*Nilaparvata lugens*), rice leaffolder (*Cnaphalocrocis medinalis* Güenée), small brown planthopper (*Laodelphax striatellus* Fallen), rice hispa (*Dicladispa armigera* Oliver), yellow stem borer (*Scirpophaga incertulas* L.) and white-backed planthopper (*Sogatella furcifera* Horvath) continue to cause losses worth millions of dollars every year (Chakravarthy et al., 2013; Sogawa, 2015). Insect pest outbreaks can be traced to the misuse of insecticides (Heong, 2009) and its use, especially during the early-season of cropping, reduces the population of natural enemies (Settle et al., 1996), Many techniques were developed to reduce usage of insecticides (Ali, Bari, Ahmed, et al., 2017; Ali, Bari, Haque, et al., 2019a;

Baba & Tanaka, 2016; Landis et al., 2000; Lee et al., 1993), but most farmers continue to use insecticides due to habit, as well as a variety of other causes such as misguided government policies and market pressures. Integrated Pest Management (IPM) and environmentally friendly farming have been shown to increase yield and reduce pesticide use (Ali, Bari, Ahmed, et al., 2017; Banerjee et al., 2015; Pretty & Bharucha, 2015; Tanwar et al., 2016). Moreover, green agriculture is one of the ways in which biodiversity can be protected (Pörtner et al., 2021; Ripple et al., 2017).

6.1.1 Spiders in paddy fields

Spiders are the most dominant group of predators in paddy fields, followed by Coleoptera, Hemiptera, Odonata, Diptera, Hymenoptera and Neuroptera (Chakraborty et al., 2016). Some paddy fields support a density of upto 90 individuals of spiders per m^2 (Hamamura, 1969). The number of studies on the relationship between the abundance or diversity of predators and their performance in pest control is rapidly increasing.

Many early season rice fields have species-rich, abundant, and well-distributed populations of generalist predators. Predator populations are nourished by insects that feed on debris and plankton, which subsequently develop into insect pests as the plants mature. The increase in organic matter in rice fields is indirectly linked to the population of natural enemies and has benefited spider populations (Settle et al., 1996). During the cropping season, the spiders first consumed insects emerging from the aquatic system and then gradually shifted to terrestrial plant and leafhopper diet later in the season, especially in rice-heterogeneous fields (Radermacher et al., 2020). Studies have shown that the population of spiders increases gradually as the crop attains full growth.

Earlier studies in central Kerala have recorded 94 species, 64 genera and 20 families in the Kuttanad (Sudhikumar et al., 2005), and 92 species from highland and lowland fields in central Kerala (Sebastian et al., 2005); whereas, Anis Joseph and Premila, 2016 reported 65 species of spiders belonging to 11 families from paddy fields in south Kerala. A comparatively smaller number of species have been reported from other states in India. For example, Singh and Singh, 2014 reported 58 species, 28 genera and 10 families of spiders were collected from the paddy fields of Uttar Pradesh in north India. Okuma, Lee, et al., 1978 recorded 21 species of spiders from the paddy fields of Suweon, Korea, and Barrion and Litsinger, 1984 document 51 species, 34 genera and 16 families from dry-land, rainfed wetland and irrigated wetland rice fields in the Philippines. Fifty-nine species of spiders belonging to 13 families were recorded from paddy fields in Sri Lanka (Bambaradeniya & Edirisinghe, 2001). Barrion and Litsinger, 1995 provided a comprehensive taxonomic overview of the spider fauna of the rice agroecosystems of South and Southeast Asia and recorded a total of 342 species, mainly from the Philippines. (Barrion, Villareal, et al., 2012) documented 167 species under 97 genera and 19 families of spiders from the rice agricultural landscapes of the Hainan island in China. Barrion, Zhu, et al., 2016 documented 38 species belonging to 11 families in fields of super hybrid rice in China. A recent review of various papers from 1972 to 1999 on Chinese rice paddy spiders shows the presence of no less than 375 species of spider (Yang et al., 2018). Hamamura, 1969 studied the seasonal fluctuation and diversity of spiders in Japan. (Okuma, Kamal, et al., 1993b) documented 55 species belonging to 36 genera and 10 families from the paddy fields of Bangladesh.

6.1.2 Guild composition

Spiders can explore all parts of the crop, but they have certain niches because of their hunting behaviour. The classification of spiders into guilds is useful for studies of ecological change in all types of biomes and habitats (Cardoso et al., 2011). Their foraging strategy, prey range, vertical stratification, circadian activity, body size, and phenology are all used to classify them. The guild composition of a crop's spider fauna, as well as the level of damage by herbivores, may be determined by structural complexity (Young & Edwards, 1990). Sensing Web weavers, Sheet Web weavers, Space Web weavers, Orb Web weavers, Specialists, Ambush Hunters, Ground Hunters, and Other Hunters are the eight currently identified guilds (Cardoso et al., 2011).

Three guilds of spiders are generally found in the rice ecosystem, namely the orb weavers, the hunting spiders and the space web spiders. The orb weavers belong to the families Araneidae and Tetragnathidae. Orb weavers belonging to *Tetragnatha, Araneus* and *Argiope* are the most common. The hunter's guild is dominated by spiders such as *Pardosa pseudoannulata*, while the space web spider guild includes the three families Theridiidae, Linyphiidae and Agelenidae (Chakraborty et al., 2016; Singh & Singh, 2014). A diverse assemblage of different spider functional groups should be effective in controlling a wide range of insect pests (Barrion, Zhu, et al., 2016).

6.1.3 Vertical stratification

The spatial arrangement of co-occurring spiders in a habitat usually reflects competition between individuals for profitable locations (Wise, 1993). Competition among conspecifics has also been shown to establish spatial structure within a colony (Salomon et al., 2010). For example, studies in *sericea lespedeza* fields have shown that immature *Argiope aurantia* and *Argiope trifasciata* place their webs to plants at different heights, but adults do not show vertical stratification (Enders, 1974). Even at small spatial scales, insect abundance, diversity and size vary with height above the ground, and this could be one of the driving factors in competition between spiders for sites (Basset et al., 2001). In some cases, the cohabitation of spiders of different sizes led to a modulation of web size at high densities, as the presence of large spiders with large webs caused smaller spiders to spin smaller webs (Leborgne & Pasquet, 1987). The structural complexity of foliage in the canopy and vegetation, such as foliage density and the number of leaves and branches, influenced the composition of spider species (De Souza & Martins, 2005; Gunnarsson, 1990; Halaj, 1996). Understanding predator-prey relationships requires research into the spatial distribution of predators and prey, as well as their interactions in paddy fields.

Murata and Tanaka, 2004 studied the spatial distribution of dominant spider species such as *Pardosa pseudoannulata, Tetragnatha keyserlingi, Clubiona kurilensis* Bösenberg & Strand, 1906 and dominant prey insects and found that there were differences in the vertical distribution of spiders and insects. Mathew et al., 2014; Sudhikumar, 2007 studied the vertical distribution of some of the dominant spiders of Kuttanad rice fields. Members of Araneidae and Tetragnathidae were found at the top layer, and reported that there was little chance of finding ground dwellers at the top level of the canopy.

This study investigates the diversity and temporal turnover of spiders in the paddy fields of Muriyad Kol wetland. The study investigates whether there are general and consistent patterns of spider community dynamics in the Virippu, Mundakan and Puncha cropping seasons in the rice fields of Muriyad Kol wetland. The following questions were asked:

1. Do crop growth, cropping season and management practises influence the abundance and richness of spider communities?

2. How does the proportion of guild composition of spiders vary among different cropping seasons?

3. Does the location of spiders on the rice plant change with the time of day?

6.2 Methodology

6.2.1 Sampling

6.2.1.1 Diversity and species turnover

Systematic sampling was done in the paddy fields of Muriyad Kol wetlands during each of the cropping seasons, namely, Virippu, mundakan and puncha, such that samples from various growth stages of the paddy plants were obtained. The study was carried out between December 2016 to May 2018. Four paddy plots grown during each season were identified and sampled at various growth stages of the crop. The sampling initiated at 25 Days after transplantation (DAT) when there was substantial growth in the paddy plants and continued at fixed intervals throughout the crop cycle till ripening. Thus, six samples at 25, 40, 55, 70, 85 and 100 DAT were obtained from each plot, covering the three main stages of crop growth: vegetative (tillering sub-stage), reproductive (flowering sub-stage) and ripening (maturity sub-stage). Altogether, it provided 72 samples representing the cropping seasons of the region. These included plots under conventional and organic management strategies followed in the wetlands.

For the analysis of temporal species turnover of spiders in paddy fields, samples collected from sampling plots L12A (Puncha), L7A (Virippu), L9A (Mundakan) were used. In all, 18 samples were used in the analysis covering all cropping seasons and successive DATs. These crops were grown under the conventional management practices.

Plots were divided into four (5 m×5 m) quadrates located at the corners and every quadrate was visually searched for signs of spiders, observed spiders were hand collected and recorded in the field note. The upper surface of the paddy crops in each of these quadrates was scanned for spiders and collected by hand. Five hills in each quadrate were thoroughly searched by slowly moving the tillers and spiders hence found were collected by hand or by aspiration method. Additionally, undisturbed paddy plants situated in the edges of the plots were gently agitated with a stick and dislodged spiders were collected in an inverted umbrella. The spiders moving about the weeds growing in the quadrates, such as grasses and sedges, were also collected.

6.2.1.2 Vertical stratification

The vertical stratification of selected spiders, namely *Oxyopes javanus* (Oxyopidae), *Pardosa pseudoannulata* (Lycosidae), *Bianor angulosus* (Salticidae), *Tylorida striata* (Tetragnathidae), *Tetragnatha javana* (Tetragnathidae) and *Araneus ellipticus* (Araneidae), on paddy plants was studied during the Puncha cropping season in the year 2017. The fully grown rice plants with an average height of 110 cm were sampled for spiders at each of the four zones (Zones A, B, C and D) on the basis of height (0-25, 25-50, 50-75, >75 cm) from the water/ground level twice a week. Spiders were collected at four time intervals, 0800-0900 hrs (designated as t1), 1300-1400 hrs (t2), 1700-1800 hrs (t3) and 2000-2100 hrs (t4). This was done to see if the position of the spiders changed in different time periods. Four rice fields were selected at sites L11 and L8. In each of these fields, four quadrats measuring 1 m×1 m were placed at the four corners of a field.The position of the spiders studied in the different zones of the plant was observed and recorded at each time interval. Care was taken not to agitate the plants during observation. Different plants were sampled for each zone to minimise disturbance of spiders in other zones when specimens were collected.

6.2.2 Statistical analysis

6.2.2.1 Diversity

Estimates of species Richness (the true diversity of order zero, $q = 0$) were provided by Chao1 estimator (Chao, 1984; Chao, Ma, et al., 2016). The estimates of Shannon and Simpson diversities were computed using iNEXT package version 2.0.20 (Chao, Gotelli, et al., 2014; Hsieh et al., 2020)by sample-size-based and coverage-based interpolation and extrapolation. The 95% confidence intervals defines the sampling variation for rarefied and extrapolated samples, constructed using 200 bootstrap replications, facilitating the comparisons of diversities across multiple assemblages (Chao & Chiu, 2016). In a Sample-size based rarefaction and extrapolation curve, the samples are all standardised to an equal size so that they provide useful sampling information for a range of sizes. But in a Coverage-based rarefaction and extrapolation, all samples are standardised to an equal coverage (or sample completeness) that it makes comparing samples of equal completeness over a range of completeness (Chao, Gotelli, et al., 2014). The diversity profile curve which plots the Hill numbers (q= 0, 1, 2) was ploted for each of the habitats studied using the SpadeR package Version 0.1.1 (Species Prediction And Diversity Estimation, Chao, Ma, et al., 2016).

6.2.2.2 Guild composition

The spider guilds were classified following Cardoso et al., 2011. GLMs with Binomial errors were used to compare the proportion of each hunting guild among habitats based on abundance, with cropping seasons modelled as the factor. Space Web Weavers, Other Hunters, Ground Hunters, Ambush Hunters, and Orb Weavers each had their own GLMs computed. Sensing Web weavers, Sheet Web weavers, and Specialists were not modelled because of their low abundance or absence. To account for the multiple testing of the relative abundance and richness data, the confidence intervals were given a Bonferonni correction. (Dunn & Smyth, 2018). However, because the number of individuals were not evenly distributed among the five guilds, the confidence intervals used to determine statistical significance using the Bonferonni correction were not set to equal, but rather to the proportion of the data set that each guild composed. The confidence intervals to infer significance for the multiple models fit to relative abundance of spiders were: Ambush Hunters < 0.001, Space Web weavers < 0.004, Other Hunters < 0.01, Ground Hunters < 0.006 and Orb Weavers < 0.02.

6.2.2.3 Effect of cropping season, crop growth and management practices on the abundance and richness of spiders

Abundance The effect of cropping seasons, crop growth and management practices on the abundance of spiders was analysed by implementing a generalized linear model (GLM) and type II Analysis of variance (ANOVA) of the fitted model using "car" package (Fox & Weisberg, 2019). The error distribution used in the GLM was negative binomial to account for the mean-variance relationships of the data at hand (O'Hara & Kotze, 2010). Cropping seasons (Virippu, Mundakan and Puncha), days after transplantation (DAT) and management practices (conventional and organic) were included as main effects in the model. Model selection of generalised linear models were based on comparisons of different models with Akaike Information Criterion (AIC). A least likelihood ratio test was performed to check goodness of fit between different models using lrtest function of the lmtest package version 0.9-37 (Zeileis & Hothorn, 2002). A model formula which included an interaction term between cropping season and management practices was selected as the best fit for the data. A type II ANOVA preserve the principle of marginality, where the main effects are tested in light of one another, but not considering the interaction term. The effects plot of cropping seasons and DAT, and coefficient plots of the model were displayed using the effects package Version

4.2-0 (Fox 2003) and sjPlot packages version 2.8.10 (Lüdecke, 2020) respectively. The assumptions of the model were tested by plotting the residuals against the fitted values and the normal Q-Q plots of the quantiles of the model. Post-hoc Tukey tests were used to make pairwise comparisons between groups after the GLM.

Richness The effect of cropping seasons, crop growth and management practices on the richness of spiders was analysed by implementing a generalized linear model (GLM) and type II Analysis of variance (ANOVA) of the fitted model using "car" package (Fox & Weisberg, 2019). The error distribution used in the GLM was negative binomial to account for the mean-variance relationships of the data at hand (O'Hara & Kotze, 2010). Cropping seasons (Virippu, Mundakan and Puncha), days after transplantation (DAT) and management practices (conventional and organic) were included as main effects in the model. The best fitted model did not have any interactions.

6.2.2.4 Turnover

Two basic approaches to assessing and evaluating differences in species composition are based on community data collected in space and over time. A single community can be compared to itself, or multiple treatment communities can be compared over time. Both methods are useful and provide complementary insights into the spatial and temporal dynamics of communities (Avolio et al., 2019). The temporal turnover of spiders in the paddy fields was analysed using the codyn package version2.0.5 (Hallett et al., 2020). The temporal diversity indices were calculated using functions available in the package which are analogous to traditional diversity indices. I investigated if the rate of change of community structure across the six DAT intervals shows a gradual or saltatory trajectory. For this, the total species turnover (tST) was calculated among the DAT intervals. It measures the proportion of total species richness lost and gained in a community from one DAT to another. In other words, it is measured as the proportion of species either gained or lost relative to the total number of species observed across both time periods. It ranges from 0 (no species gained or lost) to 1 (all species replaced), and even when the species richness remains constant the species turnover may differ. The total species turnover can be decomposed into two components: proportion of species gained ("appearances"or aST) and lost ("disappearances"or dST) (Cleland et al., 2013). Large changes in the species turnover from one growth interval (DAT) to next interval indicates an abrupt change in the community structure.

Second, mean shifts in species rank abundance were calculated. Mean rank shifts (MRS) are calculated as the average difference in species' ranks between consecutive time periods, among species that are present across the entire sampling intervals (Hallett et al., 2020). It is a measure of the relative change in species rank abundances, which indicates shifts in relative abundances over time (Collins, Suding, et al., 2008). In other words, it is the sum of species common to two sampling periods weighted for the relative rank abundance change that is displayed by the species. Larger values of MRS indicate higher amount of reshuffling in species ranks within a community. Being function of species richness in a community, MRS should be higher in more speciose communities.

I also analysed the values of richness change, evenness change and rank change between each DAT pair in each cropping season and when samples from three seasons were pooled. It is calculated as the difference in richness for a community between the two time periods divided by the total number of unique species in both time periods. When there is an increase in species richness over time, a positive value is obtained, and when there is a reduction in species richness over time, a negative value is obtained. Smith and Wilson's evenness index (E_{var}) was used to find the changes in evenness between communities found during various growth intervals. The index is based on the variance in abundance, which is calculated using log abundances obtained by examining the proportional differences between species (Smith & Wilson, 1996). It ranges from 0 to 1 with 0 indicating minimum evenness. Rank change is the absolute value of the average change in species ranks between two time periods divided by the total number of unique species in both periods.

Finally, the rate of directional change in the community composition was calculated. It is the slope of the difference in species composition within a community over increasing time intervals. It is characterised by Euclidean distances calculated on pair-wise communities across the entire data series, and these distance values are regressed against the time lag intervals (Collins, Micheli, et al., 2000). The slope is reported as an indication of the rate. I implemented linear regression for Euclidean distances as a function of square root of the time lag. I used regression analysis to summarise trends in temporal data sets, not to foresee or model temporal change statistically. A slope of zero indicates that there is stability in the community and that no change in community structure occurs with time. Significant positive and linear slopes indicates unstable communities with directional trajectories. Significant negative and linear slopes indicates unstable communities with convergent temporal trajectories (Collins, Micheli, et al., 2000).

6.2.2.5 Vertical stratification

A priori test for normality of data distribution was carried out using the Shapiro-Wilk test in order to determine the appropriate statistical test to subject data (i.e., parametric or non-parametric data analysis approach). The non-parametric approach was followed using the Zero-inflated negative binomial regression with the help of pscl package Version 1.5.5 (Jackman, 2020). A zero-inflated model assumes that zero outcome is due to two different processes. A binary model, usually a logit model, is used to model which of the two processes the zero outcome is associated with, and a count model, in this case a negative binomial model, is used to model the count process. The expected count is equal to the sum of the two processes (Zeileis, Kleiber, et al., 2008). Vuong test was used to compare standard negative binomial regression with zero-inflated negative binomial model, using MASS package Version 7.3-54 (Venables & Ripley, 2002). The model was fit to the number of individuals of 6 species (*Oxyopes javanus*, *Pardosa pseudoannulata*, *Bianor angulosus*, *Tylorida striata*, *Tetragnatha javana* and *Araneus ellipticus*) separately, with time (t1–t4) and zones (A–D) as the main effects, to model the count in the part of negative binomial model. The interaction term for species and zones was also included some of the formula. The variable zone was used to model the zeroes outcomes in the logit part of the model. In some cases, negative binomial GLM was implemented with data with negative binomial distribution. To check if our zero-inflated model is an improvement over a standard negative binomial regression, a Vuong test of the two models was done using Vuong function of pscl package. The non-nested Vuong test compares the predicted probabilities of two non-nested models. Also, Chi-squared test on the difference of log likelihoods was used to compare with null model. Model selection of generalised linear models were based on comparisons of different models with Akaike Information Criterion (AIC). A least likelihood ratio test was performed to check goodness of fit between poisson generalised linear model and negative binomial generalised linear models using lrtest function of the lmtest package version 0.9-37 (Zeileis & Hothorn, 2002).

6.3 Results

6.3.1 Diversity

This study resulted in the collection of 7804 (n = 72) individuals of spiders representing 89 species belonging to 17 families from the paddy fields of the Muriyad Kol wetlands. Table 6.3.1 provides the diversities and estimates of diversity of spiders in the paddy fields of Muriyad Kol wetlands. Virippu season with 1263 individuals recorded the lowest total abundance, while Puncha and Mundakan 1675 and 1610 individuals respectively. The same pattern followed in the case of mean abundance of spiders, wherein the abundance in Virippu season (52.62 ±25.21 individuals, ±SD) was lower than Mundakan (67.08 ±28.87 individuals) and Puncha (9.79 ±25.97 individuals) (Fig. 6.3.3A). This could be attributed to the effects of precipitation and waterlogging that is prevalent during the Virippu season which coincides with the monsoon season. The effect of various growth stages on the abundance of spiders is discussed in subsection 6.3.3.

Mundakan season had the lowest (60 species) observed species Richness ($q = 0$) from the pooled samples, and Virippu and Puncha reported 71 and 72 species respectively. The overall estimated species Richness provided by the Chao1 and First-order Jacknife estimators for this study were 105.18 ±9.75 and 107.73 ±5.68 species respectively. This value is higher than that is reported for paddy habitat in chapter 4 (Table 4.3.1). The reason for this increase might be due to the inclusion of samples from early development stages of paddy crops. Among the seasons, the estimated Richness in Puncha were 87.53 ±9.65 and 89.25 ±5.97 as computed by Chao1 and First-order Jacknife estimators respectively. It was expected to be 71.60 ±9.35 and 70.54 ±3.98 species in Mundakan, and 79.54 ±6.00 and 84.41 ±5.48 species in Virippu season. The mean Richness did not show substantial difference among the seasons. The mean Richness was around 20 species in all seasons (Table 6.3.1 and Figs 6.3.3B) However, the samples from 25 and 40 DAT had the lowest Richness (12 ±3.36 and 13 ±7.68 species respectively) as opposed to samples from 85 and 100 DAT (18 ±10.01 and 18 ±11.70 species respectively).

The estimated Shannon diversity ($q = 1$) form the overall poooled samples among the seasons was highest in the Virippu season (27.20 [27.21, 29.99], [95% confidence interval]), followed by Puncha (20.01 [21.509, 23.28]) and Mundakan (24.45 [23.78, 25.80]) seasons. The average estimated Shannon diversity was also highest (21.99 ±4.23, ±SE, species) in the Virippu and the lowest (17.99 ±2.6) in the Mundakan season. The samples from 25 DAT showed lowest (14.751 ±1.52, ±SE species) estimated Shannon diversity as compared to 100 DAT (19.35 ±6.17) samples. The estimated Simpson diversity ($q = 2$) form the overall pooled samples among the seasons was highest in the Virippu season (17.27 [17.05, 18.71], 95% confidence interval), followed by Puncha (15.55[15.42, 16.49]) and Mundakan (14.63 [14.51, 15.52]) seasons. The average estimated Simpson diversity was also highest (15.14 ±2.91 species) in the Virippu and the lowest (13.37 ±1.9) in the Mundakan season.

The percentage of rare species in the overall pooled sample was 41.67%, contributed by 19 singletons and 11 doubletons. The pooled samples from Mundakan seasons had the lowest percentage (25%) which showed 10 singletons and 5 doubletons. Virippu with 35.21% consisted of 14 singletons and 11 doubletons, and Puncha recorded the highest percentage of 37.5% with 17 singletons and 10 doubletons. The number of unique species was the highest (18 species) in Puncha, followed by Virippu (14 species) and Mundakan (11 species).

Figure 6.3.4 shows the observed Hill numbers and sample-size-based rarefaction and extrapolation plots with 95% confidence intervals for three sampling curves (Hill numbers of $q = 0, 1, 2$) up to base sample size of 2526 individuals. The base sample size was decided based on Chao, Gotelli, et al., 2014 and it was double highest minimum reference sample size (1263 individuals, Virippu season). At the minimum reference sample size of 1263 individuals (Virippu, 71 species) the rarefied species diversity of the Hill number $q = 0$ for the Mundakan and Puncha were estimated to be 57.53 [53.68, 61.39] and 66.82 [62.07, 71.58] respectively. However, the confidence interval for the Puncha and Virippu seasons overlapped, but the rarefied species diversity for Mundakan showed significant difference (except for very small sizes) from the others. When extrapolated to 2526 individuals, the species diversity was estimated at 64.33 [57.99, 70.68] for the Mundakan season, which was significantly lower than Virippu 78.05 [68.89, 87.21] and Puncha 78.49 [70.47, 86.51]. At a standardised sample size of 100 individuals, the rarefied species diversities were almost in the same range, with estimated values of 31.17 [29.84, 32.50], 26.03 [24.90, 27.16] and 27.99 [26.97, 29.02] species in Virippu, Mundakan and Puncha respectively.

The sample-size-based rarefaction and extrapolation curve for the Hill number $q = 1$ (Shannon diversity) showed significant difference (except for very small sizes) in the species diversity of Virippu (27.80 [26.03, 29.58]) from the others with no overlapping of the 95% confidence intervals. Mundakan adnd Puncha showed estimated species diversities of 21.72 [20.58, 22.85] and 24.04 [22.58, 25.50] respectively. At a standardised sample size of 100 individuals, the rarefied Shannon diversities were estimated to be 20.52 [19.45, 21.58], 17.00 [16.27, 17.73] and 18.25

Table 6.3.1: Estimates of diversity of spiders sampled during three cropping seasons of paddy at Muriyad Kol wetlands.

	Virippu	***Mundakan***	***Puncha***	**Overall**
Total individuals (number of samples)	1263 (24)	1610 (24)	1675 (24)	7804 (72)
Mean abundance, ±SD	52.62 ±25.21	67.08 ±28.87	69.79 ±25.97	63.17 ±27.42
Total observed Richness	71	60	72	89
Estimated Richness				
Chao1 estimator ±SE	79.54 ±6.00	71.60 ±9.35	87.53 ±9.65	105.18 ±9.75
First-order Jacknife estimator ±SE	84.41 ±5.48	70.54 ±3.98	89.25 ±5.97	107.73 ±5.68
Estimated Shannon diversity [95% confidence interval]	27.20 [27.21, 29.99]	20.01 [21.509, 23.28]	24.45 [23.78, 25.80]	24.85 [24.54, 25.74]
Estimated Simpson diversity	17.27 [17.05, 18.71]	14.63 [14.51, 15.52]	15.55[15.42, 16.49]	15.73 [15.68, 16.31]
Mean observed Richness	20.42 ±8.91	19.08 ±7.26	21.25 ±7.53	20.25 ±7.87
Average observed Shannon diversity,±SD	15.01 ±6.54	13.89 ±5.00	15.09 ±4.89	14.66 ±5.48
Average estimated Shannon diversity, ±SE	21.99 ±4.23	17.99 ±2.6	19.99 ±3.07	19.99 ±3.3
Average observed Simpson diversity,±SD	11.66 ±5.05	11.23 ±4.01	11.73 ±3.68	11.54 ±4.23
Average estimated Simpson diversity ±SE	15.14 ±2.91	13.37 ±1.9	14.01 ±2.14	14.17 ±2.32
Singletons	14	10	17	19
Doubletons	11	5	10	11
Unique species	14	11	18	19
Rare species %	35.21	25	37.5	41.67

[17.30, 19.20] species in Virippu, Mundakan and Puncha respectively. Similarly, in the case of Simpson diversity ($q = 2$), Virppu (17.15 [15.82, 18.49]) season remained significantly different (except for very small sizes) from Mundakan (14.55]13.65, 15.45]) and Puncha (15.46 [14.64, 16.29]). At a standardised sample size of 100 individuals, the rarefied Simpson diversities were estimated to be 14.85 [13.85, 15.85], 12.87 [12.20, 13.55] and 13.57 [12.93, 14.22] species in Virippu, Mundakan and Puncha respectively.

The sample coverages for the cropping seasons (Virippu, Mundakan and Puncha) were estimated as 98.9%, 99.4% and 99% respectively, indicating that sampling was nearly complete in samples from all seasons. Fig. 6.3.5A shows that the curves for all the seasons overlap and there seems to be no significant difference in the coverage between them. For any fixed sample size of 100 individuals,the sample coverage was less than 90% for all seasons.

Fig. 6.3.5B shows the coverage based interpolation and extrapolation curve for the Hill number $q = 0$ when the coverage is extrapolated to the value for a doubling of the minimum reference sample size. When extrapolated, the sample coverage only increased very slightly for all seasons. The minimum value of the coverage based curve of these doubled sample sizes among the seasons was 99.8% (Virippu), compared to Mundakan (99.6%) and Puncha (99.4%). Like the sample-based curves, the confidence intervals of the Mundakan showed no overlap except in lower values. Interestingly, it showed clear separation in the confidence intervals between all the seasons between 80% and 90% coverage values among the seasons (Virippu, Mundakan and Puncha).

The mean number of species present in each DAT studied did not show much differences among the seasons, Virippu, Mundakan and Puncha with 35.5, 40.5 and 40.66 species respectively. Families Araneidae (719 individuals, n= 72), Linyphiidae (184), Lycosidae (595), Oxyopidae (280), Salticidae (508), Tetragnathidae (1622) and Theridiidae (368) dominated the community of spiders in the paddy fields.

Most collected species in the Araneidae were *Araneus ellipticus*, *Argiope catanulata*, *Argiope anasuja*, *Larinia phthisica* and *Neoscona theisi.* Of these, *Araneus ellipticus* and *Argiope catanulata* were among the most dominant species in the community, with mean abundance of 28.5 ±15.26 (±SD) and 55.33 ±30.25 respectively. *Argiope catanulata* had the highest (23.83 ±13.60) abundance in the puncha, where as *Araneus ellipticus* dominated in the Mundakan with a mean abundance 13.83 ±7.02.

Linyphiidae in the commuunity was dominated by *Erigone bifurca* and *Atypena cirrifrons* with a mean abundance of 7.5±2.42 and 23.16 ±8.88 individuals respectively. The former had higher (9.66 ±5.57) mean abundance in the Mundakan and the lowest (5.83 ±1.83)in the Virippu, while the latter showed up most (3.50 ±2.50) in the Mundakan and least (1.83 ±0.98) in the Puncha season.

Lycosidae was mostly represented by *Pardosa pseudoannulata* with a mean value of 89.5 ±20.06 individuals in the community among each cropping seasons. They are primarily ground spiders, but they usually exhibit vertical migration in the paddy plants during night hours. *P. pseudoannulata* was one of the most abundant (537 individuals) species of any family in the community of spiders in the paddy fields. Mean abundance were greater than 25 individuals in all cropping seasons.

Oxyopes javanus was the most abundantly (273 individuals) found Oxyopid species in the spider community of paddy fields, with a mean abundance of 45.5 individuals. Mundakan season showed highest (18 ±5.72) abundance values followed by Puncha (15 ±4.69) and Virippu (12 ±3.93).

Salticidae in the community was dominated by species such as *Bianor angulosus*, *Bianor kolensis* sp. nov., *Hyllus semicupreus* and *Myrmarachne melanocephala* and they accounted for 399 individuals in the community. *Bianor* spp. were the most dominant among them. *B. angulosus* showed a mean abundance of 9.16±7.41 individuals in the community among seasons. Whereas, *B. kolensis* sp. nov. with a mean total abundance of 48 ±21.45 individuals in each seasonal community, was most abundant in the Mundakan season (mean= 20.33 ±8.11) and the least abundant in the Virippu season (10.66 ±5.35).

Tetragnathidae was the most dominant family in the paddy field spider community, which composed of species such as *Glenognatha dentata*, *Tetragnatha keyserlingi*, *T. javana*, *T. mandibulata*, *T. squamata* and *Tylorida striata*, make up the most common orb weavers in the paddy fields. The mean abundance of *G. dentata* present each seasonal community was 79.16±15.94 individuals, Puncha showed the highest (mean= 30.50±7.84) number of individuals and Virippu the lowest (20 ±6.83) values. The genus *Tetragnatha* composed of 786 individuals, with *Tetragnatha keyserlingi*, *T. javana*, *T. mandibulata* and *T. squamata* with a mean number of 31.5 ±13.95, 83.33 ±40.97, 6.16 ±3.37 and 5 ±4.09 individuals present in each community. *Tylorida striata* was another abundant member of the family, and 51.83 ±17.12 individuals were found in each community on average.

Theridiidae was another dominant family, of which species like *Coleosoma floridanum*, *Meotipa multuma* and *Phycosoma labialis* represented the majority with 17.83 ±4.21, 14.66 ±7.62 and 27 ±8.76 individuals on average in community belonging to each cropping

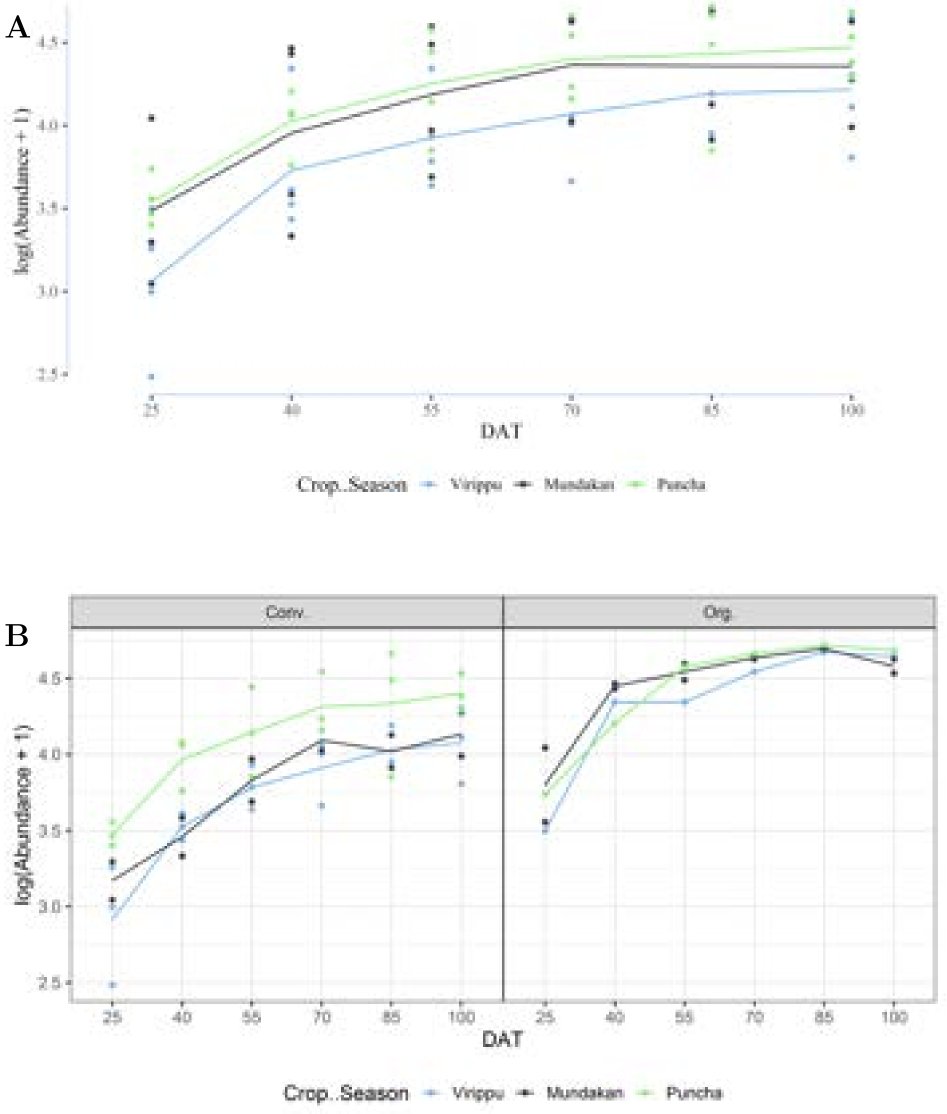

Figure 6.3.1: Abundance of spiders at various growth stages of paddy plants measured in Days after transplantation (DAT) during three cropping seasons: **A**. All treatments combined; **B**. Between conventional and organic treatment of crop management

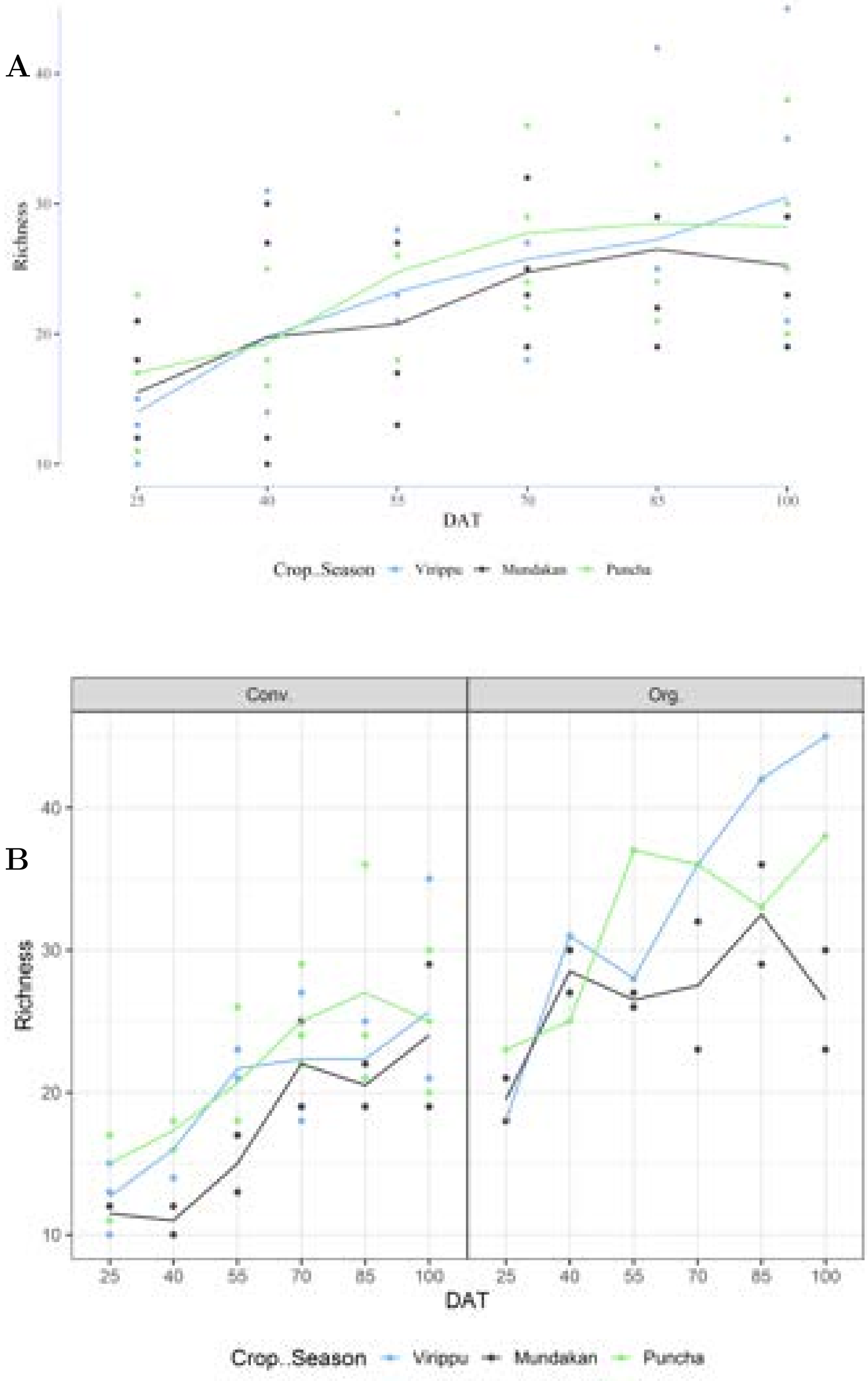

Figure 6.3.2: Richness of spiders over Days after transplantation during three cropping seasons of paddy: **A**. All treatments combined; **B**. Between conventional and organic treatment of crop management

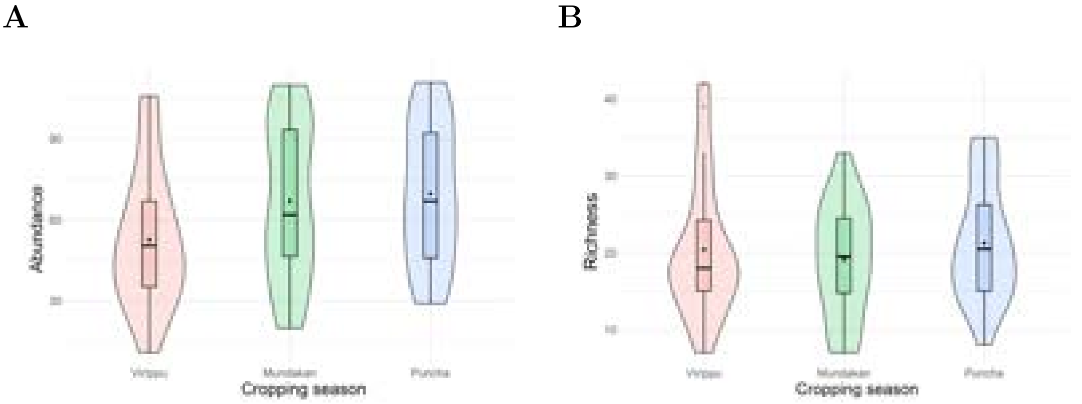

Figure 6.3.3: Abundance and Richness of spiders by cropping seasons in the paddy fields of Muriyad Kol wetlands: **A.** Abundance of spiders against cropping seasons; **B.** Richness of spiders against cropping seasons.

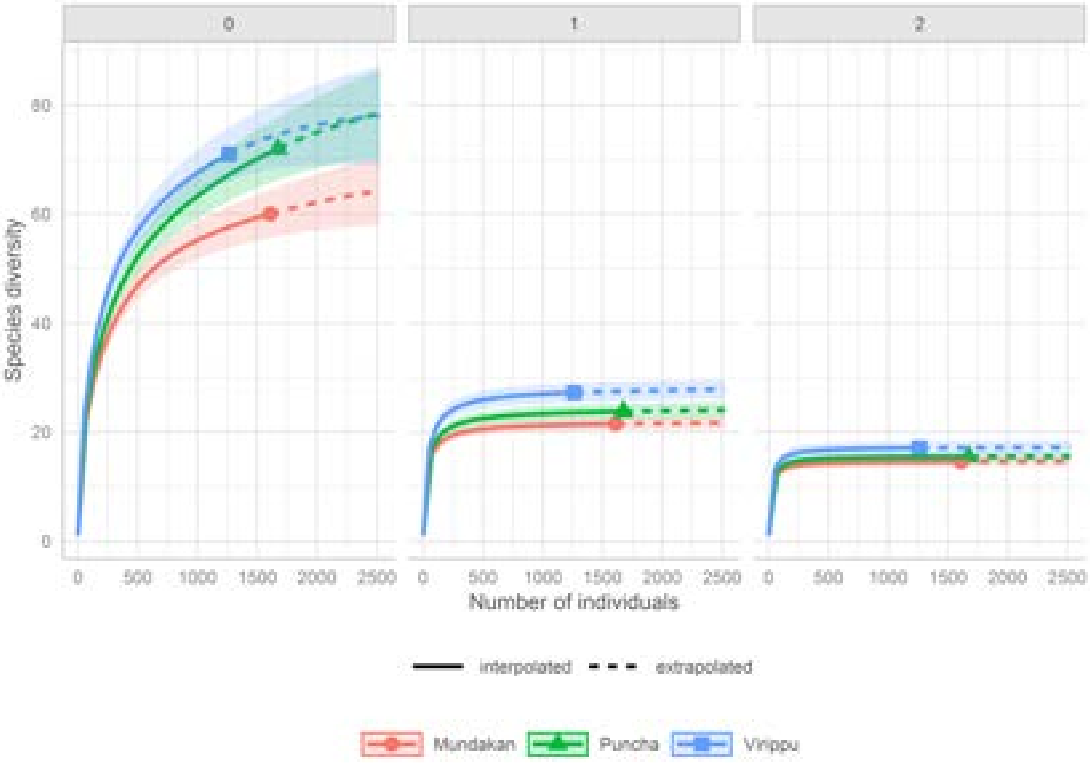

Figure 6.3.4: Sample-size-based rarefaction (solid lines) and extrapolation (dashed lines) of spider species diversity based on Hill numbers (q = 0, 1, 2) with 95% confidence intervals for the samples from Virippu, Mundakan and Puncha seasons of paddy crops in the Muriyad Kol wetlands, the symbols represent the reference samples.

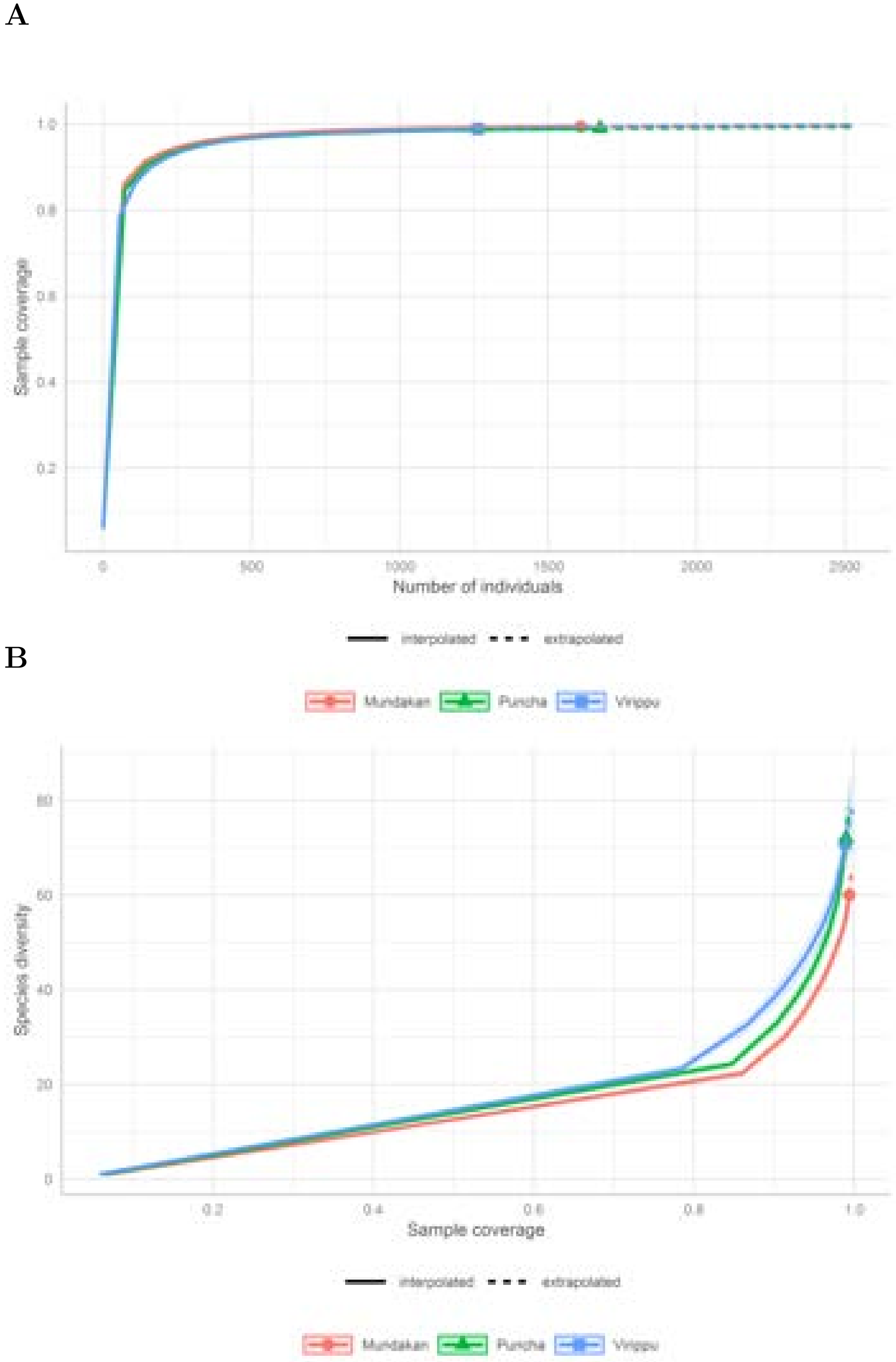

Figure 6.3.5: Coverage-based rarefaction and extrapolation curves: **A.** Sample completeness curve showing sample coverage for rarefied samples and extrapolated samples as a function of sample size for spider samples for the Virippu, Mundakan and Puncha seasons of paddy crops in the Muriyad Kol wetlands, the symbols represent the reference samples; **B.** Coverage-based rarefaction and extrapolation plots with 95% confidence intervals for spider species diversity based on hill number, $q = 1$.

6.3.2 Guild composition

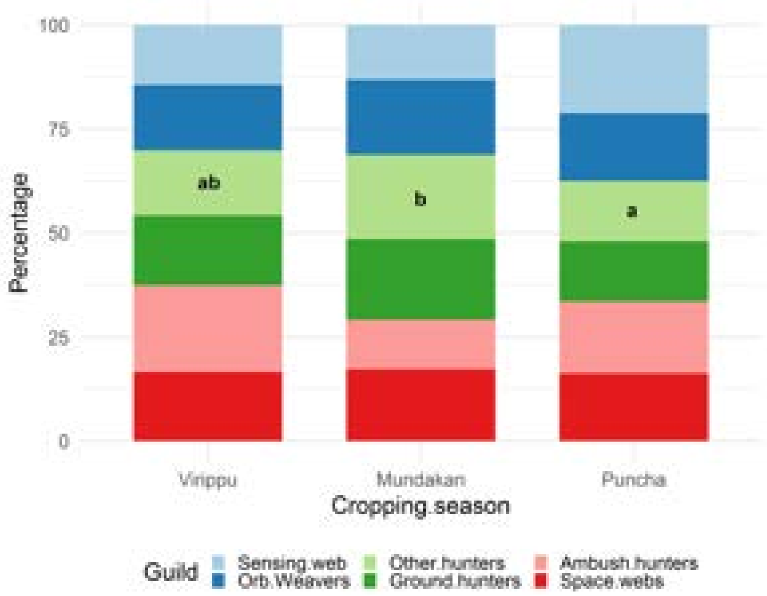

Figure 6.3.6: The relative abundance of individual spider guilds sampled during *Virippu, Mundakan* and *Puncha* cropping seasons of paddy in the Muriyad Kol wetland.

The most dominant guild identified in the samples from paddy fields in this study was Orb Weavers (2379 individuals, 52.31%), followed by Other Hunters (1051, 23.11%), Gound Hunters (634, 13.94%), Space Web weavers (410, 9.01%), Ambush Hunters (66, 1.45%) and Sensing Web weavers (8, 0.17%).

The results of the type II Analysis of deviance performed on binomial GLMs fit to the relative abundance of Other Hunters showed significant differences among the cropping seasons ($\chi^2 = 6.296$, Df = 2, p 0.043), but confidence interval was greater than the Bonferroni corrected P values ($p < 0.01$). The proportion of Orb Weavers and Ambush hunters showed differences in relative abundance among the seasons, however it was not significant (p 0.07, p 0.067 respectively). The overall result suggest that there was no significant variation in the relative abundances of guilds among the cropping seasons (Fig. 6.3.6). The number of spiders and the families of spiders collected from different cropping seasons in the Muriyad Kol wetland is given in Table 6.A.1.

6.3.3 Effect of cropping season, crop growth and management practices on the abundance and richness of spiders

6.3.3.1 Abundance

The number of adult spiders increased with each growth stages of paddy plants after transplantation until maturation (Fig. 6.3.1A). The abundance distribution of the pooled samples ranged from 11 to 111 individuals, the lowest and highest values corresponding to the DAT 25 and DAT 85 respectively. The mean (±SD) abundance of spiders at various growth stages were: DAT 25–29.83 (±11.51), DAT 40–52.42 (±21.45), DAT 55–64.25 (±22.88), DAT 70–74.42 (±23.11), DAT 85–79.17 (±27.52), DAT 100–78.92 (±20.43) individuals.

The results of the type II Analysis of deviance performed on the generalized linear model (GLM) fit to the abundance of spiders revealed significant differences between days after transplantation (DAT) ($\chi^2 = 282.682$, Df = 5, $p < 0.001$), between cropping seasons ($\chi^2 = 45.025$, Df = 2, $p < 0.001$) and crop management practices ($\chi^2 = 193.794$, Df = 1, $p < 0.001$). The model validation indicated no problems (Fig. 6.A.1). The difference were driven by the greater abundance of spiders in all growth stages of paddy, especially DAT 70, 85 and 100 (GLM estimate= 0.92, $p < 0.001$, GLM estimate= 0.98, $p < 0.001$, GLM estimate= 0.98, $p < 0.001$, respectively) Fig. 6.3.8. The pairwise Tukey test performed with the glm shows that there are significant differences between Puncha and Virippu, Puncha and Mundakan.(p, 0.001) (Table 6.A.2).The pairwise analysis between the growth stages shows that there were no significant differences in the abundances between the groups in the final stages of plant growth (DAT 70, 85 and 100). However, there were significant differences between the groups in the initial stages of crop growth Fig. 6.3.7. The abundances of samples from paddy fields that followed organic management practices were significantly higher than conventionally managed fields Fig. 6.3.8.

The fitted means in the DATs as predicted by the model were as follows: DAT 25–31.31 [20.97, 46.73] individuals, DAT 40–54.68 [36.86, 81.11], DAT 55–67.32 [45.45, 99.72], DAT 70 –78.32 [52.92, 115.91], DAT 85–83.25 [56.27, 123.15] and DAT 100–83.76 [56.61, 123.91] individuals. As for the cropping seasons, Puncha had the largest fitted mean values (74.53 [50.62, 109.72] individuals), followed by Mundakan (61.30 [41.65, 90.21]) and Virippu (54.92 [37.27, 80.92]) seasons.

6.3.3.2 Richness

The results of the type II Analysis of deviance performed on the generalized linear model (GLM) fit to the richness of spiders revealed significant differences between crop growth (DAT) ($\chi^2 = 76.461$, Df = 5, $p < 0.001$), between cropping seasons ($\chi^2 = 14.996$, Df = 2, $p < 0.001$) and crop management practices ($\chi^2 = 84.083$, Df = 1, $p < 0.001$). The model validation indicated no problems (Fig. 6.A.2). The difference were driven by the greater richness of spiders in the final growth stages of paddy (DAT 70, 85 and 100) (GLM estimate= 0.613, $p < 0.001$; GLM estimate= 0.67, $p < 0.001$; GLM estimate= 0.693, $p < 0.001$, respectively) Fig. 6.3.10. The pairwise Tukey test performed with the glm shows that there are significant differences between Mundakan and Virippu, and Puncha and Mundakan (p 0.001; p 0.001, respectively) (Table 6.A.3). The pairwise analysis between the growth stages shows that there were no significant differences in the abundances between the groups in the final stages of plant growth (DAT 70, 85 and 100). However, there were significant differences in richness between DAT 40–25, 55–40, 85–55 and 100–55 (Fig. 6.3.9). Moreover, the paddy fields managed with organic practises had significantly greater species richness than conventional fields (GLM estimate= 0.51, $p < 0.001$) Figs 6.3.2B and 6.3.10.

6.3.4 Species turnover and temporal dynamics of spiders

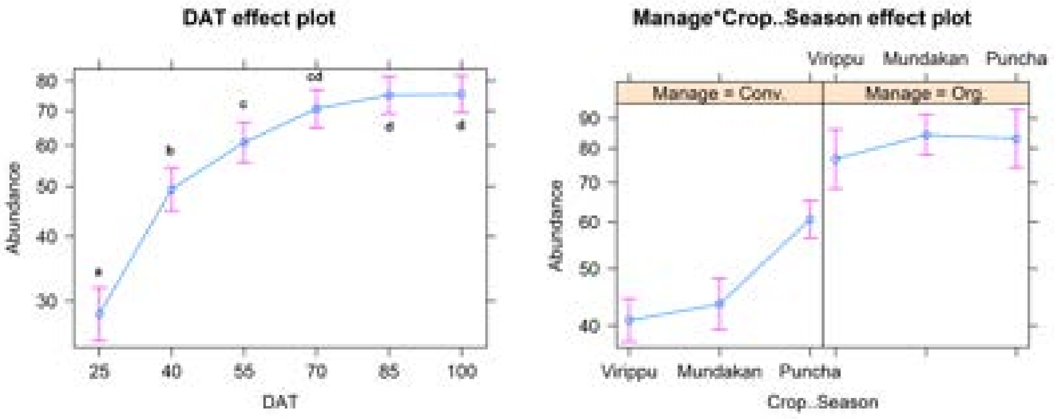

Figure 6.3.7: Effects displayed for Days after transplantation (DAT), cropping seasons and management practices in the generalized linear model (with 95% confidence intervals) fit to abundances of spiders in the paddy fields at Muriyad Kol wetland.

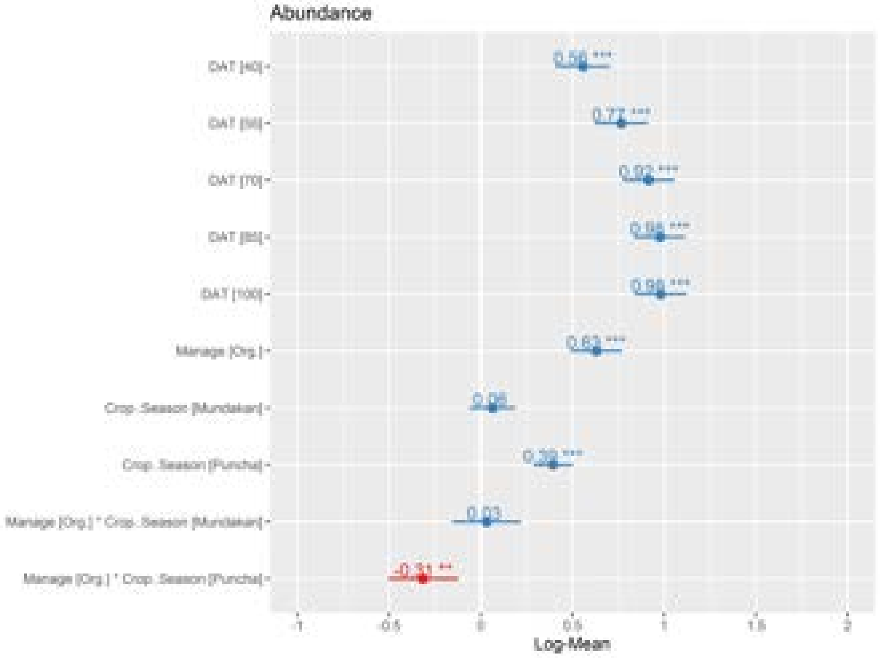

Figure 6.3.8: Coefficient plot of the generalized linear model (with 95% confidence intervals) fit to abundance of spiders against Days after transplantation (DAT), cropping seasons and management practices in the paddy fields at Muriyad Kol wetlands.

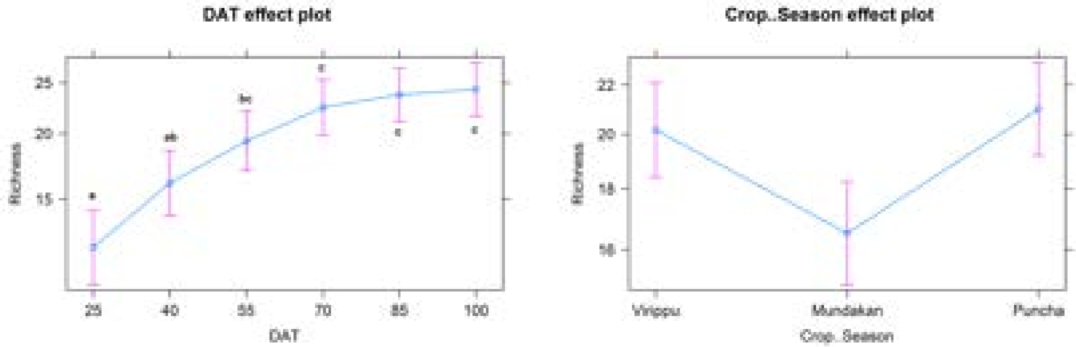

Figure 6.3.9: Effects displayed for Days after transplantation (DAT), cropping seasons and management practices in the generalized linear model (with 95% confidence intervals) fit to species richness of spiders in the paddy fields at Muriyad Kol wetland.

Changes in species turnover

The spider community in the paddy fields presented a gradually declining trend of total species turnover (tST) across the growth intervals for all cropping seasons, except in Puncha season (Fig. 6.3.11A). An abrupt decrease in the total species

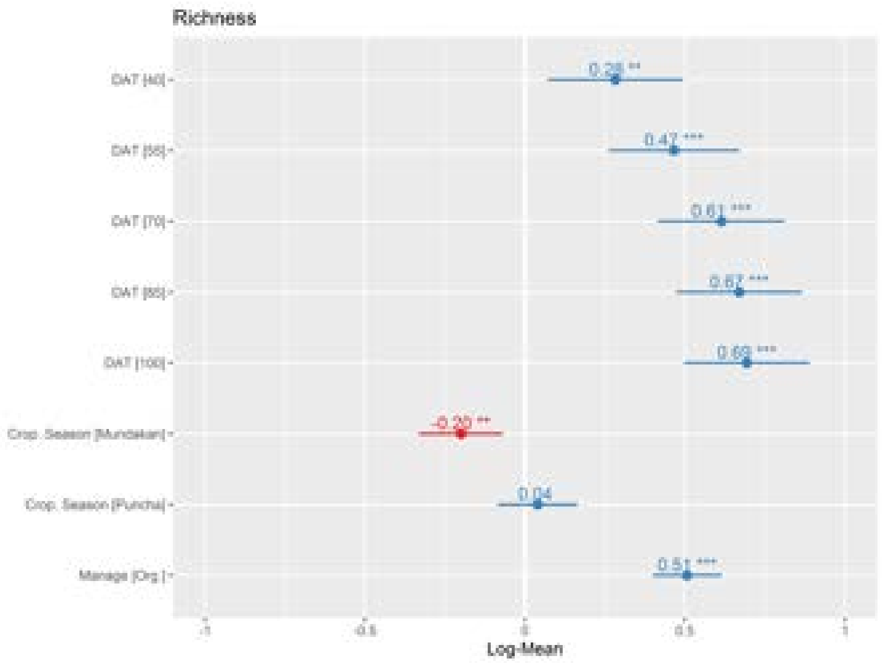

Figure 6.3.10: Coefficient plot of the generalized linear model (with 95% confidence intervals) fit to species richness of spiders against Days after transplantation (DAT), cropping seasons and management practices in the paddy fields at Muriyad Kol wetlands.

turnover in the second interval was observed in the second DAT interval (DAT 55, Fig. 6.3.11A). The mean tST of the spider community of the paddy fields were 0.42, 0.45 and 0..44 in the Virippu, Mundakan and Puncha seasons respectively. It means that in the Virippu season on average, 42 % of species sampled in one DAT appeared in the next DAT. The tST at DAT 40 were 0.55, 0.50 and 0.60 for Virippu, Mundakan and Puncha seasons respectively. In other words, 55% of the species sampled during DAT 25 was gained or lost in samples from DAT 40 in the Virippu season. As the crop matured and reached the harvest period, the value decreased gradually in the final period of 100 DAT to 0.21, 0.37 and 0.29 for Virippu, Mundakan and Puncha seasons respectively.

Figs 6.3.11B and 6.3.11C points to the larger contribution of species appearances (aST) to the pattern of temporal turnover than species disappearances (dST). The only exception being in Puncha cropping season where more species (0.38) were gained during the 55 DAT and an abrupt drop (0.16) in the successive period (DAT 70) as compared to other seasons (Fig. 6.3.11B). The mean values of aST were 0.29, 0.26 and 0.28 for Virippu, Mundakan and Puncha seasons respectively. Puncha season showed a largely saltatory pattern in Fig. 6.3.11C and larger values (0.33) of dST particularly at DAT 70. The dST pattern of the spider community

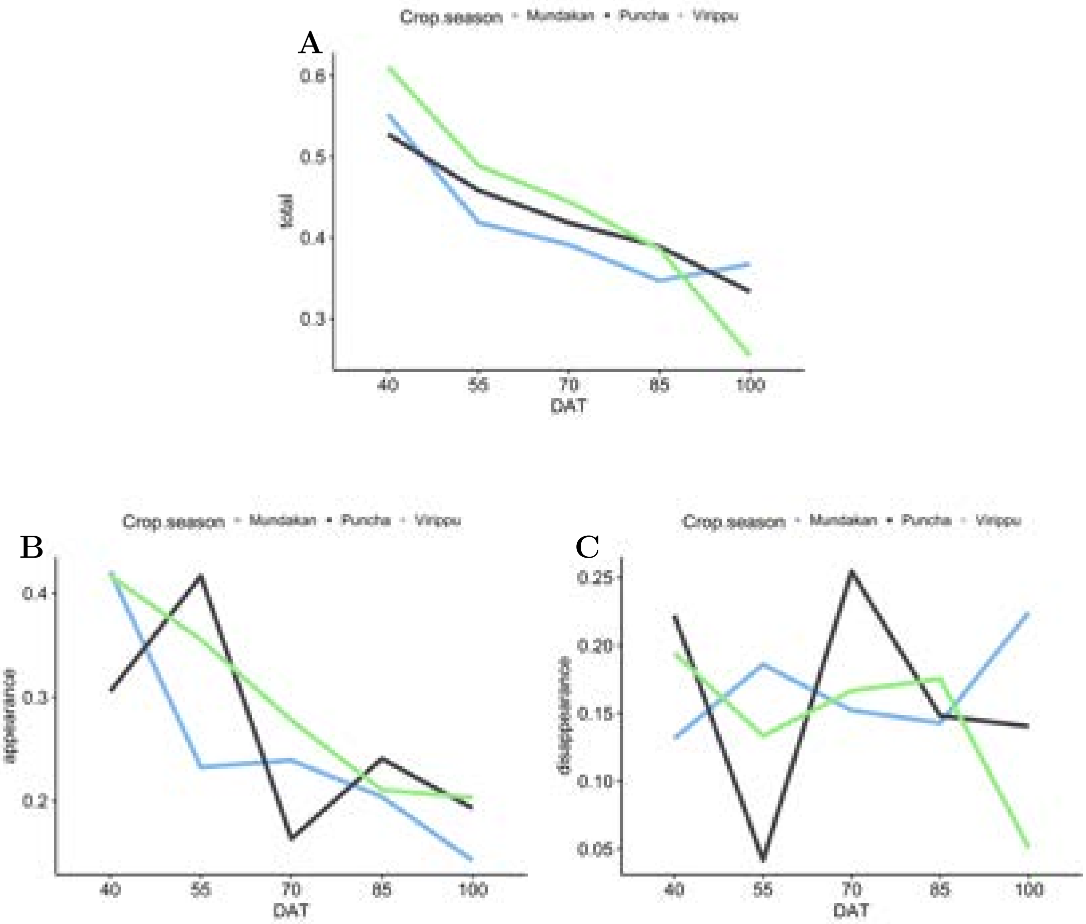

Figure 6.3.11: Species turnover within spider community across the growth stages of paddy crop in terms of Days after transplantation (DAT) by cropping seasons. **A.** Total species turnover (tST); **B.** Appearances (aST); **C.** Disappearances (dST)

in the Mundakan season was almost constant. The mean values of dST were 0.13, 0.18 and 0.16 for Virippu, Mundakan and Puncha seasons respectively.

The first spike in Figs 6.3.11A to 6.3.11C represents the initial species gain from DAT 25 which corresponds with the tillering stage of paddy. The growth of the paddy plant in height and increase in substrate surface presents many opportunities for spider species to flourish. As paddy crop grows so does the number of species sampled from them, but the frequency of species gain decreases, which is reflected in the species turnover.

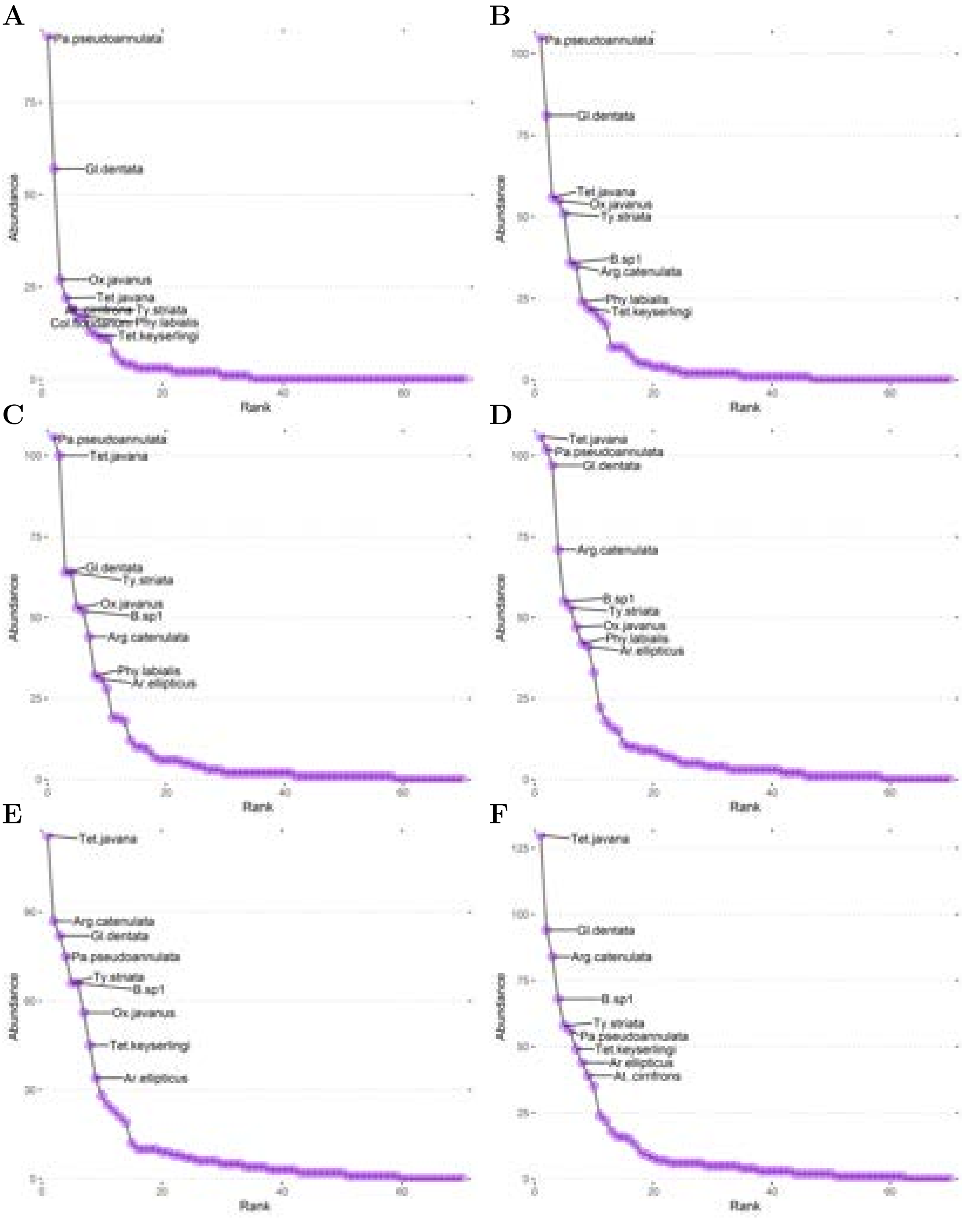

Figure 6.3.12: Rank abundance distribution of spider communities across Days after transplantation (DAT) in the paddy fields of Muriyad Kol wetlands. **A**. 25 DAT, **B**. 40 DAT, **C**. 55 DAT, **D**. 70 DAT, **E**. 85 DAT, **F**. 100 DAT.

Table 6.3.2: Richness change, evenness change, rank change, species gains (appearances) and species losses (disappearances) of spiders between Days after transplantation (DAT) pairs in the paddy fields (pooled samples) of Muriyad Kol wetlands.

DAT	DAT2	Richness change	Evenness change	Rank change	Gains	Losses
25	40	0.24	-0.1	0.15	0.33	0.1
40	55	0.2	0	0.13	0.25	0.05
55	70	0	0.01	0.12	0.11	0.11
70	85	0.02	0.02	0.13	0.11	0.09
85	100	0.04	-0.01	0.09	0.13	0.09

Table 6.3.3: Richness change, evenness change, rank change, species gains (appearances) and species losses (disappearances) of spiders between Days after transplantation (DAT) pairs among cropping seasons in the paddy fields of Muriyad Kol wetlands.

DAT	DAT2	Crop season	Richness change	Evenness change	Rank change	Gains	Losses
25	40	Mundakan	0.29	-0.16	0.17	0.42	0.13
25	40	Puncha	0.08	-0.12	0.15	0.31	0.22
25	40	Virippu	0.22	-0.09	0.15	0.42	0.19
40	55	Mundakan	0.05	0.01	0.15	0.23	0.19
40	55	Puncha	0.38	0.02	0.15	0.42	0.04
40	55	Virippu	0.22	-0.06	0.14	0.36	0.13
55	70	Mundakan	0.09	-0.02	0.16	0.24	0.15
55	70	Puncha	-0.09	0	0.15	0.16	0.25
55	70	Virippu	0.11	0.04	0.18	0.28	0.17
70	85	Mundakan	0.06	0.05	0.17	0.2	0.14
70	85	Puncha	0.09	0.04	0.13	0.24	0.15
70	85	Virippu	0.04	-0.04	0.2	0.21	0.18
85	100	Mundakan	-0.08	-0.05	0.15	0.14	0.22
85	100	Puncha	0.05	-0.04	0.14	0.19	0.14
85	100	Virippu	0.15	0.05	0.14	0.2	0.05

Changes in richness

The richness change was the highest (0.24) during DAT 25–40 when the data from three seasons were pooled (Table 6.3.2). The positive value indicates an increase in species richness of spiders over time during the initial growth phase of paddy plants. It increased from 34 to 46 species between this period for the pooled sample. The total species gain as a function of the total number of unique species in both time periods was 0.33, the highest among the entire dataset. Similarly, richness change during DAT 40–55 was lower (0.19) than DAT 25–40 in the overall community of spiders in the paddy fields. The species appearance or gain was 0.24 which was the second highest and species losses was the lowest (0.05) among the time periods. The richness of spiders leaped from 46 to 58 between DAT 40–55. Interestingly,

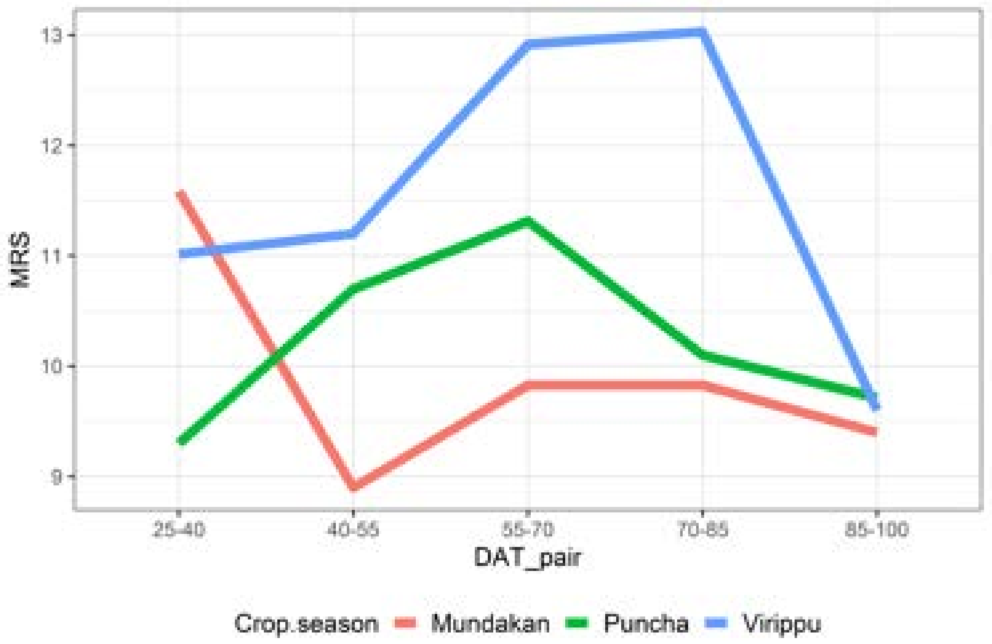

Figure 6.3.13: Mean rank shifts of spider community over six days after transplantation (DAT) intervals in the paddy fields of Muriyad Kol wetlands.

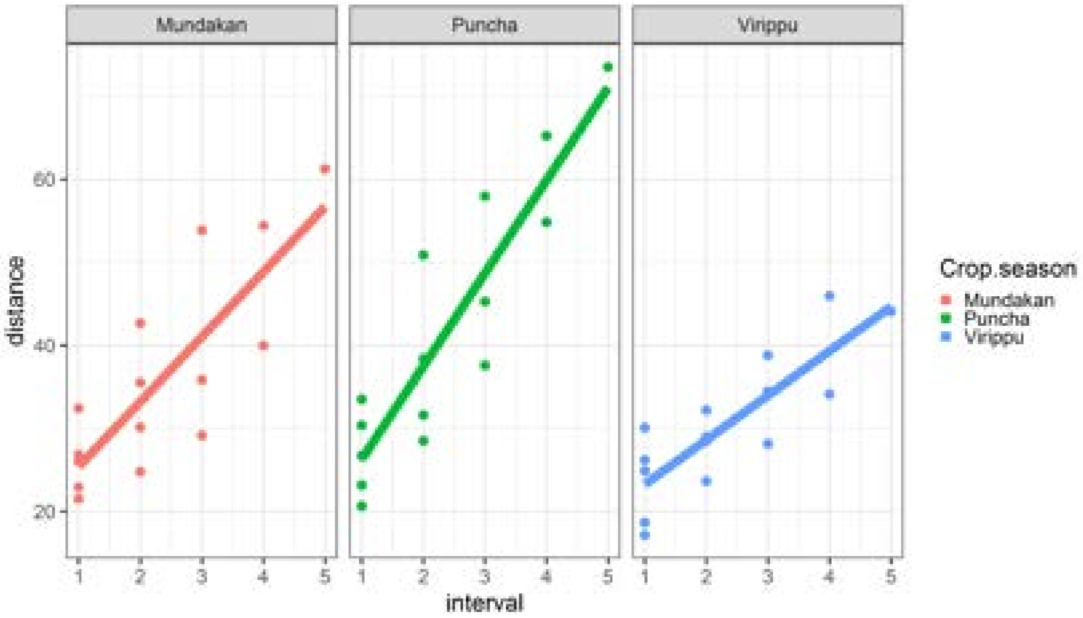

Figure 6.3.14: Community change over time (Days after transplantation, DAT) for spider species during three cropping seasons at Muriyad Kol wetlands.

the richness change was zero between DAT 55–70 with 58 species in each time period. There was equal (0.1) amount of gain and loss of species between the two periods. The richness change between DAT 70–85 and DAT 85–100 were 0.01 and 0.04 respectively (Table 6.3.2). The overall species richness increased slightly from

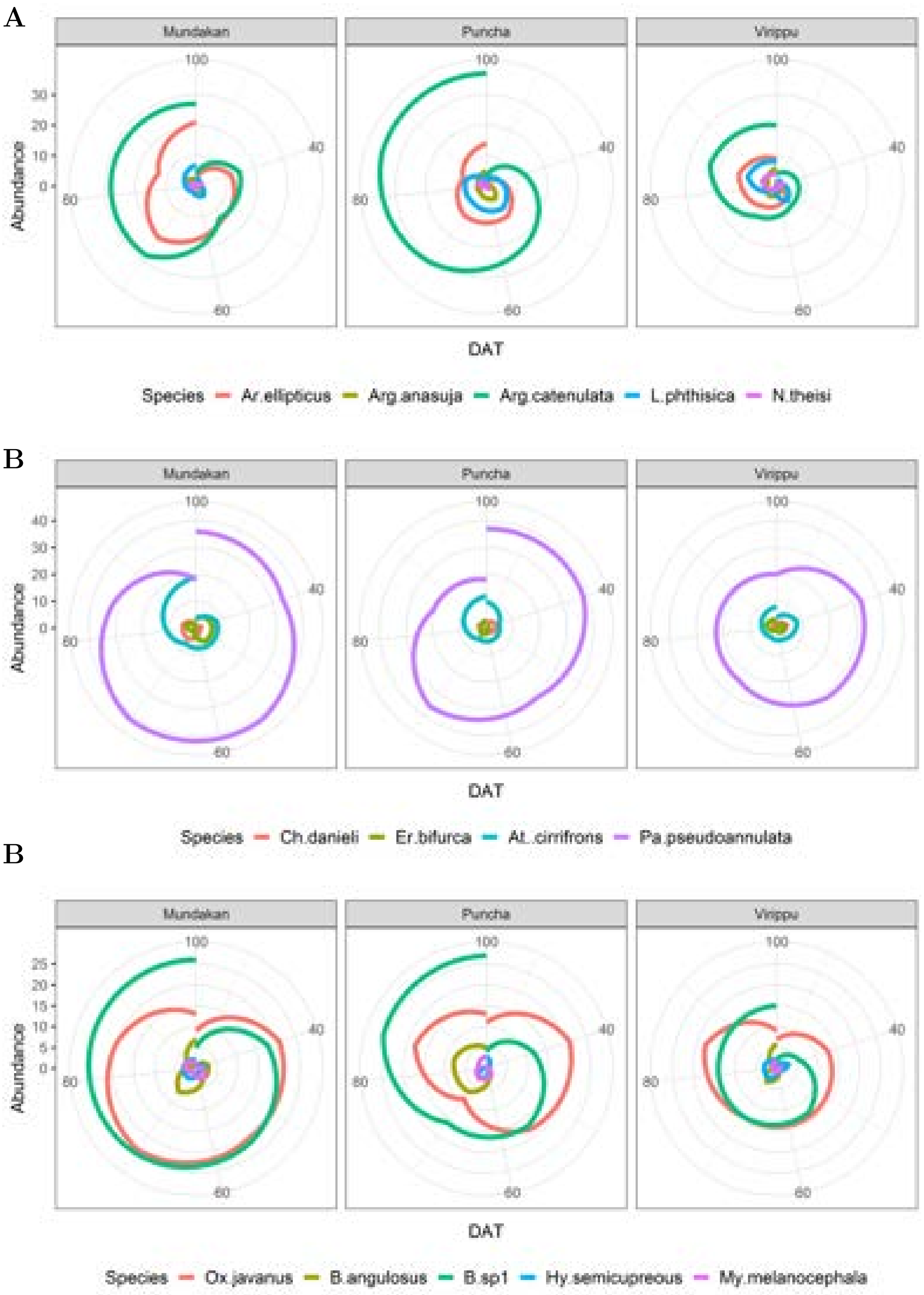

Figure 6.3.15: Abundance of dominant spiders in the paddy fields across Days after transplantation (DAT) by cropping seasons.

58 species in DAT 70 to 59 and 62 during DAT 85 and DAT 100 respectively. Only a few species appeared (mean= 0.1) and disappeared (0.09) during the these time

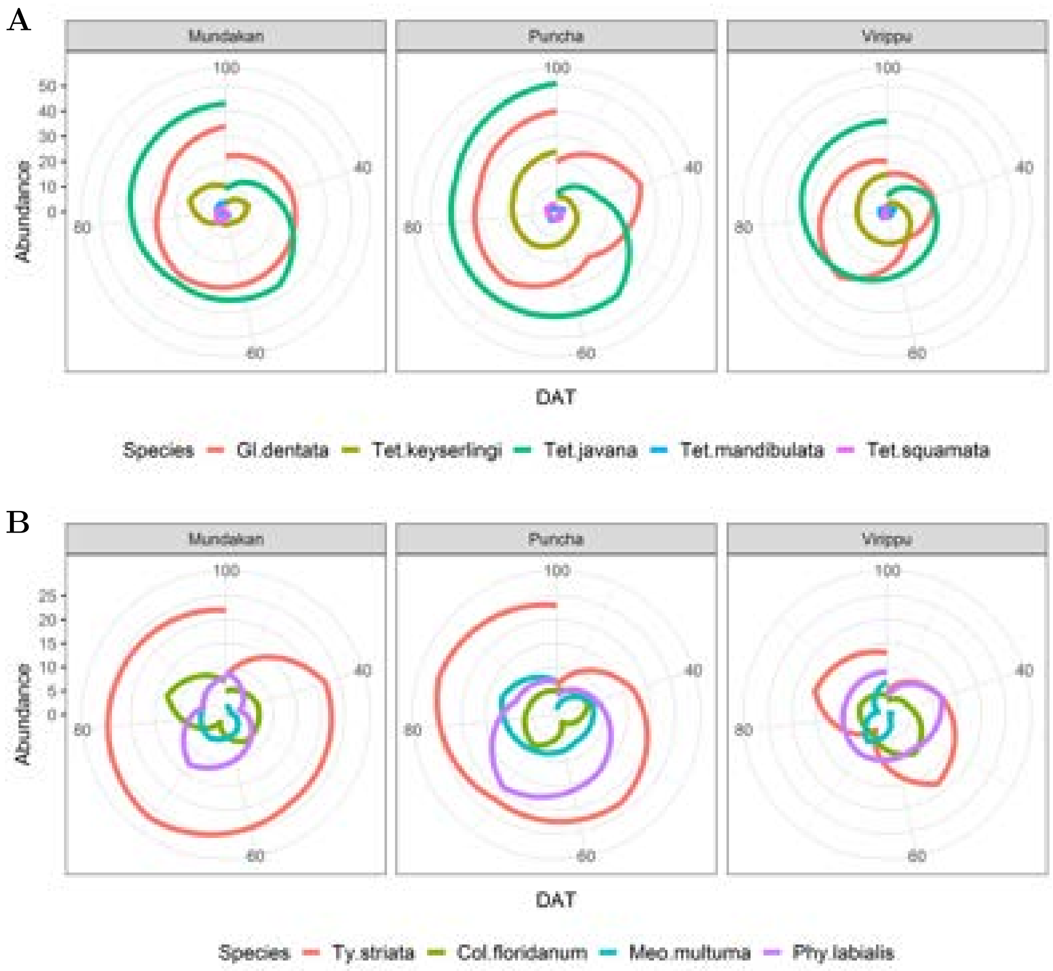

Figure 6.3.16: Continued: Abundance of dominant spiders in the paddy fields across Days after transplantation (DAT) by cropping seasons.

intervals representing samples from ripened and mature stages of crops.

Changes in species rank abundance

The communities of spiders sampled from every DAT showed similar pattern of abundance distribution and were fit to niche-preemption model on the basis of low AIC values. The shifts in the species rank abundances did not show much differences among the samples from the three cropping seasons, which was expected as the crops were grown in similar conditions and methods in the same geographical area (Fig. 6.3.13). On average, the mean rank shift values for Virippu, Mundakan and Puncha were 6.02, 5.10 and 5.41 respectively. In all seasons, Mean rank shift (MRS) values were larger between DAT 55–70 and DAT 70–85 which indicates that there was higher amount of reshuffling of species ranks from the previous period. The DAT 55–70 of the paddy growth cycle coincides with the shift from vegetative to reproductive phase of the crop. Many factors such as increase in insect population, diverse structure of the plants and prey availability contributes to the shift in species rank abundance in the community. Larger values of MRS might also be indicative of higher species richness observed during these intervals. Samples from the Virippu season showed the highest MRS values between DAT 55–70 (7.08)and DAT 70–85 (7.97). This could be attributed to the abrupt increase in species sampled following the monsoon rains and decrease in flooding events in the paddy fields during the collection period. The MRS does not vary much in the DAT 85–100 among the seasons, because the final two DATs fall in the phase of crop maturation and the paddy plants have attained its structural complexity. The MRS at DAT 25–40 for Puncha is slightly higher than Virippu and Mundakan seasons. The lower values of MRS at this interval is indicative of the lower species richness in the samples from this period.

The variation in the Mean rank shifts were caused by the reshuffling of species from one DAT to other. Analysis showed that dominant species such as *Pardosa pseudoannulata*, *Tetragnatha javana*, *Argiope catanulata*, *Tylorida striata* and *Glenognatha dentata* contributed most to the variation. The species rank within the community of spiders across DAT varied among the most dominant species (Fig. 6.3.12). This variation correlates with the different growth stages of the paddy plant and it indicates the change in the structure of the spider community coinciding with the increase in complexity of the vegetation. Overall, a gradual shift in the species rank was observed among the most dominant species, with *P. pseudoannulata* replaced by *T. javana* during the later phase of paddy growth. *P. pseudoannulata* and *G. dentata* held the first two ranks in the communtiy at 25 and 40 DAT. Some other species that dominanted during these early phases of crop growth were *Oxypes javanus*, *T. javana*, *Tylorida striata*, *Coleosoma floridanum*, *Phycosoma labialis* and *Atypena cirrifrons* (Figs 6.3.12A and 6.3.12B). Species such as *Bianor kolensis sp. nov.* and *A. catanulata* increaaed in their ranks during the second sampling period (Fig. 6.3.12B).

As the crops reached DAT 55, the number of *T. javana* increased marginally in par with *P. pseudoannulata*, but the latter was still the most dominant species in the community Fig. 6.3.12C. the abundance of Araneids like *Araneus ellipticus* increased substantially as the paddy attained diverse vegetation structure following tillering. At DAT 70, *T. javana*, *P. pseudoannulata* and *G. dentata* were dominant, while the abundance of *A. catanulata* and *A. ellipticus* increased considerably (Fig. 6.3.12D). Some changes in the community structure of spiders was observed at 85 DAT as a result of reshuffling of the species ranks. *T. javana* dominated this community and species such as *A. catanulata*, *G. dentata*, *P. pseudoannulata*, *T. striata*, *Bianor kolensis sp. nov.*, *O. javanus*, *Tetragnatha keyserlingi* and *A. ellipticus* held the following ranks. The data showed that there was no significant reshuffling in the species ranks in the next sampling period, ie. 100 DAT.

Changes in directionality

Across the six DAT intervals studied in the paddy fields, all the three cropping seasons showed positive directional change in the community. When the Euclidean distances calculated on pair-wise communities across the dataset for each seasons were regressed against time lag intervals, a positive change indicates unstable community with directional change in the community (Fig. 6.3.14). It is expected in a community thriving in a seasonal crop. The regression line of community similarity and DAT interval was positive and significant for all seasons (F= 17.04, p= <0.001, R^2= 0.686). The rate of change of the differences in the species composition within the community in Puncha was the highest (11.19) among the seasons. The slope for the Virippu and Mundakan communities were 5.35 and 7.82 respectively.

6.3.5 Vertical stratification

Table 6.3.4: Vertical distribution on paddy plants of spiders (*Oxyopes javanus*, *Pardosa pseudoannulata*, *Bianor angulosus*, *Tylorida striata*, *Tetragnatha javana* and *Araneus ellipticus*) collected from Muriyad Kol wetland. Zone A is at the bottom of the plant and Zone D is at the top.

Time	Zone A	Zone B	Zone C	Zone D
0800-0900 hrs	29.845	21.705	24.806	23.643
1300-1400 hrs	31.707	25.61	27.439	15.244
1700-1800 hrs	19.841	27.381	28.968	23.81
2000-2100 hrs	14.019	24.922	31.776	29.283

A total of 995 individuals of selected spiders were sampled from each vertical zone of the rice plant in each of the four daily time periods. The spiders such as *Oxyopes javanus* (124 individuals), *Araneus ellipticus* (88), *Bianor angulosus* (129), *Pardosa pseudoannulata* (231), *Tylorida striata* (176) and *Tetragnatha javana*

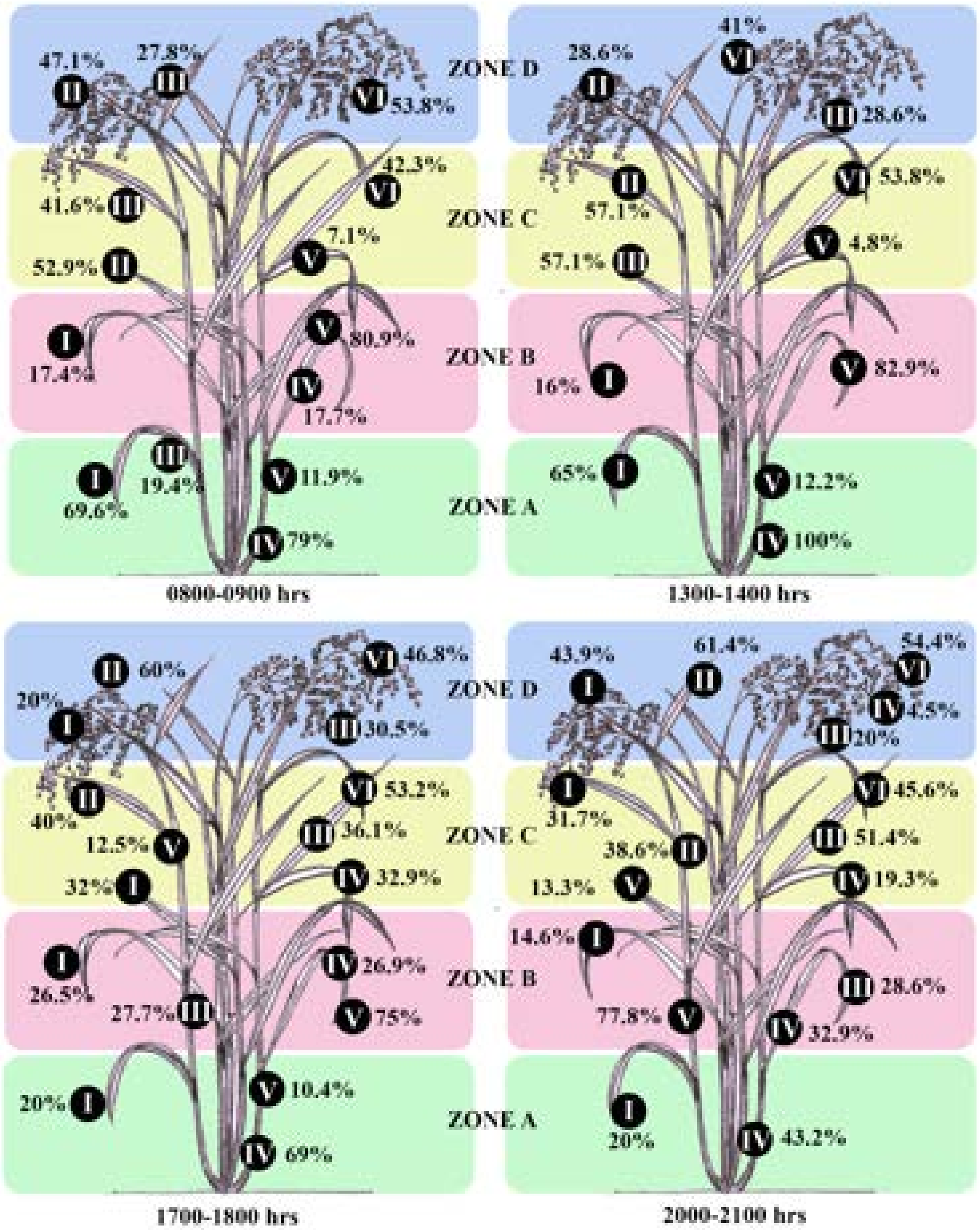

Figure 6.3.17: Location of selected spider species on rice plants during different time intervals and the percentage of the population found in each zone out of the total population of each species collected during that time. I - *Oxyopes javanus*, II - *Araneus ellipticus*, III –*Bianor angulosus*, IV –*Pardosa pseudoannulata*, V –*Tylorida striata*, VI–*Tetragnatha javana*.

(247) showed fluctuations in their abundance in different zones during different time intervals (Table 6.A.5). The data shows that the proportion of overall individuals of spiders collected during the time period 1300–1400 hrs was lower (15.24%) in the zone D than other zones (Table 6.3.4). Zone D (29.28%) had greater proportion of

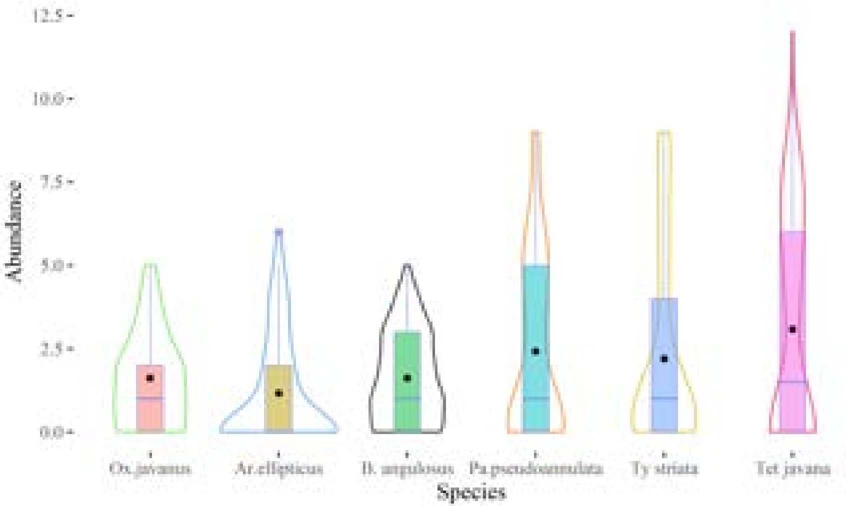

Figure 6.3.18: Abundance of selected spiders sampled from four vertical zones of paddy plants grown during *Puncha* cropping season of 2017 in the Muriyad Kol wetland. Species: Ox.javanus–*Oxyopes javanus*, Ar.ellipticus–*Araneus ellipticus*, B.angulosus–*Bianor angulosus*, Pa.pseudoannulata–*Pardosa pseudoannulata*, Ty.striata–*Tylorida striata*, Tet.javana–*Tetragnatha javana*. Time: t1–0800-0900 hrs, t2–1300-1400 hrs, t3–1700-1800 hrs, t4–2000-2100 hrs.

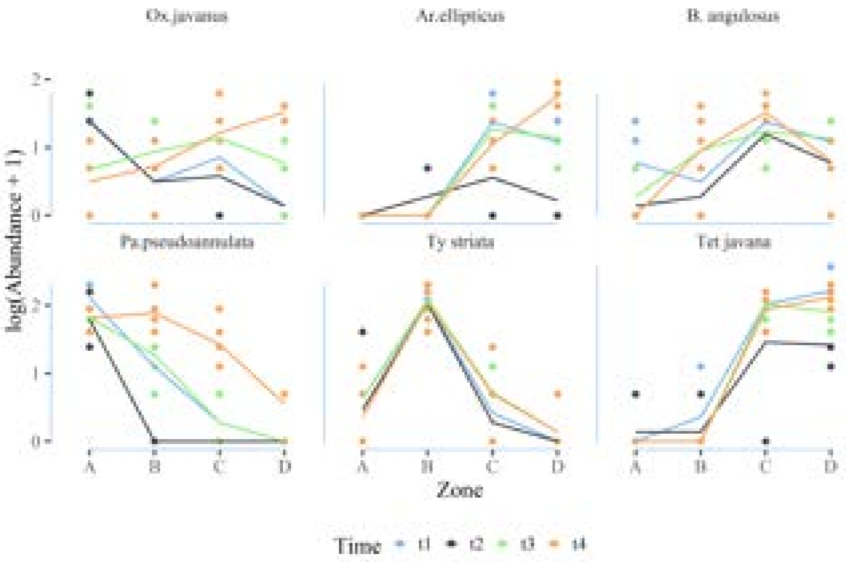

Figure 6.3.19: Vertical distribution (log(abundance + 1)) of some selected spiders collected at different Zones of paddy plant during various time periods grown during *Puncha* cropping season of 2017 in the Muriyad Kol wetland. Lines indicate mean value of log(abundance + 1). Species: Ox.javanus–*Oxyopes javanus*, Ar.ellipticus–*Araneus ellipticus*, B.angulosus–*Bianor angulosus*, Pa.pseudoannulata–*Pardosa pseudoannulata*, Ty.striata–*Tylorida striata*, Tet.javana–*Tetragnatha javana*. Time: t1–0800-0900 hrs, t2–1300-1400 hrs, t3–1700-1800 hrs, t4–2000-2100 hrs.

Table 6.3.5: Estimated regression parameters, standard errors, z-values and P-values for Zero-inflated negative binomial generalised linear model fit to the number of *Oxyopes javanus* sampled from different Zones (A–D) of paddy plant during various time periods (t1–t4) in paddy fields of Muriyad Kol wetland. Log likelihood–-123, df–12.

Count model coefficients (negbin with log link):	**Estimate**	**Std. Error**	**z value**	**P-value**
(Intercept)	0.675	0.246	2.742	0.006
ZoneB	-0.86	0.27	-3.186	0.001
ZoneC	-0.561	0.248	-2.262	0.023
ZoneD	-0.446	0.319	-1.398	0.162
Timet2	0.132	0.297	0.444	0.657
Timet3	0.447	0.296	1.513	0.13
Timet4	0.605	0.29	2.087	0.036
Log(theta)	12.27	195.204	0.063	0.95

Zero-inflation model coefficients (binomial with logit link):	**Estimate**	**Std. Error**	**z value**	**P-value**
(Intercept)	-1.589	0.676	-2.35	0.018
ZoneB	-9.697	199.477	-0.049	0.961
ZoneC	-11.402	347.65	-0.033	0.974
ZoneD	0.604	1.147	0.526	0.599

spiders during 2000–2100 hrs than during other times. The distribution of these spiders in different vertical zones during various time periods of the day is provided in Fig. 6.3.17 The spiders collected from Zones (Zone A–D) of the rice plant during the four time periods (Time t1–t4) were analysed separately using generalised linear models for changes in the spatial position of individuals in relation to the different periods and zones.

Individuals of *Oxyopes javanus* were present in all zones at different time intevals. Around 34.6% of all individuals of *Oxyopes javanus* were collected from Zone A, followed by Zone C and D (25% and 21.7% respectively). The results of the type II Analysis of deviance performed on the Zero-inflated negative binomial regression fit to the number of individuals of *Oxyopes javanus* revealed significant differences among Zones (χ^2 = 11.091, Df = 3, p = 0.011), but no significant difference in the number of individuals found between time periods. The best model fit had no interaction terms in the formula as one of the main effects. The data indicated a significant changes in the abundance of spiders during the t3 and t4 time periods. The species were found to occur predominantly in the upper strata at night hours. In the logit model, the baseline odds of being among the

Table 6.3.6: Estimated regression parameters, standard errors, z-values and P-values for negative binomial generalised linear model fit to the number of *Bianor angulosus* sampled from different Zones (A–D) of paddy plant during various time periods (t1–t4) in paddy fields of Muriyad Kol wetland. Residual deviance–65.93, residual df–73.

	Estimate	**Std. Error**	**z value**	**P-value**
(Intercept)	-0.58	0.346	-1.683	0.092
Timet2	-0.49	0.27	-1.82	0.068
Timet3	-0.001	0.23	0	0.995
Timet4	-0.002	0.23	-0.119	0.905
ZoneB	0.95	0.37	2.568	0.01
ZoneC	1.77	0.34	5.19	< 0.001
ZoneD	1.22	0.35	3.402	< 0.001

Table 6.3.7: Estimated regression parameters, standard errors, z-values and P-values for negative binomial generalised linear model fit to the number of *Araneus ellipticus* sampled from different Zones (A–D) of paddy plant during various time periods (t1–t4) in paddy fields of Muriyad Kol wetland. Residual deviance–25.78, residual df–32.

	Estimate	**Std. Error**	**z value**	**P-value**
(Intercept)	0.588	0.333	1.763	0.078
Timet2	-0.811	0.601	-1.349	0.177
Timet3	-0.118	0.486	-0.242	0.809
Timet4	0.636	0.412	1.543	0.123
ZoneD	-0.118	0.486	-0.242	0.809
Timet2:ZoneD	-0.575	0.993	-0.579	0.562
Timet3:ZoneD	0.523	0.667	0.785	0.433
Timet4:ZoneD	0.58	0.576	1.007	0.314

individuals of spiders that do not occur in Zone A was 0.19 and was significant ($p = < 0.05$) (Table 6.3.5). However, other zones no effect on the odds of being among the individuals of spiders that do not occur. However in the count model, individuals of *Oxyopes javanus* had significant positve association with Zone A (GLM estimate= 0.67, $p = < 0.001$), but Zones B and C had a significant negetive association with $p = 0.001$ and $p = 0.023$ respectively.

Individuals of *Bianor angulosus* were represented in all Zones during different periods. Most individuals occured in zone C (45.7%), followed by zone D (26.3%), zone B (20.2%) and zone A (7.7%) respectively. A negative binomial generalised linear model was fit to the number of individuals of *Bianor angulosus* with Zones and Time as the predictors, and no interaction term. This model was selected

Table 6.3.8: Estimated regression parameters, standard errors, z-values and P-values for negative binomial generalised linear model fit to the number of *Pardosa pseudoannulata* sampled from different Zones (A–D) of paddy plant during various time periods (t1–t4) in paddy fields of Muriyad Kol wetland. Residual deviance–32.29, residual df–64.

	Estimate	**Std. Error**	**z value**	**P-value**
(Intercept)	2.282	0.143	15.975	< 0.001
ZoneB	-1.494	0.334	-4.477	< 0.001
ZoneC	-3.199	0.721	-4.434	< 0.001
ZoneD	-23.585	11459.491	-0.002	0.998
Timet2	-0.525	0.234	-2.239	0.025
Timet3	-0.308	0.22	-1.404	0.16
Timet4	-0.254	0.216	-1.176	0.24
ZoneB:Timet2	-21.567	11459.491	-0.002	0.999
ZoneC:Timet2	-19.862	11459.491	-0.002	0.999
ZoneD:Timet2	0.525	16206.168	0	0.998
ZoneB:Timet3	0.55	0.459	1.197	0.231
ZoneC:Timet3	0.308	1.024	0.301	0.763
ZoneD:Timet3	0.308	16206.168	0	1
ZoneB:Timet4	1.224	0.415	2.949	0.003
ZoneC:Timet4	2.394	0.778	3.077	0.002
ZoneD:Timet4	21.334	11459.491	0.002	0.999

based on comparisons of different models with Akaike Information Criterion (AIC) and model with the lowest value was selected. The results of the type II Analysis of deviance performed on the negative binomial generalised linear model fit to the number of individuals of *Oxyopes javanus* revealed significant differences among Zones ($\chi^2 = 40.244$, Df = 3, $p = 0.001$), but no significant difference in the number of individuals found between time periods. Individuals of *Bianor angulosus* had a negative association with Zone A, but was not significant (GLM estimate= -0.58, $p = < 0.092$). However other Zones had a positive association with the number of individuals occuring in them, among them Zone C and D were highly significant ($p = < 0.001$) (Table 6.3.6).

Most individuals of *Araneus ellipticus* were collected from zones C and D at different time periods. Only one individual was represented in the Zone B. Majority individuals were collected from zone D (55.9%), the rest in zone C (43.2%). According to the Vuong test, the standard negative binomial model outperformed the zero-inflated negative binomial model in this case. A negative binomial generalised linear model was fit to the number of individuals of *Araneus ellipticus* with Zones (C and D) and Time as the predictors, and interaction between

Table 6.3.9: Estimated regression parameters, standard errors, z-values and P-values for negative binomial generalised linear model fit to the number of *Tylorida striata* sampled from different Zones (A–D) of paddy plant during various time periods (t1–t4) in paddy fields of Muriyad Kol wetland. Residual deviance–49.23, residual df–54.

	Estimate	**Std. Error**	**z value**	**P-value**
(Intercept)	-0.14	0.271	-0.518	0.605
ZoneB	2.044	0.251	8.16	< 0.001
ZoneC	-0.057	0.338	-0.169	0.866
Timet2	-0.024	0.22	-0.11	0.913
Timet3	0.112	0.212	0.53	0.596
Timet4	0.047	0.216	0.216	0.829

Table 6.3.10: Estimated regression parameters, standard errors, z-values and P-values for negative binomial generalised linear model fit to the number of *Tetragnatha javana* sampled from different Zones (A–D) of paddy plant during various time periods (t1–t4) in paddy fields of Muriyad Kol wetland. Residual deviance–37.9, residual df–54.

	Estimate	**Std. Error**	**z value**	**P-value**
(Intercept)	-1.372	0.509	-2.697	0.007
ZoneC	3.384	0.508	6.657	< 0.001
ZoneD	3.434	0.508	6.76	< 0.001
Timet2	-0.719	0.198	-3.635	< 0.001
Timet3	-0.23	0.17	-1.349	0.177
Timet4	-0.137	0.166	-0.827	0.408

the predictors. The results of the type II Analysis of deviance performed on the negative binomial model fit to the number of individuals of *Araneus ellipticus* revealed significant differences among Time (χ^2 = 34.813, Df = 3, p = < 0.001), but no significant difference in the number of individuals found between Zones C and D and for interaction term. Number of *Araneus ellipticus* had a positve association with Time t1, but it was not significant (GLM estimate= 0.58, p = 0.07) (Table 6.3.7).

Individuals of *Pardosa pseudoannulata* were represented in all Zones of the paddy plant at different periods. Majority individuals were observed in zone A (65.8%), followed by zone B (23.37%). A negative binomial generalised linear model was fit to the number of *Pardosa pseudoannulata* with Zones, Time and interaction of both as the predictors. The results of the type II Analysis of deviance performed on the negative binomial generalised linear model fit to the number of *Pardosa* *pseudoannulata* revealed significant differences among Zones (χ^2 = 223.08, Df = 3, p = < 0.001), Time (χ^2 = 32.079, Df = 3, p = < 0.001), and their interaction (χ^2 = 57.441, Df = 9, p = < 0.001). Individuals of *Pardosa pseudoannulata* had a significant positive association with Zone A and Time t1 (GLM estimate= 2.28, p = < 0.001). Significant negative association of spiders was found with Time t2 (GLM estimate= -0.52, p = 0.025). Also, the individuals were positvely associated with the interaction of ZoneB and Time t4, and Zone C and Time t4 (p = < 0.001) (Table 6.3.8).

Majority individuals of *Tylorida striata* were collected from Zone B (78.9%) of the paddy plant at different periods, but some individuals were also found to occur in Zones A (10.22%) and C (9.6%). A negative binomial generalised linear model was fit to the number of *Tylorida striata* with Zones and Time as the predictors, with no interaction terms. The results of the type II Analysis of deviance performed on the negative binomial generalised linear model fit to the number of *Tylorida striata* revealed significant differences among Zones only (χ^2 = 159.118, Df = 3, p = < 0.001). Time had no significant effect on the location of spiders on any of the zones. Individuals of *Tylorida striata* had a significant positive association with Zone B only (GLM estimate= 2.04, p = < 0.001). The individuals wer negetively associated with the Zones A and C, but not significant (Table 6.3.9).

Majority individuals of *Tetragnatha javana* were found in Zone D (50.2%) and C (47.8%) of the paddy plant at different periods. A negative binomial generalised linear model was fit to the number of *Tetragnatha javana* with Zones and Time as the predictors, but no interaction terms. The results of the type II Analysis of deviance performed on the negative binomial generalised linear model fit to the number of *Tetragnatha javana* revealed significant differences among Zones (χ^2 = 164.27, Df = 2, p = < 0.001) and Times (χ^2 = 15.15, Df = 3, p = 0.001). Individuals of *Tetragnatha javana* had a significant negative association with Zone B (GLM estimate= -1.37, p = 0.007). There was significant positive associations with the Zones C and D (p = < 0.001). While, Times t1 and t2 were significantly negetively associated with the individuals of spiders (Table 6.3.10).

6.4 Discussion

The results suggest that the paddy fields in the Muriyad Kol wetlands harbour a considerable diversity of spiders, which is consistent with other studies in the region (Sebastian et al., 2005; Sudhikumar et al., 2005) and higher than from paddy fields in south Kerala (Anis Joseph & Premila, 2016). The species richness in the paddy fields of Muriyad Kol wetland based on the samples collected during the study period was estimated to be about 107 species using the first-order jacknife estimator. Each pooled sample from the Virippu, Puncha and Mundakan cropping seasons consisted of 60–70 species. During the study period, the diversity of spiders of rice fields were comparatively higher during the Puncha, which coincides with the summer. Species richness and diversity of spiders increased gradually with crop age and plant height in the rice fields (Bambaradeniya & Edirisinghe, 2009; Sudhikumar et al., 2005). The diversity and abundance of spiders in the kuttanad rice fields were the highest during the ripening stage (Sudhikumar et al., 2005).

Tetragnathidae, Araneidae, Salticidae, Lycosidae, Therdiidae, Oxyopidae and Linyphiidae were found to be the dominant families in the paddy fields of Muriyad Kol wetland. Tetragnathidae was mostly composed of *Glenognatha dentata, Tetragnatha javana, T. keyserlingi, T. mandibulata, T. squamata* and *Tylorida striata.* Of these, *G. dentata* was found to be most abundant in the paddy fields. Among Araneids, *Argiope catanulata, Araneus ellipticus, Argiope anasuja* and *Larinia phthisica* dominanted the fields. While, species like *Bianor kolensis* nov. sp., *B. angulosus* and *Hyllus semicupreus* were the most abundant among Salticidae. *Pardosa pseudoannulata* of Lycosidae was the most abundant species found in the paddy fields. Linyphiidae was mostly represented by *Erigone bifurca* and *Atypena cirrifrons*, whereas *coleosoma floridanum, Meotipa multuma* and *Phycosoma labialis* were the most dominant among Theridiids.

Glenognatha dentata, Pardosa pseudoannulata, Erigone bifurca, Tetragnatha mandibulata, Atypena adelinae, Phycosoma martinae, Araeneus ellipticus, and *T. cochinensis* were the dominant spiders in the Kuttanad rice fields (Sudhikumar, 2007). *Pardosa pseudoannulata* is considered as one of the most dominant species known in the rice agroecosystem, and as an important predator of *Nilaparvata lugens* (Ali, Kabir, et al., 2020; Okuma, Kamal, et al., 1993a). It was also the dominant species of Lycosidae in Chinese rice fields (Lu et al., 2002; Yang et al., 2018). Species like *G. dentata, Tetragnatha mandibulata, T. keyserlingi, T. javana, T. vermiformis, T. virescens, T. hasselti, T. ceylonica, T. chauliodus* (Thorell, 1890), *T. nitens* and *T. jaculator* Tullgren, 1910 represented the Tetragnathids in paddy fields of Bangladesh (Okuma, Kamal, et al., 1993a). The dominant species like *T. javana, T. keyserlingi , Leucage decorata, T. mandibulata, Araneus inustus, Argiope catanulata*, *Neoscona theisi*, *Pardosa pseudoannulata, Oxyopes javanus* and

Callitrichia formosana Oi, 1977 are highly adapted to wetland and dryland rice field environments (Barrion & Litsinger, 1984). In earlier studies, Tetragnathidae was mostly composed of spiders like *G. dentata, Tetragnatha javana, T. mandibulata* and *T. keyserlingi* (Sebastian et al., 2005; Singh & Singh, 2014; Sudhikumar, 2007; Sudhikumar et al., 2005). Other dominant spiders in paddy fields of the region were *Pardosa pseudoannulata, Erigone bifurca, Argiope catenulata, Atypena adelinae* Barrion & Litsinger, 1995, *Phycosoma martinae* and *Araeneus ellipticus* (Sudhikumar, 2007).

6.4.1 Guild composition

The study revealed that the proportion of guilds of spiders among different cropping seasons did not show any significant variations. Orb weavers, Other hunters, Ground hunters, Space Web weavers, Ambush Hunters and Sensing Web weavers were the guilds identified in the paddy fields during the study. Orb weavers dominated the spider assemblages in paddy fields, and it composed of spiders such as *G. dentata*, *T. striata*, *T. javana*, *T. mandibulata*, *T. keyserlingi*, *A. catenulata, A. ellipticus* and *L. phthisica.* Other hunters formed around a quarter of all individuals of spiders collected during the study and it included species such as *O. javanus*, *B. kolensis* sp. nov., *B. angulosus*, *E. bifurca* and *A. cirrifrons.* The number of species belonging to this group were greater than other guilds. However, *P. pseudoannulata* contributed most to the proportion of Ground hunters in the samples collected from the paddy fields. While Space web weavers were composed of species such as *Phycosoma labialis, coleosoma floridanum* and *Meotipa multuma.* A similar pattern of guild composition occurs in other rice ecosystems in the Kuttanad region of Vembanad-Kol wetland (Sudhikumar, 2007), and low-land and highland fields (Sebastian et al., 2005). Similar patterns of guild composition were observed in irrigated fields in northern India, with populations of different guilds peaking in rice fields reaching a peak by 90 DAT (Singh & Singh, 2014).

Each hunting behavior is best suited to a certain type of habitat structure (Hatley & Macmahon, 1980). In addition, the density of web-building spiders is related to the density of foliage, and larger web-building spider species were expected to be found in plants with a more open architecture. Because of the open structure of the crops as a whole, paddy fields provide plenty of opportunities for orb weavers. The guild composition of a crop's spider fauna, as well as the level of herbivore damage, may be influenced by structural complexity. (Sebastian et al., 2005). Different methods of obtaining a resource, as seen in the paddy fields, may result in the formation of multiple guilds within a microhabitat (Simberloff, 1991).

6.4.2 Effect of cropping season, crop growth and management

Spider abundance and diversity tend to rise in tandem with crop growth. In the rice fields of Muriyad Kol wetland, later stages of crop growth sustain a greater number of individuals and species than early growth stages. The abundance of spiders in paddy fields was found to be influenced by crop growth stages and cropping seasons, according to the current study. However, there was no discernible difference in the abundance of spiders in seasonal samples at different growth stages. Puncha season had the most individuals, followed by Mundakan and Virippu, during the cropping season. The abundance and density of spiders and their webs in irrigated highland rice fields has been shown to be largely influenced by the availability of prey or pests (Betz & Tscharntke, 2017; Kiritani et al., 1972). It has also been shown that the peak of spider population density is associated with an increase in insect pests (Kiritani et al., 1972; Yang et al., 2018). Spiders in late-stage rice fields had bigger niche breadth and niche overlap indices than spiders in early-stage rice fields.

Population ecology characteristics of paddy spiders vary by spider species, pest dynamics, region, rice planting patterns, and growth season (Yang et al., 2018). As the rice field matured, the spatial distribution of dominating spiders changed. Spiders in heterogeneous rice fields tend to change their prey type during the cropping season. They first feed on insects emerging from the aquatic system and then switch to terrestrial plant- and leafhopper prey later in the season (Radermacher et al., 2020). In response to population levels of rice pests such as planthoppers and leafhoppers, the niche breadth of spiders such as *P. subpraticus, Ummeliata insecticeps* (Bösenberg & Strand, 1906), and *T. keyserlingi* increased or decreased (Peng et al., 1997). Contrary to the present study, *T. javana* was associated with earlier stages of rice growth in studies done in Tamil Nadu (Jayakumar & Sankari, 2010). While *A. catanulata* was predominant with later stages of pladdy growth, *P. pseudoannulata* was present through out the cropping season. *Tetragnatha* spider abundance varies with plant growth, peaking during the reproductive phases of the plants and plummeting dramatically after harvest, most likely due to temporal changes in the attachment substrates and insect prey availability (Saksongmuang et al., 2020). Several insects move to paddy fields during the reproductive stage of the plants, drawn by the rice flowers, which provide them with a valuable source of food (Wilson et al., 2014). Spider population and richness declined after harvest, when the vegetation structure consisted of rice straw, stumps, and a tiny amount of vegetation, as a result of a decrease in insect diet and microhabitat. During these unfavourable conditions the spiders tend to migrate to surrounding habitats which provide more suitable conditions such as grasslands, levees or ditches (Bambaradeniya & Edirisinghe, 2009; Tsutsui, Tanaka, et al., 2016)

Organic or environmentally friendly management of rice fields in the region harboured greater abundance and richness of spiders compared to conventionally grown rice. The presence of weeds in some of these fields provide shelter and foraging space different from the monotonous paddy plants for spiders such as *Bianor* spp., *Larinia* spp., and *Araneus* spp. Herbaceous weed enhances spider species richness, most likely due to increased structural diversity, which gives web-building spiders additional options for fixing their webs or provides shelter for free-hunting spiders (Tahir & Butt, 2009). Organically managed fields provide a more complex and diverse physical environment that protects spiders from natural enemies while improving microhabitat. Organic farming can improve soil diversity and thus prey abundance, which in turn increases spider abundance. However, low levels of fertilizer and pesticide inputs have been shown to cause no adverse effect on the abundance of spider families in less intensive highland paddy fields in Kerala (Betz & Tscharntke, 2017).

Earlier studies have shown that environmentally friendly farming increased the populations of various organisms in agricultural fields (Ali, Bari, Ahmed, et al., 2017; Ali, Bari, Haque, et al., 2019b; Anitha et al., 2019; Baba & Tanaka, 2016). It also enhances species diversity and abundance of organisms in paddy field (Tsutsui, Tanaka, et al., 2016). It reduces agricultural output in most situations due to the abundance of diseases, pests, and weeds in rice fields. However, one way out may be to recognise and promote certain environmental conditions, such as landscape structures that favour a higher density of natural enemies in rice fields (Miyashita et al., 2012; Takada et al., 2012). Observations and discussions with farmers in the region show that organically managed rice fields adjacent to conventional fields are more resistant to pest invasions and produce better yields. Huge swarms of pest populations migrate from conventional fields to organic fields when pesticides are applied. However, it was observed that this had little impact on the organic fields as they were already saturated with natural enemies such as spiders. Application of natural manure, manual weed removal and non-aggressive natural pesticides were found to be sufficient to control pest outbreaks which rarely occur. Use of organic manure likely promote the population of detritivores and plankton feeders which in turn increase the spider populations. Furthermore, research have indicated that aggregated agricultural diversification strategies such as intercropping and non-crop strips, as well as intermittent diversification measures like as undersowing, partial weediness, mulching, and reduced tillage, boosts spider abundance (Sunderland & Samu, 2000).

Conventional farmers' arguments against organic farming are founded on the notion that it will not result in higher yields the following season. Organic farmers, on the other hand, say that, in addition to the numerous short-term benefits, organic fields have the potential to provide larger yields in later years with comparatively less investment. It has been shown that biodiversity does not respond immediately to changes in agricultural practises, but only with a delay. The time since conversion from conventional to organic farming seems to influence the abundance of some arthropods in rice fields (Andersson et al., 2010; Tsutsui, Kobayashi, et al., 2018).

Management practices such as Integrated Pest Management (IPM), organic or environmentally friendly farming have been shown to increase yield substantially. Practising IPM provided higher yields as well as high benefit cost ratio than conventional methods (Salam et al., 2021, August; Tanwar et al., 2016). It has the potential to improve crop resilience, and reduce damage to environmental systems associated with the excessive, indiscriminate usage of chemical pesticides. The abundance of Predators like coccinellids and spiders increased significantly in IPM experimental plots in the Kol wetland which was treated with parasitoid *Trichogramma japonicum* (Lyla et al., 2010). Excessive use of insecticides applied 3-4 times in a rice growing season has been shown to have no significant effect in controlling the pest population compared to the fields of IPM. The population of natural enemies increased when no pesticides were used, especially in the early stages of plant development, a period upto 30–40 DAT (Ali, Bari, Ahmed, et al., 2017; Baba, Kusumoto, et al., 2018). Synthetic pesticides can harm non-target pest organisms and could induce outbreaks of secondary pest (Ahmed et al., 2002; Travisi et al., 2006), therefore avoiding unnecessary application of insecticides during the early stages of paddy growth could boost populations of natural enemies, such as spiders, which could be enough to control abnormal pest outbreaks and minimise crop loss. Excessive use of pesticides can also harm beneficial animals such as birds, frogs, lizards, beetles and parasitoids (Dutcher, 2007). Furthermore, the proportion of organic rice fields in the landscape was found to be positively related to waterbird diversity and abundance (Ibáñez et al., 2010; Katayama et al., 2019). A well-thought-out pest management strategy, on the other hand, improves services while also providing food for a variety of natural enemies (Hillocks & Cooper, 2012).

Investigations in this area are critical for developing solid government policies on sustainable and ecologically friendly agriculture. Future studies on the long-term changes in predator structure in converted rice fields in the region could be useful to understand how it will enhance biodiversity and prevent further degradation of the fields.

6.4.3 Species turnover and changes in species rank abundance

The study suggested that the spider community has a gradually declining trend in species turnover across the growth interval of the paddy crops. Species turnover was the lowest during the flowering and maturation stages of paddy growth. Species appearances contributed most to the overall species turnover in the paddy fields. Growth stages between 25–40 DAT showed greater values in terms of richness change compared to other stages of crop growth. This increase is presumed to be due to the increase in colonisation by novel species from the surrounding habitats into the paddy fields, probably driven by increased structural complexity of vegetation and insect prey availability. Earlier studies have shown that the population density of web-builders and non-web builders in the paddy fields of Kuttanad differed among the growth stages (Sudhikumar, 2007).

The shift in species rank abundance was similar and showed no major differences between cropping seasons. However, the results suggest a greater reshuffling in species ranks occuring during the periods of transition from the vegetative to the reproductive phase in rice fields. There was variation in the species rank of dominant spiders across different growth stages from the initial to the time of harvest. For example, there was a gradual shift in the ranks of *T. javana* and *P. pseudoannulata* during the cropping seasons. The latter is a dominant ground hunter, found in large numbers in the structurally less diverse habitat in the initial phase of crop growth. However, as the crop becomes more structurally complex, species such as *T. javana*, which is an open hub orb weaver, proliferate and occupy the top position of the rice plants. Yet, the population of *P. pseudoannulata* remained high among the top dominant spiders in the later stages of paddy growth.

Spider population growth is thought to be due to a bottom-up effect in ecosystems such as rice fields, and is dependent on the abundance of insect prey such as dipterans, like in the case of *Tetragnatha* (Tsutsui, Tanaka, et al., 2016). Tetragnatha species such as *T. keyserlingi* and *T. extensa*, are known for their complementary ultilisation of paddy and adjacent ditches through the seasons for survival (Saksongmuang et al., 2020; Tsutsui, Tanaka, et al., 2016). Different ecological, physical or geographical factors affect the degree of temporal turnover across organisms and ecosystems. The degree of temporal turnover was also influenced by organism characteristics, with larger organisms with active mobility having a slower temporal turnover than smaller organisms (Korhonen et al., 2010).

6.4.4 Vertical stratification

Studies on the vertical stratification of selected spiders at different times of the day in the paddy fields revealed that spiders such as *P. pseudoannulata* changed their vertical location on the rice plant depending on the time of the day. Ground hunter *P. pseudoannulata* was generally found in the lower strata of the rice plants during the day, although it also foraged in the upper stratas during the night hours, albeit with low frequency. *P. pseudoannulata* is adapted to life on water surfaces and is often seen moving over it when fields are flooded. The vertical position of the spider increases with the growth of the rice fields and also depends on the availability of prey as the crop grows (Kiritani et al., 1972). Solar radiation and temperature may affect the vertical location of spiders, since spiders like *P. pseudoannulata* was observed at higher parts at night (Murata & Tanaka, 2004). The spiders keep themselves in the lower parts of the plants probably to prevent heating up their body to a dangerous level during the day time (Kiritani et al., 1972).

T. javana, on the other hand, preferred to make orb webs in the upper zones of the plant during the night hours and in the morning and evening, but it has been observed that they retreat to lower zones when the sun begins to hit hard. During the day and when agitated, spiders retreat to the undersides of leaves and among the tillers. Tetragnathids generally forage at night and also found occuppying webs in the early morning and evening on rice fields (Murata & Tanaka, 2004). Most of the Tetragnathidae and Araneidae of paddy fields prey on insects such as adults of stem borer, leaf folder adults, green leaf hopper, Diptera, dragonflies, damsel flies flying at heights of the rice canopy (Anitha et al., 2019).

During the day, species such as *O. javanus* were most abundant in the lower zones of the plant, but at night majority of individuals were collected in the upper zones. *Bianor angulosus* was predominantly found to occur in the upper zones of the plants, but they are also found rarely in the bottom zones. *T. striata*, on the other hand, are orb weavers that mostly occupy the region between 25 to 50 cm above the ground. Stratification was also observed among the juveniles and adults in orb weavers. Juveniles of *T. striata* and *T. javana* forage in the lower strata compared to the adults. Orb web spiders are known to chose different vegetation heights at different instars (Enders, 1974). Some spiders in the paddy fields, such as *Clubiona kurilensis*, use a foraging strategy in which they switch prey species based on prey density and congregate in areas with high prey density. (Murata & Tanaka, 2004). Environmental opportunity within a habitat may result in size-dependent spatial distribution (Salomon et al., 2010). *G. dentata*, the orb weaver, is almost exclusively found in the paddy plant's lower zone, foraging in the gap between the rice stalks. Also, space web weavers are commonly seen in the plant's lower two zones. Shade and humidity are ideal circumstances for little spiders of the Linyphiidae and Theridiidae, which thrive in dense and compact vegetation (Mathew et al., 2014).

6.5 Conclusion

Paddy fields harbour a diverse group of terrestrial arthropods, including spiders, which play an important role as predators of pests and are known to be good natural pest control agents. The unique geographical features of the landscape require different management practises for rice cultivation. This often affects the abundance and diversity of spiders in the fields. The findings of the study show that there was a general and consistent pattern in the community dynamics of spiders during the cropping season. There was also a significant influence of crop growth, cropping season and management practises on spider community abundance and richness. In the Puncha and Mundakan cropping seasons, spider abundance was greater than in the Virippu cropping season. There were no significant variation in the proportion of functional groups between the different cropping seasons. Abundance and species richness gradually increased as the plants grew until they reached maturation phase. Species turnover, on the other hand, showed a declining trend as most species appeared in the initial phase of crop growth. However, with the increasing structural complexity of the vegetation and the availability of prey, novel species appear to colonise the fields from the surroundings. The study also suggests that major shifts in community structure occur during the transition from the vegetative to the reproductive phase.

Many species in the agroecosystem compete for the same resources and forage at different levels of the plant, depending on size, foraging strategy, availability of prey, structural complexity and so on. The spatial distribution of many dominant species changes as the crop matures and the structural complexity of the plants increases. In the later stages of crop growth, when spider diversity and abundance increase, the niche breadth and niche overlap of many species become greater. In addition, there is also vertical stratification within the population of many species. The clearest example would be species of *Tetragnatha*, whose adults forage with larger horizontal webs near the leaf canopy of the rice plant, while the smaller juveniles forage with smaller webs in the lower strata of the plant. The study on the vertical spatial distribution of selected species showed that their positions on the plants change with the time of day. Various factors and circumstances such as prey availability, competition, structural complexity, protection from predators, space, shade, humidity and temperature could be the reason for the development of such foraging strategies.

Environmentally friendly farming methods in paddy fields are a good way to increase the spider richness and abundance compared to conventional methods. The population of spiders in fields is strongly influenced by the availability of prey or pests, which is especially noticeable in environmentally friendly fields with a higher density of insects. Many studies have supported the promotion and enhancement of natural pest control in rice fields. Environmentally friendly or organic farming and, to a lesser extent, integrated pest management methods are the best way to promote sustainable agriculture and counteract agricultural intensification, which always has a negative impact on biodiversity. Besides increasing crop yields and improving natural pest control, these methods also have the potential to enhance biodiversity and prevent further degradation of existing rice fields. However, it is important to realise that the road to organic farming takes time, as the converted fields would need a few crop cycles to reach their full potential as a higher yielding system. With this in mind, we need to find ways to reduce the impact of yield losses during the transition period and motivate farmers.

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Appendix

Table 6.A.1: Families and individuals of spiders sampled from Virippu, Mundakan and Puncha cropping seasons in the Muriyad Kol wetland.

Guild	**Family**	**Virippu**	**Mundakan**	**Puncha**
Orb Weavers	Araneidae	191	253	275
Other hunters	Clubionidae	8	7	7
Ground hunters	Corinnidae	4	8	4
Ground hunters	Gnaphosidae	0	0	1
Other hunters	Linyphiidae	49	83	60
Ground hunters	Lycosidae	169	223	203
Other hunters	Miturgidae	13	16	14
Sensing web	Oecobiidae	2	2	4
Ground hunters	Oonopidae	1	1	0
Other hunters	Oxyopidae	78	111	91
Ground hunters	Philodromidae	10	3	7
Space webs	Pholcidae	5	15	14
Other hunters	Salticidae	135	188	185
Other hunters	Scytodidae	1	0	0
Other hunters	Sparassidae	2	0	3
Orb Weavers	Tetragnathidae	443	557	622
Space webs	Theridiidae	113	120	143
Orb Weavers	Theridiosomatidae	15	8	14
Ambush hunters	Thomisidae	24	15	27
Orb Weavers	Uloboridae	0	0	1
	Total	**1263**	**1610**	**1675**

Table 6.A.2: Estimated regression parameters, standard errors, z-values and P-values for the negative binomial GLM fit to abundance of spiders sampled from different cropping seasons of paddy fields in Muriyad Kol wetland, including the multiple comparisons of means using Tukey contrasts. Bold numbers indicate significance. Residual Df–74.107, Df 61.

	Estimate	**Std. Error**	**z value**	**P-value**
Effects				
(Intercept)	3.011	0.07	43.152	0.001
DAT40	0.558	0.075	7.399	0.001
DAT55	0.766	0.073	10.448	0.001

Continued on next page

Table 6.A.2 – continued from previous page

	Estimate	Std. Error	z value	P-value
DAT70	0.916	0.072	12.709	0.001
DAT85	0.977	0.072	13.638	0.001
DAT100	0.981	0.072	13.7	0.001
ManageOrg.	0.63	0.071	8.852	0.001
Crop..SeasonMundakan	0.063	0.065	0.974	0.33
Crop..SeasonPuncha	0.395	0.055	7.184	0.001
ManageOrg.:Crop..SeasonMundakan	0.032	0.095	0.332	0.74
ManageOrg.:Crop..SeasonPuncha	-0.314	0.098	-3.216	0.001
Linear Hypotheses:				
Mundakan-Virippu	0.063	0.065	0.974	0.99
Puncha-Virippu	0.395	0.055	7.184	0.001
Puncha-Mundakan	0.332	0.061	5.409	0.001
40-25	0.558	0.075	7.399	0.001
55-25	0.766	0.073	10.448	0.001
70-25	0.916	0.072	12.709	0.001
85-25	0.977	0.072	13.638	0.001
100-25	0.981	0.072	13.7	0.001
55-40	0.209	0.065	3.225	0.019
70-40	0.359	0.063	5.67	0.001
85-40	0.419	0.063	6.686	0.001
100-40	0.423	0.063	6.753	0.001
70-55	0.15	0.061	2.468	0.204
85-55	0.211	0.06	3.497	0.007
100-55	0.215	0.06	3.566	0.005
85-70	0.061	0.059	1.034	1
100-70	0.065	0.059	1.103	1
100-85	0.004	0.058	0.069	1

Table 6.A.3: Estimated regression parameters, standard errors, z-values and P-values for the negative binomial GLM fit to richness of spiders sampled from different cropping seasons of paddy fields in Muriyad Kol wetland, including the multiple comparisons of means using Tukey contrasts. Bold numbers indicate significance. Residual Df–52.59, Df 63.

	Estimate	Std. Error	z value	P-value
Effects				

Continued on next page

Table 6.A.3 – continued from previous page

	Estimate	Std. Error	z value	P-value
(Intercept)	2.381	0.092	25.984	0.001
DAT40	0.283	0.108	2.614	0.009
DAT55	0.466	0.104	4.472	0.001
DAT70	0.613	0.101	6.051	0.001
DAT85	0.67	0.1	6.669	0.001
DAT100	0.693	0.1	6.931	0.001
Crop..SeasonMundakan	-0.2	0.067	-3.002	0.003
Crop..SeasonPuncha	0.04	0.063	0.632	0.527
ManageOrg.	0.507	0.054	9.298	0.001
Linear Hypotheses:				
Mundakan-Virippu	-0.2	0.067	-3.002	0.008
Puncha-Virippu	0.04	0.063	0.632	1
Puncha-Mundakan	0.24	0.066	3.635	0.001
40-25	0.283	0.108	2.614	0.134
55-25	0.466	0.104	4.472	0.001
70-25	0.613	0.101	6.051	0.001
85-25	0.67	0.1	6.669	0.001
100-25	0.693	0.1	6.931	0.001
55-40	0.183	0.096	1.909	0.845
70-40	0.331	0.093	3.559	0.006
85-40	0.387	0.092	4.211	0.001
100-40	0.41	0.091	4.49	0.001
70-55	0.148	0.088	1.671	1
85-55	0.204	0.087	2.337	0.292
100-55	0.227	0.087	2.622	0.131
85-70	0.056	0.084	0.67	1
100-70	0.08	0.083	0.957	1
100-85	0.024	0.082	0.287	1

Table 6.A.4: Summary of generalised linear model fit to the relative abundance of individual spider guilds among different cropping seasons of paddy in the Muriyad Kol wetland, including the multiple comparisons of means using Tukey contrasts.

	Estimate	Std. Error	z value	P-value
Space web weaver				

Continued on next page

Table 6.A.4 – continued from previous page

	Estimate	Std. Error	z value	P-value
Effects				
(Intercept)	-2.271	0.097	-23.484	0.001
HabitatMundakan	-0.119	0.132	-0.902	0.367
HabitatPuncha	0.004	0.128	0.035	0.972
Other hunters				
Effects				
(Intercept)	-1.226	0.067	-18.238	0.001
HabitatMundakan	0.138	0.088	1.558	0.119
HabitatPuncha	-0.066	0.09	-0.735	0.462
Linear hypotheses				
Mundakan-Virippu	0.138	0.088	1.558	0.358
Puncha-Virippu	-0.066	0.09	-0.735	1
Puncha-Mundakan	-0.204	0.083	-2.463	0.041
Orb weavers				
Effects				
(Intercept)	0.059	0.056	1.042	0.298
HabitatMundakan	-0.024	0.075	-0.317	0.751
HabitatPuncha	0.125	0.075	1.671	0.095
Ground hunters				
Effects				
(Intercept)	-1.767	0.08	-22.151	0.001
HabitatMundakan	0.002	0.107	0.017	0.986
HabitatPuncha	-0.146	0.108	-1.348	0.178
Ambush hunters				
Effects				
(Intercept)	-3.942	0.206	-19.129	0.001
HabitatMundakan	-0.723	0.331	-2.182	0.029
HabitatPuncha	-0.167	0.283	-0.589	0.556

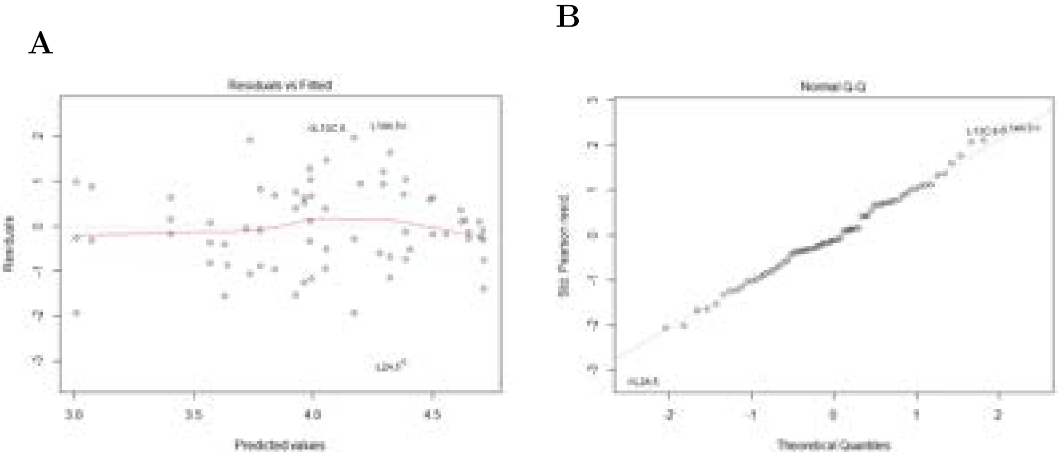

Figure 6.A.1: Diagnostic plots of negetive binomial GLM fit to abundance of spiders in the paddy fields: **A.** Residual vs. fitted values plot to check the quadratic mean–variance assumption of negative binomial regression; **B.** Normal Q-Q plot.

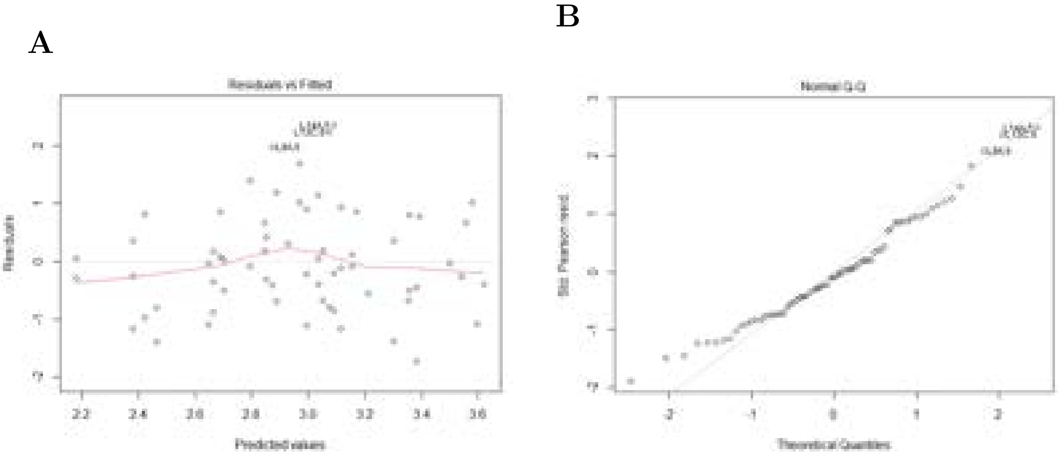

Figure 6.A.2: Diagnostic plots of negetive binomial GLM fit to species richness of spiders in the paddy fields: **A.** Residual vs. fitted values plot to check the quadratic mean–variance assumption of negative binomial regression; **B.** Normal Q-Q plot.

Table 6.A.5: Vertical straification of *Oxyopes javanus*, *Araneus ellipticus*, *Bianor angulosus*, *Pardosa pseudoannulata*, *Tylorida striata* and *Tetragnatha javana* on paddy plants in the Muriyad Kol wetland. Zone A is at the bottom of the plant and Zone D at the top.

	Oxyopes javanus				*Pardosa pseudoannulata*			
Time	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**
0800-0900 hrs (t1)	16	4	2	1	49	11	2	0
1300-1400 hrs (t2)	16	4	5	1	29	0	0	0
1700-1800 hrs (t3)	7	9	11	7	36	14	2	0
2000-2100 hrs (t4)	4	6	13	18	38	29	17	4
Total	43	23	31	27	152	54	21	4
	Araneus ellipticus				*Tylorida striata*			
Time	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**
0800-0900 hrs (t1)	0	0	9	8	5	34	3	0
1300-1400 hrs (t2)	0	1	4	2	5	34	2	0
1700-1800 hrs (t3)	0	0	8	12	5	36	6	1
2000-2100 hrs (t4)	0	0	17	27	3	35	6	1
Total	0	1	38	49	18	139	17	2
	Bianor angulosus				*Tetragnatha javana*			
Time	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**
0800-0900 hrs (t1)	7	4	15	10	0	3	33	42
1300-1400 hrs (t2)	1	2	13	6	1	1	21	16
1700-1800 hrs (t3)	2	10	13	11	0	0	33	29
2000-2100 hrs (t4)	0	10	18	7	0	0	31	37
Total	10	26	59	34	1	4	118	124

7 | Summary and Conclusion

The Muriyad Kol wetland is one of the most valuable and threatened freshwater ecosystems in Kerala. These wetlands harbour numerous specialised and generalist spider species typically associated with vegetation. The landscape consists of low-lying, seasonally or perennial water logged area, plains, elevated, and crested areas that form a mosaic of diverse man-made and natural or semi-natural habitats, such as agricultural lands, fallow lands, riparian areas, home gardens, groves, streams, grasslands, and lakes. This study provides an inventory of the spiders that inhabit the different habitats in the wetland landscape. Emphasis was placed on understanding diversity patterns and ecological processes at spatial and temporal scales.

7.1 Survey of spiders

The spider survey identified a total of 195 species in the wetland landscape, including 10 new spider species. The new species accounted for about five per cent of all species reported during the study. It also provided the taxonomic accounts of many species with descriptions and illustrations, which included the redescription of species. *Bianor kolensis* sp. nov., *Cocalus lacinia* Sudhin, Nafin, Sumesh & Sudhikumar, 2019, *Epeus triangulopalpis* Malamel, Nafin, Sudhikumar & Sebastian, 2019, *Hyllus kerala* sp. nov., *Chinattus thamannae* sp. nov., *Piranthus planolancis* Malamel, Nafin, Sudhikumar & Sebastian, 2019, *Stertinius aluva* sp. nov., *Tamigalesus noorae* sp. nov., *Tamigalesus* sp. nov. and *Tetragnatha concordia* sp. nov. were the new species found in the study. The results also include some redescriptions, first reports of five species and one genus from India, and the revision of the genus *Psellonus*. The natural history of many species was also discussed. The oriental genus *Piranthus* was also rediagnosed based on the discovery of the first male specimen of the genus. The species such as *Phoroncidia septemaculeata* O. Pickard-Cambridge, 1873, *Argyrodes kumadai* Chida & Tanikawa, 1999, *Larinia* *tabida* (L. Koch, 1872), *Tetragnatha squamata* Karsch, 1879 and *Tetragnatha serra* Doleschall, 1857, and the genus *Stertinius* are reported from India for the first time.

7.2 Diversity and community structure of spiders

The wetland landscape of the study area is a matrix of different habitats, including tiny fragments of semi-natural landscape structures that harbour diverse assemblages of spiders uniquely associated with the respective habitats. The study showed that habitat type, crops and management practices influence the abundance, diversity, and community structure of spiders. The most species-rich and diverse habitat in the study area was the uncultivated or semi-natural habitat, followed by riparian and mixed crops. On the other hand, the results showed that paddy fields, grasslands and banana plantations had comparatively lower diversity. The spider community in paddy fields showed variability in abundance depending on many factors such as area, habitats surrounding the field, etc. Diversity was also lower in paddy fields and grasslands than in closed canopy habitats, with the exception of banana plantations. The spider communities showed a considerable degree of variation in species identities between habitats. Monsoon rains were found to be the driver responsible for seasonal changes in spider communities, and influences on local diversity and seasonal changes within sites belonging to different habitats. Analysis of multiple site dissimilarity based on abundance and richness metrics showed that balanced variation and species replacement contributed more to overall dissimilarity. Studies on community structure showed that paddy fields are characterised by a community dominated by a few highly successful spider species that use the majority of the resources. Grasslands and uncultivated sites showed a distribution typical of unstable habitats, usually linked to a number of factors acting in sequence. In contrast, banana plantations, mixed crops and riparian sites had a distribution typical of stable and diverse communities.

7.3 Composition and habitat associations of spiders

The study showed that the different habitats in the Muriyad Kol wetland supported distinct species assemblages. Many species were found to be significantly associated with different habitats. The results show that sites belonging to paddy fields and grasslands have significantly different species composition, although they share many of the species in their assemblages. The composition of spider guilds also showed significant differences in their proportions between habitats, both in terms of relative abundance and relative species richness. The study also provided a reduced list of indicator species for each habitat, and some species that were strongly associated with the habitats also had higher indicator values.

7.4 Paddy field spiders: Turnover, temporal dynamics and vertical stratification

This chapter dealt with the spiders of the paddy fields in the wetlands. Spiders are the predominant group of predators in paddy fields of Muriyad Kol wetlands and the Richness was estimated to be about 107 species using the first-order jacknife estimator. Tetragnathidae, Araneidae, Salticidae, Lycosidae, Therdiidae, Oxyopidae and Linyphiidae were the dominant families in the paddy fields. Different management practises for rice cultivation in the wetlands often affect the abundance and diversity of spiders. The results of the study show that there was a general and consistent pattern in the community dynamics of spiders during the cropping season. There was also a significant influence of crop growth, cropping season and management practises on spider community abundance and richness. During the study period, the diversity of spiders in the paddy fields was higher in the Puncha cropping season than in the Virippu and Mundakan seasons. Species richness and diversity of spiders gradually increased with crop age and plant height in the paddy fields. Species turnover, on the other hand, showed a declining trend as most species appeared in the early stages of crop growth. The studies showed that community structure of spiders changes greatly during the transition from the vegetative to the reproductive phase of the crop. The proportion of spider guilds in the different cropping seasons did not show significant differences. The results showed that the vertical distribution of selected species such as *Oxyopes javanus, Pardosa pseudoannulata, Bianor angulosus, Tylorida striata, Tetragnatha javana* and *Araneus ellipticus* on the plants changed with the time of day. The spatial distribution of many predominant species also changes with the maturity of the crop and the structural complexity of the plants.

8 | Recommendations

The Muriyad Kol wetland is part of the Kol wetland, which is one of the most important and unique wetlands in Kerala. The objective of the present study was to investigate the diversity of spider fauna in the Muriyad Kol wetlands. It was also an attempt to elucidate some of the questions related to diversity patterns and ecological processes of spiders at spatial and temporal scales. However, the study area hosts a huge population of diverse taxa that directly or indirectly provide ecosystem services that benefit the crops predominant in the landscape and the people living around them. Studies in agroecosystems should therefore include multiple taxa and their interactions to understand the dynamics and impacts of different management practices. Currently, the world is experiencing an unprecedented decline in biodiversity due to a variety of reasons, and the extent of the loss is unimaginable due to the lack of sufficient taxonomic and ecological knowledge about many extant fauna and flora. This is especially true for arthropods, which account for more than 80 % of all known living animal species. Traditional agricultural areas are among the systems that have the potential to conserve biodiversity and are identified as important areas outside protected areas under the novel concept of “other effective area-based conservation measures”(OECMs). The following are the recommendations for future research and conservation in agroecosystems such as Kol wetlands:

1. Research on taxonomy and systematics of spiders and other invertebrates should be encouraged. The Western Ghats region is one of the biodiversity hotspots in the world and hosts many protected and unprotected areas. Moreover, many of the agricultural landscapes in the region are capable of harbouring greater biodiversity. Further surveys should be encouraged not only in the protected areas but also in the agricultural landscapes, including those surrounded by semi-urban areas such as the Kol wetlands.

2. Further studies to improve the biological control potential of spiders in

agroecosystems, especially rice ecosystems. Several factors are known to increase the population of spiders in the paddy fields. For example, fallow fields adjacent to paddy fields and the presence of keystone structures in the fields are known to improve the population and resistance of spiders to pesticide applications.

3. A study of particular interest would be to investigate the influence of different farming systems and management practices on multiple taxa (plants, birds, invertebrates, amphibians, etc.).

4. Environmentally friendly or organic farming has many advantages over conventional farming methods, especially in paddy fields, both in terms of conservation and improved crop resistance to pest attack. Environmentally friendly farming systems vary significantly by region, depending on differences in landscape, climate and trophic interactions, which in turn shape the biological communities in rice agro-ecosystems. Therefore, regional studies need to focus on the trade-offs between farm-scale biodiversity, yields and yield stability in environmentally friendly fields. In addition, studies at regional or larger spatial scales would be useful to determine whether the proportion of organic fields in a landscape has an impact on water bird richness and abundance.

5. A study of the socio-economic impact of environmentally friendly or organic farming on marginal farmers in the region is needed, taking into account the increased labour input, yield loss and input price that goes into the process.

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Glossary

Cyperus iria also called rice flat sedge, considered a weed in paddy fields.

Echinochloa crus-galli a type of wild grass, also called barnyard grass, considered one of the world's worst weeds, it reduces crop yields and causes crop failure by removing up to 80% of the available soil nitrogen.

Hieroglyphus banian a grasshoper belonging to family Acrididae, considered as pest of paddy, polyphagous, both adults and nymphs feed on paddy and other crops causing defoliation.

Oxya nitidula also called rice grasshoppers, considered as paddy pest, belonging to family Acrididae

Pelopidas mathias also called dark small-branded swift, considered a rice pest butterfly, belonging to the family Hesperiidae.

Abdomen opisthosoma; posterior part of the body of a spider.

Apophysis an appendage changing the general cylindrical or globular shape of a sclerite, used for description of male palp.

Calamistrum a comb-like row or rows, or oval area, of modified setae on metatarsus iv of cribellate spiders, used to comb silk produced by the cribellum.

Carapace dorsal sclerite covering cephalothorax, anterior part of body.

Cephalic region frontal part of cephalothorax, delimited by cervical grooves.

Chelate chelicerae in which the fang closes down on a tooth like process.

Chelicerae the first pair of appendages of the head, consisting of a stout basal portion and a terminal fang which fits into a groove or furrow.

Colulus short median protuberance in front of spinnerets, considered a modification of the cribellum.

Condyle lateral boss at base of chelicerae.

Cribellate provided with a cribellum.

Culm the culm is the jointed rice stem that develops from the plumule (primary bud of the seed embryo) and is composed of solid centres and hollow internodes.

Cymbium dorsal part of male palpal tarsus, often hollow, usually with carrying a complex bulb.

Ecribellate without a cribellum and calamistrum.

Embolus part of male palpal bulb, usually slender, pointed and strongly sclerotized, carrying terminal part of sperm duct.

Entelegyne refers to spiders with an epigyne, having separate ducts for sperm transport during insemination towards spermathecae and fertilization towards uterus.

Epigyne a chitinous plate with the genital openings on ventral side of female abdomen; fully developed in adult females of entelegyne spiders; spiders belonging to mygalomorphae and haplogyne araneaomorphae do not have an epigyne.

Femur one of the seven leg segments, third segment from base.

Fovea a central depression on carapace, often reduced to a longitudinal dark stripe, corresponding with an internal ridge to which muscles are attached.

Haematodocha membranous and inflatable part of bulb in male palp.

Haplogyne spiders lacking an epigyne, having only one pair of ducts for transport of sperm from uterus to spermathecae during insemination and back to uterus for fertilization.

Kleptoparasitism a form of feeding in which one animal takes prey or food material that was caught by other animal, including stored food.

Labium sclerite situated between endites in front of sternum.

Leg cuspules very short macrosetae present on legs, typical of many members of Trachelidae, most often in males

Male palp modified tarsus of the palp in male spiders, a copulation organ with no direct connection to testes. consisting of an enlarged and hollow tarsus or cymbium, sometimes split in two (cymbium and paracymbium), holding the sexual organs. the shape and complexity varies and are the most important characters for species identification in male spiders.

Median apophysis an apophysis of male palpal bulb, usually with membranous insertion.

Onychium ventrally extended part of the tip of tarsi bearing the claws.

Orb a web consisting of circular strands and radii, in one plane.

Panicle a much-branched inflorescence of grass.

Paracymbium appendage of cymbium on male palp, may be a separate sclerite.

Promargin dorsal margin of cheliceral furrow.

Rachis a stem of a plant, especially a grass, bearing flower stalks at short intervals.

Radix basal segment of the embolic subdivision.

Rebordered with a thickened edge; a sclerite in which the margin is thicker than the main part.

Retrolateral tibial apophysis an excrescence or appendage on the retrolateral side of tegulum of male palpal bulb.

Retromargin ventral margin of cheliceral furrow

Sclerite a single sclerotized part of external, hardened tegument.

Scopulae brush of setae on distal end os endites or ventral region of distal leg segments or promargin of chelicerae; enhance grip on prey or substrate.

Scutum sclerotized plate on abdomen of some spiders.

Septum a partition separating two cavities.

Setae hair-like, tapered and flexible structure on the surface of legs and body (cf. spine and trichobothrium), s = seta.

Sigilla s = sigillum, circular impressions on sternum of some mygalomorphae and dorsum in some araneomorphae, corresponds with internal muscular attachment.

Spigots tiny cusps at apex of spinnerets from which silk emerges.

Spine pointed strong structures found on body and legs, usually articulating.

Stabilimentum band of dense silk in a web.

Sternum a large sclerite on ventral side of cephalothorax, between leg coxae and behind the labium.

Striae a slight ridge or groove on the surface of integument.

Sustentaculum a thick macroseta with bent tip situated behind the accessory claws on tarsi iv.

Synanthropic organisms living in close association with humans.

Tapetum a light-reflecting layer in secondary eyes (ale, pme and ple); eyes appear pale or creamy in colour; assumably used for nocturnal vision.

Tarsi seventh segment of leg from the base, s = tarsus.

Tegulum part of the bulb housing sperm duct which terminates in embolus.

Thoracic region posterior part of cephalothorax.

Tibia one of the seven leg segments, fifth segment from base.

Tiller rice tiller is a specialized grain-bearing branch that is formed on the unelongated basal internode and grows independently of the mother stem (culm) by means of its own adventitious roots.

Trichobothria flexible hair-like structure of variable length, on legs and palp, implanted in shallow alveolus.

Trilobate membrane three lobed membrane on the distal metatarsi, allowing for hypermobility of tarsi.

Trochanter second segment of leg from the base.

Annexure

LIST OF PUBLICATIONS AND PRESENTATIONS

Publications in Journals

Nafin, K. S., Maddison, W. P., & Sudhikumar, A. V. (2020). The first described male of the Asian jumping spider genus *Piranthus* Thorell, 1895 (Araneae: Salticidae: Baviini). *Peckhamia*, 207(1), 1–7. **ISSN 21618526**

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Nafin K.S., Sudhin P. P., Sudhikumar A. V. Effect of fringe vegetation on the diversity and community structure of paddy field spiders (Arachnida: Araneae) of Muriyad Kol Wetlands, Kerala. In: *Faunal diversity and re-*

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International Seminars

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Effect of fringe/surrounding vegetation on the abundance and diversity of paddy field spider (Arachnida: Araneae) of Kol wetlands, Kerala, India. 31st European Congress of Arachnology, Vac, Hungary, July 2018.

Effect of forest fire on diversity of spiders- a case study from Western Ghats, India.31st European Congress of Arachnology, Vac, Hungary, July 2018.

Diversity of sand dune spiders in Great Indian Thar desert, 31st European Congress of Arachnology, Vac, Hungary, July 2018.

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