A PRELIMINARY STUDY ON BIODIVERSITY OF BUTTERFLIES IN CHRIST AUTONOMOUS COLLEGE, IRINJALAKUDA, KERALA, WITH SPECIAL FOCUS ON HOST PLANT AND NECTAR PLANT

DISSERTATION SUBMITTED

IN PARTIAL FULFILMENT OF THE REQUIREMENTS

FOR THE AWARD OF THE DEGREE OF

MASTER OF SCIENCE IN ZOOLOGY

UNIVERSITY OF CALICUT

By

ANAGHA CHELAT

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JULY 2023

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DECLARATION

I, Anagha Chelat, do hereby declare that the dissertation entitled **A PRELIMINARY STUDY ON BIODIVERSITY OF BUTTERFLIES IN CHRIST AUTONOMOUS COLLEGE, IRINJALAKUDA, KERALA , WITH SPECIAL FOCUS TO HOST PLANT AND NECTAR PLANT,** is an authentic record of original work carried out by me under the guidance of Dr.Sr.Dilla Jose, Assistant Professor, Christ College, Irinjalakuda and that no part of the thesis has been presented for the award of any other degree or diploma in any University.

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CONTENTS

A STUDY OF AVIAN DIVERSITY IN THE THREE SELECTED HABITATS OF MATTATHUR PANCHAYAT, THRISSUR, KERALA

DISSERTATION SUBMITTED

IN PARTIAL FULFILMENT OF THE REQUIREMENTS

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MASTER OF SCIENCE IN ZOOLOGY

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I further certify that no part of the work has been presented before for the award of any other degree/ diploma.

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I feel the inadequacy in expressing my sincere heartfelt gratitude towards **Dr. Sr.Dilla Jose**, Assistant professor, Department of Zoology, Christ College (Autonomous), Irinjalakuda for suggesting this topic and encouraging me throughout my study. Without her expert guidance and dedicated involvement at each and every step, this research work would not have never been accomplished in the present form. I would like to express my indebtedness and deep sense of gratitude to **Dr.Sudhikumar A.V,** Head of the Department of Zoology, Christ College, Irinjalakuda for all his support and the facilities provided to me in the department. My heartfelt thanks to **Rev. Dr. Jolly Andrews**, Principal, Christ College, Irinjalakuda for granting me all the facilities for the work. I also thank **Mr. Prakashan Injakundu** for his valuable support and guidance during my fieldwork. I am indebted to all the teaching and non-teaching staff of the department and to my friends for their timely help and encouragement. Finally, I recall with sincere gratitude to my parents, friends and all those who have helped me in one or another way in my endeavour and above all, almighty god.

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Dissertation submitted to the University of Calicut in partial fulfillment of the requirement for the

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2) Name & Signature of Examiner 2

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I further certify that no part of the work has been presented before for the award of any other degree/ diploma.

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DECLARATION

I hereby declare that this is an authentic record of the work carried out by me under the supervision of **Dr. Abhilash Peter, Assistant Professor, Department of Zoology, Christ College, Irinjalakuda** and no part of dissertation has previously formed the basis for the award of any Degree or Diploma as stipulated in the statutes of the University of Calicut.

Ann Jaquelen Jaison

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I feel the inadequacy of diction in expressing my sincere heartfelt thanks towards Dr. ABHILASH PETER, Assistant Professor, Post Graduate and Research Department of Zoology, Christ College, Irinjalakuda for suggesting me this topic and for encouragement throughout the course of my study. Without his expert guidance and dedicated involvement at each and every step, this research work would have never been accomplished in the present form.

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Ann Jaquelen Jaison

CONTENTS

DIVERSITY AND GUILD STRUCTURE OF SPIDERS IN THE SELECTED NUTMEG AGROECOSYSTEMS OF MOTHIRAKKANNY, CHALAKUDY, KERALA, INDIA

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Submitted for the university examination
held on ……………….

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CANDIDATE'S STATEMENT

I hereby declare that the work incorporated in the present project is original and has not been submitted to any other university or institution for the award of a degree. I further declare that the results presented in the thesis and the considerations made there in, contribute in general to the advancement of knowledge in science.

PLACE - IRINJALAKUDA
DATE-

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ACRONYMS AND ABBREVIATIONS

WSC	World Spider Catalogue
ha	Hectare
MS Office	Micro Soft Office

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ABSTRACT

The largest order of arachnids in the phylum Arthropoda is represented by spiders. Except for Antarctica, practically every environment and continent is home to a spider. Spiders are widespread terrestrial predators that employ a variety of predation techniques, occupy a wide range of niches, and display guild specific reactions to environmental changes. Present work is an attempt to study on the diversity and guild structure of spiders in the selected habitat of nutmeg agroecosystem of Mothirakkanny, Thrissur. The study was conducted during the period of May 2022 to February 2023 in the fields of nutmeg agroecosystem of Mothirakkanny. Spider samples were gathered using a variety of sampling techniques, including visual search, beating vegetation, litter sampling, and ground and aerial hand collection. Using the literature that was accessible, the collected specimens were preserved in ethyl alcohol and identified up to the level of genus or species. The purpose of this study was to study about the spider diversity, guild structure and species abundance in the selected habitat of nutmeg agroecosystem of Mothirakkanny, Thrissur. During the study period, a total of 26 species from 25 genera in 9 families were collected from the total study area. The Araneidae and Salticidae families were the most dominant of the 9 families studied in the total study area. The analysis of feeding behaviour of collected spiders revealed a total of five feeding guilds.

Key words: Spider, diversity, Nutmeg, Agroecosystem, Guild structure

1. INTRODUCTION

The phrase "biodiversity," as well as the concept it represents, have been noteworthy developments in recent cultural development: ten years ago, the word did not exist, with the possible exception of sporadic, eccentric usage. It has become one of the biological sciences' most widely used idioms today, and as a result, a household word.

The term "Biodiversity" was first used at the National Forum on Biodiversity, which the National Academy of Sciences and the Smithsonian Institution sponsored in Washington, D.C., from September 21–24, 1986.The forum’s proceedings, under the title Biodiversity(after referenced by most authors as Biodiversity with less than bibliographical precision) in 1998, became a best – seller for the National Academy Press. Biodiversity is means to as all heritably based changes at all stages of organization, starting with a single local population or species genes, moving on to the species that make up all or part of a local community, and finally , moving to the communities themselves that make up the living components of the various ecosystem around the world. A lot of people recently understand the importance of biodiversity, or the existence of different types of species of animals and plants. The existence of variety of species is significant to the majority of people because these species physiological variations provide man with a variety of supplies for food, clothing, shelter and medicinal needs too, additionally, chemical and physical features differ between species. From small single celled plants to blue whale and humans, life on earth exists in a different variety of shapes and sizes. The biodiversity of our world is build by all of these different types of species working together. Biologists have just came to know that how little we actually know about the creatures that share our planet with us, Particularly, it has been little bit difficult to count the number of species in existence (Biodiversity II: Understanding and Protecting Our Biological Resources, Marjorie L. Reaka-Kudla et al., 1997).

Phylum Arthropoda is one of the largest phyla which consist about nine lakh species. They may be aquatic, terrestrial or even parasitic too. Their appendages are jointed and exoskeleton is chitinous. This phylum comprises various large classes and consist of class Insecta which itself represents a major portion of the animal species in the world. They show the ability to survive in every habitat. 28 chapters by various teams of experts on diverse taxa of the Arthropoda were released in the most recent volume on animal higher-level classification and survey of taxonomic richness, but there were still much more holes to be addressed (Zhang 2011b). The biggest and most diverse group in the animal kingdom is called as the phylum Arthropoda (arthros means jointed and podos means foot in Greek). Arthropods have characteristically adaptive diversity that helps them to live in a variety of habitats, including freshwater, terrestrial, and aerial. They are the ones who have most successfully encroached upon terrestrial environment on the earth. Over 800,000 species have been recorded. As a result, Arthropoda makeup about 80% of all known animal species (Ayyar & Ananthakrishnan 1994). It’s proven that many of its members are important from an economic standpoint; this group is primarly interesting to humanity. Arthropods are thus directly or indirectly related to the health, wealth, and prosperity of humanity. Symmetry of arthropods body belongs to bilateral symmetry. Their body parts are arranged so that one side is a mirror copy of the other. Their body parts are arranged so that one side is a mirror copy of the other. The body is metamerically segmented, with segmentation visible from anterior to posterior axis. These parts of them are referred as somites or metameres (Hickman et al., 2003). Antennae and sensory hairs, compound eyes and ocelli, auditory organs, and statocysts are some of the examples of sense organs. The sexes are separate and dimorphism is frequently observed. Internal fertilization takes place, and larval stage uses for direct or indirect development. The largest phylum of animals is phylum Arthropoda. Body segments are the characteristic feature of this group. The antennae, eyes, and mouth are found on the head. In crustacean and Arachnida, certain trunk segments are frequently united with the head to form cephalothorax. In different classes, the number of segments that make up the thorax and abdomen vary. Metamorphosis is usually perform hand in hand with development (Arthropod morphology, Simimol Sebastian & Akash Gautam, 2021).

The class Arachnida, which includes spiders, is an order of arthropods(invertebrate animals with jointed limbs) identified by the presence of four pair of legs and two major body regions: the cephalothorax (fusion of head and thorax) and abdomen. The spiders (Order Araneae) differ from other arachnids (Scorpions – Order Scorpions; Daddy Longlegs – Order Opiliones; Ticks and Mites – Order Acari) in that they have venomous fangs (jaws called chelicerae); a construction between the cephalothorax and abdomen; and silk producing glands in the abdomen. The world's spider species count is about in thousands. Although the accurate number of species in Malaysia and the surrounding areas are not well known, it almost surely exceeds hundreds, and many of them are still need to be discovered and named. Identification of spider is based on their genitalia, body markings, and the number and placement of their eyes. Colour and colour combinations can be helpful, but they are quite subjective. Spiders build webs with incredible architectural talent and an omnipresent way of living. The majority of them live in terrestrial settings such forests, plantations, gardens, caves, shrubs, and even termite and ant nests inside of structures.

A spider's body is covered in a variety of hairs and bristles that serve as detectors for different signals that may signify food, enemies, mates, and other things. Those in front are furthermore, utilised for observing and gathering signals from the environment. The front legs are used for sensing the environment and for exploration. Every spider has spinnerets, which are placed in abdomen and used to spin silk produce by silk glands. Diverse types of silks are used for variety of functions including encasing sperms, eggs and prey. Female one of the group are always larger than male of the same species. Conspecific male and female spider varies from each other in terms of their body hue and pattern of colours. All spiders are hunters that primarily eat insects.

A number of important adjustments are needed to convert an ecosystem into an agroecosystem. At least in terms of the boundaries of its biological and physico-chemical properties, the system itself is better explained. These become more angular and impermeable, with lesser and channelled connections to other systems. The removal of most of the native flora and fauna as well as the loss of many natural physic-chemical processes significantly simplifies the system. The system is simultaneously made more complex by the addition of human management and activities (Gordon R. Conway, 1986). The farms and gardens food production system rely on agroecosystem. The human activity for agriculture, as the name suggests, forms the basis of an agroecosystem. In agroecology and regenerative agriculture using ecological techniques, they serve as the fundamental unit of study, Agroecosystem, like other ecosystems, are partially closed systems in which living things are interdependent on one another and frequently interact with their surroundings. They are defined as a geographically and functionally integrated unit of agricultural activity in a rather arbitrary manner (Agro-Ecosystem Health Project, University of Guelph, 1996).

1.1 OBJECTIVES OF THE STUDY

This study was carried out with the primary goal of getting the approximate representation of spider fauna from selected habitat of Nut mug agro-ecosystem, Mothirakkanny, Chalakudy, India within the limited time period.

1. To estimate the species abundance, diversity and richness of spider population in the selected habitats
2. To study the guild structure of spiders in the study area
3. To study about the spiders in nutmeg agro-ecosystem
4. To conduct an exploratory survey of spiders in a habitat in Mothirakkanny locality and identification of spiders up to genus or species level

1.2 RELEVANCE OF THE STUDY

Spider surveys are a practical technique to assess how biodiversity is affected by changes in land use and habitat degradation. Most orders of arachnids have been found to be impacted by pollution and changes in habitat structure. Because of their predatory behavior, brief life cycles, varied means of dispersal, and sensitivity to changes in vegetation structure, spiders make excellent ecological indicators. Spiders are definitely an important element of biodiversity, as they stands to maintain the prey-predator balance in the ecosystem. The spider fauna in this area is being investigated for the first time. The goal of the study was to determine the variety and quantity of spiders in the selected habitat. Data on species distribution and diversity, guild structure, richness, and evenness in particular habitats are provided by this study. This study's objective is to examine the local spider fauna in order to establish a baseline for subsequent investigations.

2. REVIEW OF LITERATURE

Phylum Arthropoda's spiders are a functionally important but mainly understudied group. The distribution, diversity, and quantity of spiders have intrigued naturalists all around the world since the 18th century. In the globe, there are 4,314 genera and 51,090 currently valid spider species described (WSC, 2022). As biological and ecological indicators of natural ecosystems, spiders have drawn the attention of numerous scientists (Mclver et al., 1990; Churchill, 1997). Spiders are one of the most important bio-indicator species among the less species employed in ecological studies (Kapoor, 2008; Noss, 1990). Due to changing environmental conditions, as well as the wide range of behavioural patterns present on them, spider species exhibit significantly different colours (Dharmaraj et al., 2017; Pocock, R. I. 1900). The variety and assembly of spiders in the environment has been the subject of further inquiry in the recent years. Arachnologists have previously underlined the importance of spiders in a number of different ways. As a result, research is being conducted globally. The study of spiders has gained importance recently because each study results astounding findings and advances scientific knowledge.

Prey density, which is typically influenced by seasonal variation and plant structure and may change throughout the year, determines the diversity of spiders. This in turn limits the diversity and quantity of spiders. According to Kumar, A et al., (2017), the occurrence of a higher spider variety may be attributed to the forest's diverse vegetation, which provides spiders with enough space to build webs of varying sizes and shelter them from predators. The abundance and variety of spider species have been shown to be significantly influenced by habitat heterogeneity in both natural (Greenstone 1984) and agricultural situations (Rypstra & Carter 1999). According to research, the number of spider species is dwindling as a result of habitat deterioration brought on by both natural disasters and human activity. A lot of spider species are becoming extinct as a result before they can be studied (Misal et al., 2019). A better understanding of arachnid's role in ecosystems and ecosystem processes has resulted in a substantial shift in arachnid research in Kerala in recent years. At the Kerala Agricultural University Campus in Thrissur, Kerala, Adarsh & Nameer (2015) researched spiders. A preliminary examination of the spider fauna in Kerala's Mannavan shola forest was conducted by Sudhikumar et al., (2015). A total of 72 species, broken down into 57 genera and 20 families, were gathered. In the Kerala region of the Western Ghats, Pradeep (2018) identified 70 species of ground-dwelling spiders, which were split into 48 genera and 20 families. A fascinating study was carried out by Smitha & Sudhikumar (2020) to catalogue the spider biodiversity on a cashew field in Kerala. There were discovered 63 different species of spider, which were split into 52 genera and 14 families. With 33 and 27% of the entire spider fauna, respectively, Salticidae and Araneidae have the most species. During the analysis of guild structure, six feeding guilds were found. 779 individuals were counted from 102 species and 73 genera spread over 18 groups in the sacred woods of Kannur District. Six functional groups including stalkers, orb-web builders, ambushers, space web builders, ground runners, and foliage runners, were discovered as a result of guild structure examinations of reported spiders (Peedikayil et al., 2021). 93 species belonging to 71 genera and 19 families were discovered in the various Western Ghats plantations, making up around 49% of the families discovered in Western Ghats of Kerala (Shabnam et al., 2021). In a study by Misal et al, (2019), spiders of the order Araneae from the Western Ghats were examined. A checklist of the spider's behaviours, habitats, and species diversity was made, and it included information on 27 groups, 101 genera, and 178 species, including several new ones. Sumesh (Sudhikumar, 2020) created a checklist of the spiders found in the holy groves of

Northern Kerala. A total of 257 spider species, broken down into 130 genera and 28 families, were found in the research area. Theridiidae,Thomisidae, Salticidae, and Araneidae were the next four most abundant families, making up around 47% of the total abundance. Five families with less than two members were noted as being rare in the research area.

Biodiversity is too complex to define and measure. According to Knopf (1992), there are as many different kinds of ways to define biodiversity as there are biological resources. The concept of biodiversity includes both flora and wildlife. Arthropods are the largest animal phylum, and they include a wide range of species that live in a variety of settings, including arachnids, insects, crustaceans, and others. The diversity of spiders from different nations has been the subject of intense research by many scientists. Our knowledge of our spider diversity has been substantially boosted by the recent publication of numerous studies on spiders in Southeast Asia. In Southeast Asia, there are 2,299 spider species, which are categorized into 67 families and 552 genera. The 552 genera contain 49 monotypic taxa each represented by a single species, 65 genera unique to one or more South Asian nations, and over 1,830 species native to the regions (Siliwal & Molur, 2007). 42,473 species, belonging to 3,849 taxa, and more than 100 families, are included in the 12.0th edition of Platnik's World Spider Catalogue (2011), representing spiders from all over the world. According to many experts and scientists, there may be up to 1, 70,000 species on earth. Clearly, there are still a lot of spider's species that need to be named and identified. In the Fanjing Mountain Nature Reserve, China, researchers Xuan-Kong, J, et al., and Wang, L. et al, (2018) studied spider diversity. They found 17 coelotine spider species, including 6 new species, and 14 species of Clubionidae, 6 of which were previously unknown to science. The first thorough listing of Indian spiders was made by Tikader (1987), who included 1,067 species broken down into 249 genera and 43 families. A book on Indian crab spiders was written by Tikader (1980b), and it contained 23 new species in addition to 115 species from 25 genera and 2 sub families. This article gives a summary of the primary morphological traits of crab spiders. Beginning in 1960, Tikader's works made up a sizeable percentage and provided a solid foundation for arachnology, Vijayalaksmi & Preston (1993) give a succinct introduction of spiders. Tikader (1993) provided the most comprehensive description of Indian spiders. A total of 43 families and 1,066 species are listed in this book. The first comprehensive study of Indian spider was provided by Pocock (1900a), who listed 216 spider species in 17 families.

A spider researcher can surely rely on Vijayalakshmi & Preston's book (1993), which is a descent introduction to spider research for beginners. Wise (1993) asserts that spiders play significant part in ecological webs. Spiders are wide spread in terrestrial ecosystems and can be found in both natural and agricultural settings (Turnbull, 1973; Nyffeler & Benz, 1987). In the animal kingdom, spiders are among the most widely distributed predatory animal groups (Riechert & Lockley, 1984). Due to their small size, spiders may make use of very minor and specific environmental components. The diversity of species and web shapes mirrored the overall seasonal pattern in spider abundance (Lubin, 1978). Despite their widespread occurrence across the nation, we know very little about Indian spiders. Blackwell (1867), Karsch (1873), Simon (1887a&b), Thorell (1895), and Pocock (1900a&b) were the forerunners of Indian arachnology. They provided descriptions of numerous spider species found in the eastern world. The number of spider species known from India has steadily increased, from 1,067 species (Tikader, 1987), 1,442 species (Siliwal et al., 2005), and 1520 species (Sebastian & Peter, 2009), to 1,686 species (Keswani et al., 2012). Currently, there are 1,906 species divided into 61 families and 490 genera. The most recent World Spider Catalogue Version has been updated to reflect this list. There are 1,852 species total, of which, 1,002 are native to the Indian subcontinent, 71 to the Andaman and Nicobar Islands, and 1 to Lakshadweep (Siliwal et al., 2005). Thomisidae, with 38 genera and 164 species, is the family in India with the second-highest number of genera and species after Salticidae (Uniyal & Hore, 2008). Assesment of spider diversity is challenging, particularly in tropical settings where dozens of species may coexist (Privet et al., 2020). As a result of the destruction and loss of natural ecosystem worldwide, biodiversity is being lost (Foelix, R. 1996). Jose et al., (2018) undertook the initial attempt to catalogue the variety of spiders in a lateritic biotope of Southern India. Araneidae family was the most prevalent, making up 21.5% of all spider species. There were 112 spider species in total, classified into 81 genera and 21 families. In their study of the richness of spiders in Calcutta and the surrounding areas, Tikader & Biswas (1981) recognized 15 families, 47 genera, and 99 species using descriptions and diagrams. By providing thorough lists of the new spider species found in West Bengal and Manipur, Biswas & Biswas (2004) made a substantial contribution to the diversity of spiders. In Uttarkhand, there are 27 spider species, broken down into 49 genera and 17 families, according to Biswas & Biswas (2010). In Gujarat and Tamil Nadu, paddy fields with spider varieties were researched by Kumar & Shiva Kumar in 2006. In the state of Uttar Pradesh's Kedarnath Wild Life Sanctuary, Quasin & Uniyal (2010) conducted a preliminary investigation of diversity. Malhotra et al., (2019) report that a baseline survey of spider diversity in Northern Rajasthan found 39 species of spiders in 11 families, with riparian land habitat having the highest species richness.

The diversity and distribution of spiders in Assam's Gibbon Wild Life Sanctuary were studied by Chetia and Kalita in 2012. In a study by Kumar et al., (2017) on the variety of spiders in the Kukrali forest near Lucknow, 61 spider species from 45 genera and 16 families were identified. The salticidae family, formerly the Araneidae family, included the bulk of spider species. Nearly a fourth of all spider families discovered in India are represented by the total number of species mentioned here. According to Dharmaraj et al., (2017), a total of 40 spider species from 36 genera and 1 family were discovered during the research of spider diversity in Nilgris, Tamil Nadu. While some families distributions were quite discontinuous, others showed a consistent pattern. The spider diversity in Uttarakhand was researched by Thapliyal et al., (2020), who were among the first to barcode the state's spider species, look at their population diversity, and provide information on which spider species might be used as bio-indicators. At a home garden in West Tripura, Dey A et al., (2013) did a study on the diversity of spiders. A total of 47 spider species, broken down into 14 families and 36 genera, were gathered. The investigated assemblage was dominated by the Salticidae family, which made up about 38% of all the species gathered. India has less knowledge about the diversity and distribution of spiders than other parts of the world. Spider surveys may provide helpful in determining how habitat degradation and altered land use affect biodiversity (Sumesh & Sudhikumar, 2020). In order to support a high species richness, heterogeneous landscapes provide a large number of suitable habitats for species with various ecological requirements (Tilman, 1982). For a variety of reasons, spiders (Araneae) are good model species for community ecology study. In the majority of terrestrial environments, they are the main predators. They are necessary for ecosystems to function properly because they have a direct impact on ecosystem processes through predation (Michalko et al., 2019; Nyffeler & Birkhofer, 2017.

On the other hand, in agroecosystems, communities are not primarily formed by natural processes of competition and dispersal because agricultural management significantly alters the nature and intensity of these processes and introduces new, exotic species to the community that can outcompete local species. The eradication of species that do not tolerate current or historical management frequency and intensity, as well as habitat isolation, will have a greater impact on community composition. The functional groups contributions to agroecosystem services for production can be broken down into four categories: services to the food web, gene flow, direct crop production, and soil-related processes (such as increased nutrient cycling, decomposition rate, aggregate stability, organic matter formation, and water regulation). In a strict sense, increasing soil related activities, food web services, and gene flow are what lead to the crop production service. A negative primary production service brought on by crop enemies is yield production (Functional biodiversity: An agroecosystem approach, Anna-Camilla Moonen*,Paolo Barberi,2008). Natural selection operates in natural ecological systems in a way that supports population size, productivity of ecological systems, and survival, all of which contribute to sustainability. It may or may not make choices that favour stability as used above. Natural selection is partially replaced in agroecosystems by human manipulation, which affects both individuals and entire systems. Various system characteristics are preferred based on the pre dominate human aims and values. Thus, it is possible to think of agricultural development as a series of adjustments in the relative importance of key system properties (Agroecosystem Analysis, Gordon R Conway, 1983).

3. MATERIALS AND METHODS

3.1 STUDY AREA

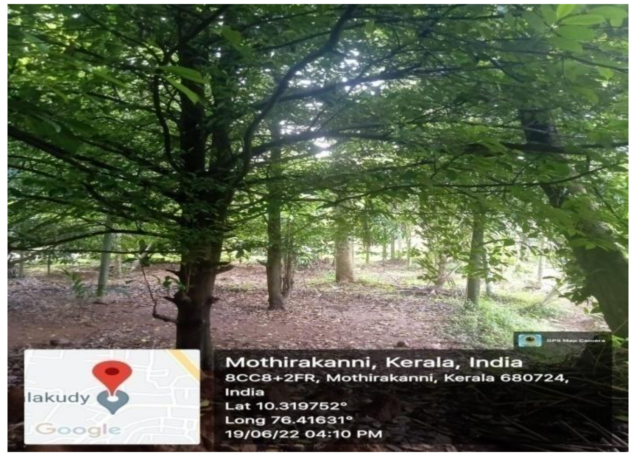
The site selected for the study is a nut mug ecosystem which is located at Mothirakkanny, Thrissur district, Kerala. It is located 10°18´6.192´´ North latitude & 76º20´10.932´´ East longitude with an area of 10 ha. The average altitude of collection area is about 25.9 m above mean sea level. This is a warm, humid region and the seasonal variation in temperature ranges from 24°C to 35°C. Humidity is also showing seasonal fluctuation and is about 75% to 85%.

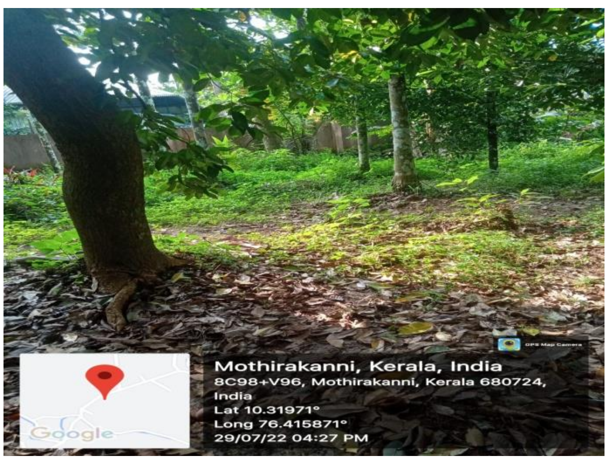
3.2 STUDY PERIOD

The observation and collection of spiders was done during the period of 10 months from May 2022 to February 2023. 10 samples in all were taken from the study regions. The collection window was from 4:00 to 6:00 in the evening. For the purpose of collecting spiders, the study area was meticulously searched for any potential spiders.

PLATE 1

PHOTOGRAPHS OF SAMPLING SITES IN THE STUDY AREA





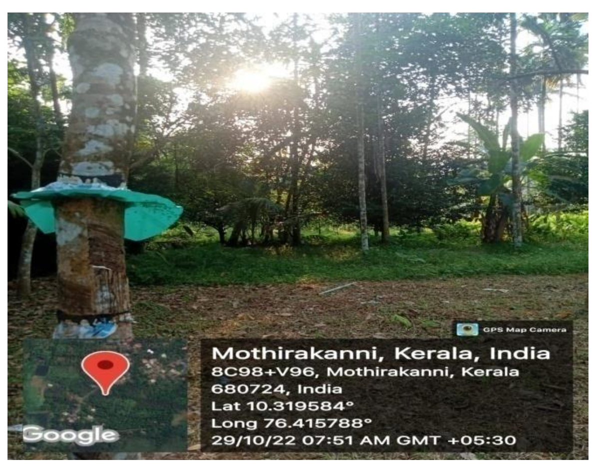
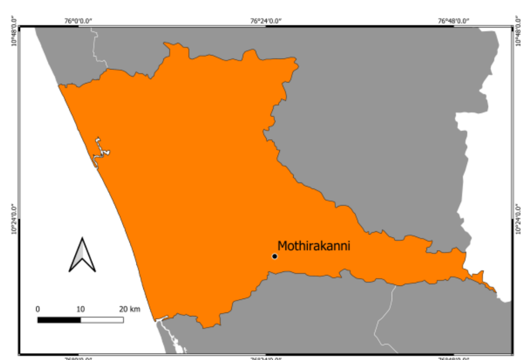


PLATE 2

PHOTOGRAPHS OF SAMPLING SITES IN THE STUDY AREA

Sampling sites in nut meg agroecosystem in Mothirakkanny of months May-February

Figure1. Map showing the study



3.3 SAMPLING METHOD

A Sample is a collection of items drawn from a broader population that serves as a representative sample and provides the necessary data. Samples are a necessary component of population ecology and are used to draw conclusions about the population.

In the current study, the spider fauna from certain study sites was sampled using the line transect approach. There were a total of 14 Line transects placed throughout the selected habitats, each measuring 100 meters in length, 1 meters in width, and 2 meters in height. Throughout the 100 meter transects, which were sampled for 1-3 hours, spiders were gathered. 10 samples were taken throughout the study period from the entire study region. To prevent the edge effect, transects were placed 20 meters inside the boundary. Spiders were gathered using a variety of methods, including vegetation beating, ground hand collection, aerial hand collection, and litter sampling. In certain sample locations, standardized sampling procedures for collecting spiders are used. The following are thorough descriptions of the collection methods:

3.3.1 Ground Hand Collection – From the ground up to knee height, spider samples are collected using the ground hand collection method. Spiders are collected using this technique from the ground, trash, broken logs, rocks etc.

3.3.2 Aerial Hand Collection – Hand collection in the air gathering of samples from knee to arm length level is one of the greatest ways to gather spiders. The samples were carefully selected by hand, and using this technique, spiders on the stems and leaves of high herbs, trees, and other plants were accessed for web-building and free-living spiders. Smaller spiders were captured by guiding them into alcohol-filled tubes. Another option is to gently whack the specimen into a collection bottle with a tiny, soft paint brush. Spiders discovered on the webs were captured in the jar by tapping into it with the lid while holding the jar open beneath them.

3.3.3 Vegetation Beating – The technique is used to gather spiders from stronger vegetation, such as shrubs, tall herbs, bushes, and tiny tree branches. By pounding the foliage with a stick and gathering the samples on an upside-down umbrella or sheet beneath the tree or shrub, the spider are collected. After pounding, check the tray or umbrella to catch any spiders that may have fallen before they escape.

3.3.4 Litter Sampling – Litter was manually gathered from the ground and placed on a large tray. Spiders were separated from the tray's litter

With the above techniques, the spiders were collected and observed.

3.4 PRESERVATION AND IDENTIFICATION

The spiders that were trapped were kept separately in bottles of 80% ethyl alcohol. Each bottle was marked with the collecting date, habitat, and other significant information. For the purpose of taxonomic identification, preserved specimens were studied in the lab using a stereo zoom microscope (Leica-MS5). With the aid of the literature that was accessible, spiders were recognized down to the species level (Sebastian & Peter, 2009; WSC 2023; Caleb & Sankaran, 2023). A field record was kept throughout the duration of the investigation. The species richness, evenness, species diversity, and relative abundance of the dominating spiders found in various locations are also determined using field collecting data.

PLATE 3

TECHNIQUES USED FOR SPIDER SAMPLING IN THE STUDY AREA

Ground collection – (A), Aerial sampling – (B) & (C), Beating method – (D)

3.5 DIVERSITY INDICES

The Excel 2013 application that comes standard with MS Office was used to calculate the spider diversity, richness, and evenness indices. Two diversity indices were utilized in the study: Simpson index (D), which is sensitive to changes in the most abundant species in a community, and Shannon-Wiener index (H), which is sensitive to changes in the abundance of uncommon species in a community. The ordinal scale of the Shannon Wiener index rises as more species are present in the community. Species richness is a metric used to determine the number of species present in a habitat. Overall species richness is the diversity metric that is most frequently employed. The Simpson's index is a scale that goes from 0 (for a sample with considerable diversity) to 1 (for a sample with a small number of dominant species).

Shannon index is defined as; $\mathbf{H'} = -\sum_{I=1}^{S} \left(\frac{ni}{N}\right) \ln\left(\frac{ni}{N}\right)$

Where: pi = the observed relative abundance of a particular species (ni/N).

Simpson index is defined as: $\mathbf{D} = 1 - \sum_{i=1}^{S} \frac{ni(ni-1)}{N(N-1)}$

Where: ni = the number of individuals of species$i$, and N = Σni

Shannon's index (H′), however, has started to be employed more frequently as a result of the moves towards taking species abundance into account. This indicator of diversity is not the most difficult to interpret (Ludwig & Renolds, 1988). Two conditions can be compared using a diversity index. If values for diversity indices are frequently difficult to interpret, then species richness and evenness are presented as independent values. In this way, they offer crucial information on the distinctions between ecological groups or the ecological changes that take place through time (Bisby, 1995). The evenness index reaches its maximum when all species in a sample are equally plentiful, and then decreases to zero as the relative abundance of species deviates from evenness.

Probably the most often used evenness index among ecologists is $\boldsymbol{E = H'/\ln(S)}$.

The evenness index shouldn't be impacted by the number of species in the sample. An evenness index should logically remain constant regardless of the number of species present, it would appear. It has been proven that adding a rare species to a sample that only contains a few species drastically alters the value of E.

The index of species richness (d) was calculated using the formula given by **d = S/ N.**

'N' on the other hand, is the total number of individuals across all species. In their habitats, spiders are constrained by both biological and physical forces.

3.6 GUILD STRUCTURE STUDIES

Environmental factors such family level daily activity patterns; prey species, web structure, and foraging behaviour were all submitted to guild classification. Graphs were used to organize the analysis's output. Based on the families gathered for the study, the habitat based spider guild categorization was created. In the present study, guild classification was done using Cardoso et al., (2011) findings.

4. RESULTS

4.1 SPIDER DIVERSITY IN THE STUDY AREA

The study was carried out during a period of 10 months, from May 2022 to February 2023. During the study period, a total of 215 individuals were collected. 26 species from 9 families were listed from the collected individuals. List of spiders collected is provided, as well as general explanation of the spider families in the collection. Photographs of the spiders collected from study area are also provided.

FAMILY	NO OF SPECIES	NO OF GENERA
ARANEIDAE	7	8
CHEIRACANTHIIDAE	1	1
CORINNIDAE	1	1
LYCOSIDAE	3	2
OXYOPIDAE	1	1

SALTICIDAE	6	6
TETRAGNATHIDAE	4	3
THERIDIIDAE	2	2
THOMISIDAE	1	1
	26	25

Table1. Representation of genera and species in different spider families of the entire spider assemblage recorded in the study area

Out of the 10 families collected during the study, the family Araneidae and family Salticidae were the dominant families with 7 and 6 species belonging to 8 and 6 genera. Family Tetragnathidae was the second dominant family with 4 species belonging to 3 genera. Family Thomisidae represents the third dominant family with 1 species belonging to 1 genus. The family Theridiidae was the fourth, which reported 2 species with 2 genera. Family Lycosidae and family Oxyopidae was fifth dominant with 2 and 1 species belonging to 2 and 1 genera. Cheiracanthiidae was the sixth dominant with 1 species and 1 genus. Corinnidae were the next dominant family with 1 species and 1 genus.

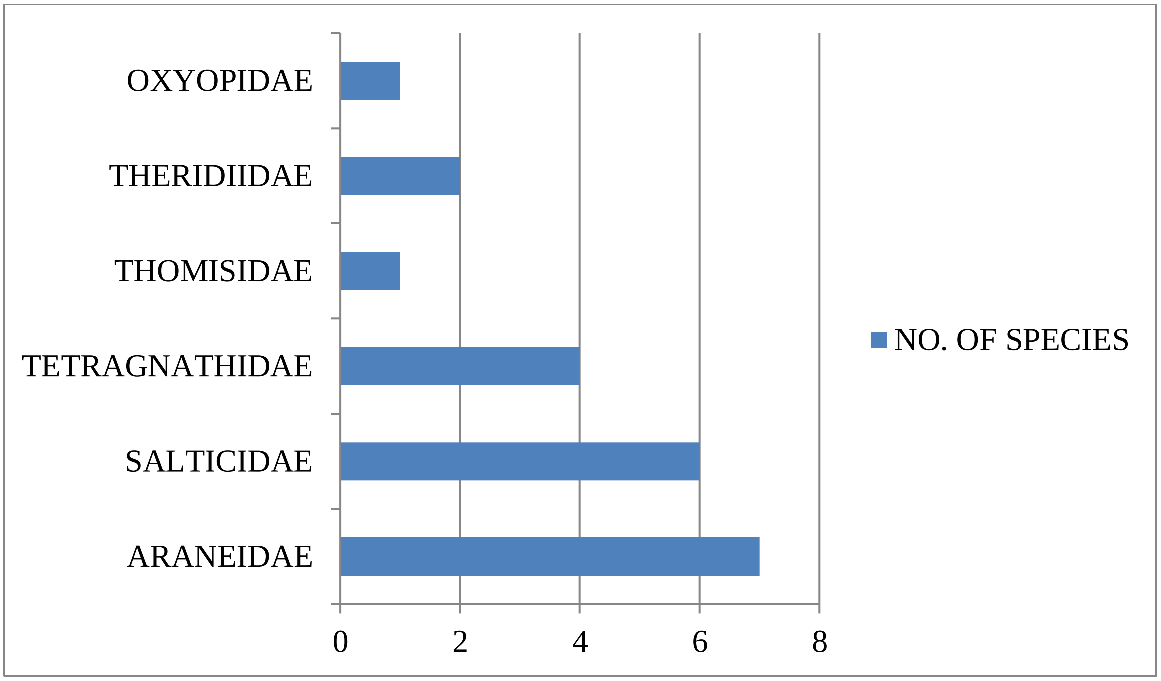


Figure2. Graph showing the distribution of genera and species in different Spider families of the entire spider assemblage recorded in the study area

SL.NO	FAMILY/GENUS/SPECIES	SPECIES ABUNDANCE
	1. ARANEIDAE	
1	*Anepsion keralensis (Sunil Jose, 2011)*	3

2	*Argiope aemula (Walckenaer, 1841)*	1
3	*Argiope pulchella Thorell, 1881*	4
4	*Argiope sp.*	3
5	*Cyclosa hexatuberculata Tikader, 1982*	1
6	*Cyclosa neilensis Tikader, 1977*	1
7	*Eriovixia laglaizei (Simon, 1877)*	1
8	*Eriovixia poonaensis (Tikader& Bal, 1981)*	7
9	*Eriovixia sakiedaorum Tanikawa, 1999*	1
10	*Eriovixia sp.*	5
11	*Gasteracantha geminata (Fabricius, 1798)*	5
12	*Macracantha hasselti (C. L. Koch, 1837)*	2
13	*Neoscona mukerjei Tikader, 1980*	2
14	*Neoscona sp.*	3
15	*Nephila pilipes (Fabricius,1793)*	1
	2. CHEIRACANTHIIDAE	
	Cheiracanthium danieli Tikader, 1975	4
	3. CORINNIDAE	

1	*Castianeira zetes Simon, 1897*	2
	4. LYCOSIDAE	
1	*Hippasa sp.*	1
2	*Pardosa sumatrana (Thorell, 1890)*	5
3	*Pardosa sp.*	1
	5. OXYOPIDAE	
1	*Oxyopes lineatipes (C. L. Koch, 1847)*	3
2	*Oxyopes sp.*	1
	6. SALTICIDAE	
1	*Carrhotus viduus (C. L. Koch, 1846)*	1
2	*Epeus indicus Prószyński, 1992*	2
3	*Epeus tener (Simon, 1877)*	6
4	*Epeus sp.*	2
5	*Hyllus semicupreus (Simon, 1885)*	4
6	*Indopadilla insularis (Malamel, Sankaran& Sebastian, 2015)*	38
7	*Stenaelurillus lesserti Reimoser, 1934*	2
8	*Telamonia dimidiata (Simon, 1899)*	7

	7. TETRAGNATHIDAE	
1	*Leucauge decorata (Blackwall, 1864)*	38
2	*Leucauge fastigata (Simon,1864)*	3
3	*Leucauge tessellate (Thorell, 1887)*	3
4	*Tetragnatha viridorufa Gravely, 1921*	1
5	*Tetragnatha sp.*	1
6	*Tylorida ventralis (Thorell, 1877)*	43
	8. THERIDIIDAE	
1	*Meotipa multuma Murthappa, Malamel, Prajapati, Sebastian &Venkateshwarlu, 2017*	1
2	*Nihonhimea mundula (L. Koch, 1872)*	4
	9. THOMISIDAE	
1	*Amyciaea Hesperia Simon, 1895*	2

Table2. Checklist of spiders collected from entire study area

4.1.1 Details of the families collected from the study area

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

The size of the spiders ranges from little to enormous. Size dimorphism, or how much smaller males are than females, can vary dramatically. They have eight eyes in two rows of four, with the lateral and middle eyes being widely spaced apart. The distribution of this family is international. The vast majority of the family's members build flawless orb webs to capture prey, and they can be found in a range of habitats. They create forage webs with a sticky spiral that are nearly vertical ecribellate or webs that can be greatly altered or completely lacking one. They use the "spin-wrap-attack" method to subdue their prey. These spiders dangle in the web with their heads bowed and are passive predators. One could say that the internet is their native environment. Between genera and subgroups, there are differences in the basic shape of the web, the number of radii, spirals, hub shape, and web ornaments. Some spiders employ stability to decorate their webs. Web design may be influenced by the spider's size, weight, and location in relation to the web.

List of species in the present study: - 8 Genera and 7 Species

Anepsion keralensis (Sunil Jose, 2011)

Argiope aemula (Walckenaer, 1841)

Argiope pulchella (Thorell, 1881)

Argiope sp.

Cyclosa hexatuberculata (Tikader, 1982)

Cyclosa neilensis (Tikader, 1977)

Eriovixia laglaizei (Simon, 1877)

Eriovixia poonaensis (Tikader& Bal, 1981)

Eriovixia sakiedaorum (Tanikawa, 1999)

Eriovixia sp.

Gasteracantha geminata (Fabricius, 1798)

Macracantha hasselti (C. L. Koch, 1837)

Neoscona mukerjei (Tikader, 1980)

Neoscona sp.

Nephila pilipes

2. Family Cheiracanthiidae, Wagner: 1887 (Yellow sac spiders)

Typically, they have an abdomen that ranges in colour from yellow to light brown. Sizes for both sexes range from 0.5 to 1.0 cm. The body is frequently yellow but can also be tan, light brown or pale green depending on the environment and food. On the rear of their abdomen, they have a brown stripe. They have long legs, the first pair being longer than the others. Black stiff hairs on all legs make them excellent climbers. A sac spider normally creates a flat silk sac to serve as its daytime resting area. The corners of walls and ceilings, as well as outside, under any object or in a leaf, are common places to find these silk sacs in homes. The silk sacs may go unnoticed in homes with light, neutral-colored walls and ceilings because they are small and blend in with the background colour. The female yellow sac spiders make about 5 silken egg sacs, each containing 30 to 50 eggs, and they guard them by remaining close. The baby spider lings frequently spend some time within the silken sac before emerging at night to look for food. Although yellow sac spiders are known to be only minimally venomous to humans, they are helpful predators in agricultural fields. Since they never spin a web, they are active hunters who look for prey rather than trying to catch it in one. They may come into contact with humans while hunting for prey at night in human-occupied areas and bite them. The first agony from their bite is typically excruciating, followed by skin redness, swelling, and itching. The bite's accompanying burning feeling lasts for an hour, followed by 1–10 hours of rash and blistering.

List of species in the present study:-1 Genera and 1 Species

Cheiracanthium danieli (Tikader, 1975)

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

This family of spiders includes little to medium-sized creatures that live underground. Elongated or ovoid cephalothorax. Eight eyes in two rows, either widely or closely placed apart. With claw tufts on both tarsal claws, the legs are long and slender. The dorsal surface of the abdomen may contain stripes, and it can be either spherical or elongated. The anterior spinnerets are gathered in a single group. Many species have a tight constriction on the abdomen around the lungs. The forest floor, leaf litter, and other shady areas are all good places to look for these spiders. Numerous members of this family have been observed imitating ants. Their general appearance and manner of walking are comparable to ants'. They move their first set of legs upward to resemble ant antennae while walking by moving their abdomens up and down. The colour of these spiders range from black to grey to reddish and brownish. They create refuge that resemble sacs in coiled leaves. They are hard to catch since they run away swiftly when disturbed.

List of species in the present study:-1 Genera and 1 Species

Castianeira zetes (Simon, 1897)

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

The size of lycosid spiders can range from little to huge. The cephalothorax is longer than it is wide, thinner, and elevated in the cephalic region in individuals with a longitudinal fovea. Eight black eyes are grouped in three rows of four, two, and two. Compared to nursery web spiders, which have eight eyes of roughly identical size, the posterior median eyes are the largest. The legs are average in length, with notched trochanters with spines, and have scopulae. The abdomen is shaped like an oval. These spiders have a variety of markings on their bodies and are dark or grey in colour. This family of spiders mostly consists of free-living ground spiders, which are the most prevalent spiders in the wild and are frequently seen crawling on the ground. The egg sac that females carry is connected to their spinnerets. The egg sacs are typically larger than the female's abdomen and are typically white or pale in colour. Spider lings assemble on the female's abdomen until they disperse. On the surface of the abdomen, certain species feature distinguishing hairs that are utilized to move spider lings on the mother's body. Several lycosids construct silken shelters and burrows. These spiders actively hunt and have excellent vision. Many lycosids are active during the day, but some also engage in night time hunting. Larger lycosids make ground-level burrows. Smaller species don't spin any webs at all, while others spin silky webs and hide in the grass.

List of species in the present study:-2 Genera and 3 species

Hippasa sp.

Pardosa sumatrana (Thorell, 1890)

Pardosa sp.

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

Oxyopids can be identified by their long, spiny legs, hexagonal arrangement of the eyes, and two diminutive anterior median eyes that are situated below. The colouring of the body could be bright green, yellowish brown, or dark brown. The cephalothorax is longer, has noticeable stripes and spots, is high and convex at the front, and slopes backwards. Back of the abdomen tapering, with bands or patches. The integument is covered in tiny setae and occasionally ornamented with iridescent scales. Because of the way their eyes are positioned, lynx spiders are named after cats with lynx-like faces. The three tarsal claws and trochanters have a little notch. They are free-range, plant-dwelling hunters who leap and dash across low bushes and leaf litter. Whether they hunt during the day or at night, hunters with good vision can find game fast. Legs are used to seize prey, usually by leaping into the air to catch the flying insect. Both sexes are almost the same size. The egg sac is attached to a twig or leaf or strung in a tiny, crooked web. The female is responsible for guarding the eggs.

List of species in the present study:-1 Genera and 1 Species

Oxyopes lineatipes (C. L. Koch, 1847)

Oxyopes sp.

6. Family Salticidae, Blackwall, 1841 (Jumping spiders)

The most frequently observes to large araneomorph spiders are salticids. Due to their propensity for jumping or leaping long distances, these energetic hunters are commonly referred to as “Jumping spiders”. They are entelegyne spiders without a cribellum, and their carapace has a square shape. The sternum can be different sizes and shapes. In most species, the pedicel that joins the cephalothorax to the abdomen is hidden, but in some genera, it is lengthy and conspicuous. The abdomen is typically small, circular or elliptical, and it occasionally has the ability to enlarge. Usually, the dorsal side of the abdomen is covered with hairs that create eye-catching patterns and colours and help identify species. Jumping spiders can be recognized by their distinctive eye pattern, which is simple to recognize. Eight eyes are present, and they are organized in three or four rows across the width of the carapace. The anterior median eyes are quite large, while the anterior lateral eyes are smaller and pointed forward. Together, these two eyes provide outstanding 360 degree vision. Salticids are colour sensitive and can distinguish their prey at a considerable distances. Legs feature two claws and claw tufts. The anatomy of the legs, especially the first pair, differs in certain species, and hair fringes are occasionally seen. Chelicerae have teeth in a variety of sizes and shapes on the outside and inside edges, as well as fang.

List of species in the present study: -6 Genera and 6 Species

Carrhotus viduus (C. L. Koch, 1846)

Epeus indicus (Prószyński, 1992)

Epeus tener (Simon, 1877)

Epeus sp.

Hyllus semicupreus (Simon, 1885)

Indopadilla insularis (Malamel, Sankaran& Sebastian, 2015)

Stenaelurillus lesserti (Reimoser, 1934)

Telamonia dimidiata (Simon, 1899)

7. Family Tetragnathidae, Menge, 1866 (Long jawed spiders)

The size of these spiders ranges from little to enormous. They have long bodies, a cephalothorax that is wider than it is long, and a uniform colour of brown or grey with silvery patterns. The abdomen can range in size and shape from stretched to round to round. In some species, the abdomen may almost stretch straight back to the spinnerets. Whether they have spines or not, legs are long and slender. They create a nearly horizontal ecribellate orb web. They are known as "long jawed spiders" because of their long chelicerae. Chelicerae are characterized by a row of enormous teeth and strong, projecting spurs. Two rows of four eyes each make up their eight eyes, which are occasionally joined by tubercles.

List of species in the present study: -3 Genera and 4 Species

Leucauge decorata (Blackwall, 1864)

Leucauge tessellata (Thorell, 1887)

Leucauge fastigata (Simon, 1877)

Tetragnatha viridorufa (Gravely, 1921)

Tetragnatha sp.

Tylorida ventralis (Thorell, 1877)

8. Family Theridiidae, Sundevall: 1833 (Comb footed spiders)

The term "comb footed spider" refers to the distinctive setae that resemble combs on the tarsus of the fourth legs. These modified setae, also known as tarsal comb, are used to direct gooey silk pouring from the spinnerets to encircle the animal during prey capture. Males and smaller species may have decreased or absent tarsal combs. The cephalothorax can have a wide range of shapes, from high to low, and some species can alter the cephalothorax's frontal region. The abdomen has a variety of shapes, including elliptical, circular, raised, and elongated, and it extends past the spinnerets. Chelicerae may be few in number or quite long and without cheliceral teeth. There are eight eyes total, which are arranged in two rows and each have a brown ring around them. The femur of three-clawed animals lack spines, and the tarsi taper towards the end. The legs are long and curved. Typically, they build a complex three-dimensional space network of different shapes. The spider may capture flying insects using webs that are constructed from crisscrossing viscous strands. Prey may attempt to run, but the strands may break suddenly, leading prey stuck to them to get further tangled. Some species construct distinct hiding places inside or outside the structure of the web by covering the web with plant or dirt particles that aid in camouflaging. Some other species prefer to find shelter in a dark or debris filled silken refuge built into the edge of the web. Few members of this family do not build webs at all and can be seen walking among fallen leaves on the ground or, in the case of cryptic species, relaxing on exposed branches or sticks.

List of species in the present study:-2 Genera and 2 Species

Meotipa multuma (Murthappa, Malamel, Prajapati, Sebastian &Venkateshwarlu, 2017)

Nihonhimea mundula (L. Koch, 1872)

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

These spiders come in all sizes, from little to enormous. Because their front two pairs of legs are normally robust and they resemble crabs, they are known as “crab spiders”. The cephalothorax can have an oval, elongated, or semi circular form. Eight eyes are arranged in two rows, and the lateral eyeballs are situated on tubercles that may be spherical or pointed. On the lateral side, the legs are in line with the body. The abdomen can have any shape, including elongated, ovoid, pentagonal, and more. They feature a colulus and tiny, closely spaced front spinnerets. Many genera have been documented to change colour depending on the surface they are present on, and their bodies have brilliant colours like white, green, or brown. There are no cheliceral teeth and the chelicereae are free. There is a sternum with a heart form. Typically, the labium and maxilla are wider than they are long. These spiders don't make webs, therefore they hunt by sneakily attacking their victim and capturing it with their strong, spiky legs. The abdomen can vary in size and shape from spherical to oval or elongated, and is often covered in distributed simple setae. It can also be larger than the cephalothorax. The members generally have a crab like appearance, and they walk crab like or to the sides. They are daily. They produce highly potent venom while having weak chelicerae, which enables them to take on huge insects. The absence of cheliceral teeth causes prey to be eaten dry rather than crushed.

List of species in the present study: -1 Genera and 1 Species

Amyciaea Hesperia Simon, 1895

4.2 GUILD STRUCTURE STUDIES

Guild is a collection of organisms that uses the same kind of resources in similar ways. According to Uetz (1991), Guilds are groups of animals that share similar hunting techniques and predation habitats and use the same class of natural resources in a comparable fashion. Spiders collected from the selected habitats of study area were classified into six guilds based on their feeding behavioraccording to the results of Cardoso et al., (2011). :- (1) Ambush hunters

(Family Thomisidae); (2) Ground hunters (Corinnidaeand Lycosidae); (3) Orb web weavers (Araneidae and Tetragnathidae); (4) Space web builders (Theridiidae); and (6) Other hunters (Cheiracanthiidae, Oxyopidae and Salticidae)

(1) Ambush hunters

For prey capture, these spiders use a "sit-and-wait" strategy. Family Thomisidae is included in this guild type, consisted of 1 species from the total study area.

(2) Ground hunters

This guild of spiders primarily feeds on the ground layer, rarely venturing into the plant's foliage or canopy for prey. This guild includes spiders from the Corinnidae and Lycosidae families and a total of 4 species from these families constitute this guild.

(3) Orb web weavers

This guild's spiders weave perfect beautiful orb webs to catch prey. This category includes spiders from the Araneidae and Tetragnathidae families and 21 spider species represent this guild; from the total study area.

(4) Space web builders

These spiders use uneven space webs to catch prey. This category includes spiders from the Theridiidae family. A total of 2 species of spiders from these families constitute this guild.

(5) Other hunters

Stalkers or foliage runners are considered as other hunters. This guild includes spiders from families, Cheiracanthidae, Oxyopidae, Salticidae and a total of 11 spider species represent this guild from the total study area.

4.3 SPECIES RICHNESS AMONG GUILDS

Results of spider species richness among guilds in the total study area shows that the guild of orb web showed the highest species richness with 53.85% (21 species) followed by other hunters with 28.20% (11species). There are remaining 5.13% of space web builders (2 species), 10.25% of ground hunters (4 species) and 2.57% of ambush hunters (1 species).

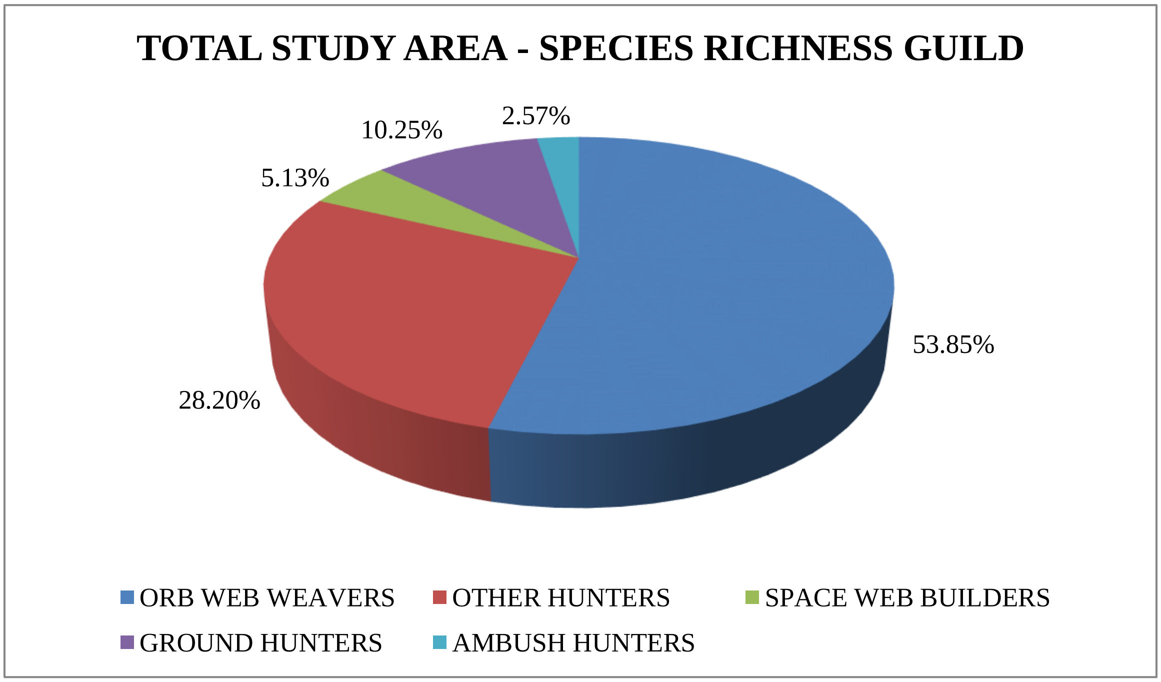


Figure3. Species richness of spiders in the guilds of total study area

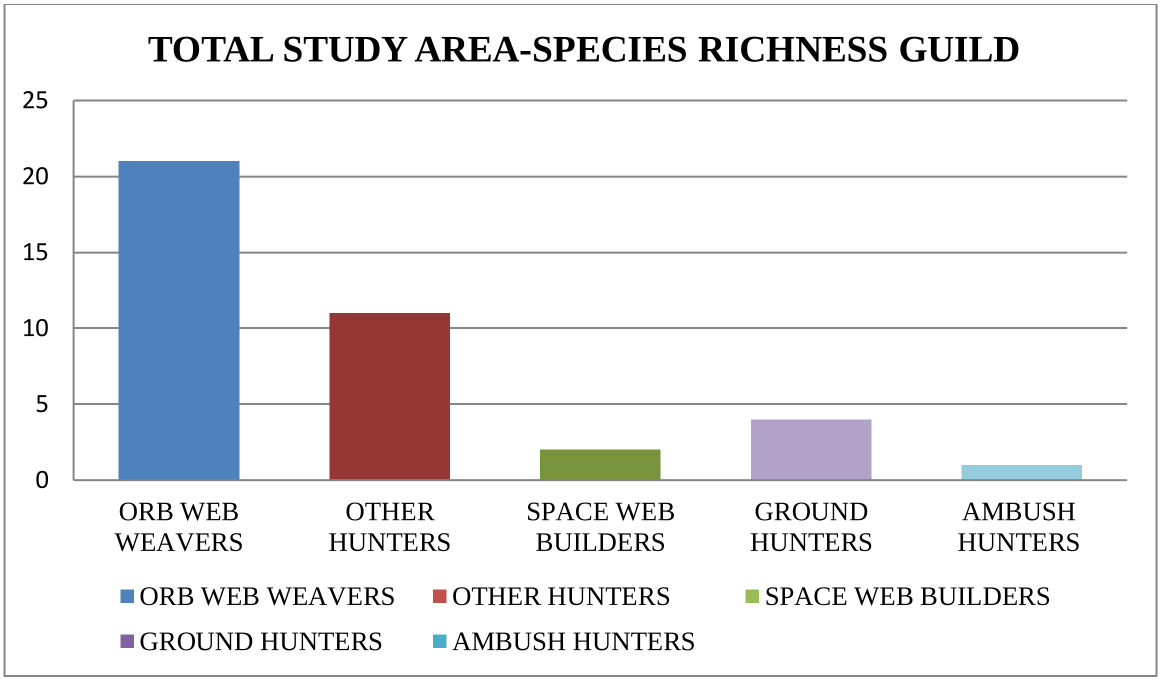


Figure4. Species richness of spiders in the guilds of total study area

4.4 SPECIES ABUNDANCE AMONG GUILDS

Composition of species abundance in the guilds of total study area constitute 50.23% orb web weavers (108 individuals), 22.80% other hunters (49 individuals), 20.46% ambush hunters (44 individuals), 4.19% ground hunters (9 individuals) and 2.32% space web builders (5 individuals). Highest abundance was shown by the guild of other hunters followed by orb web weavers and the least abundance by the specialists.

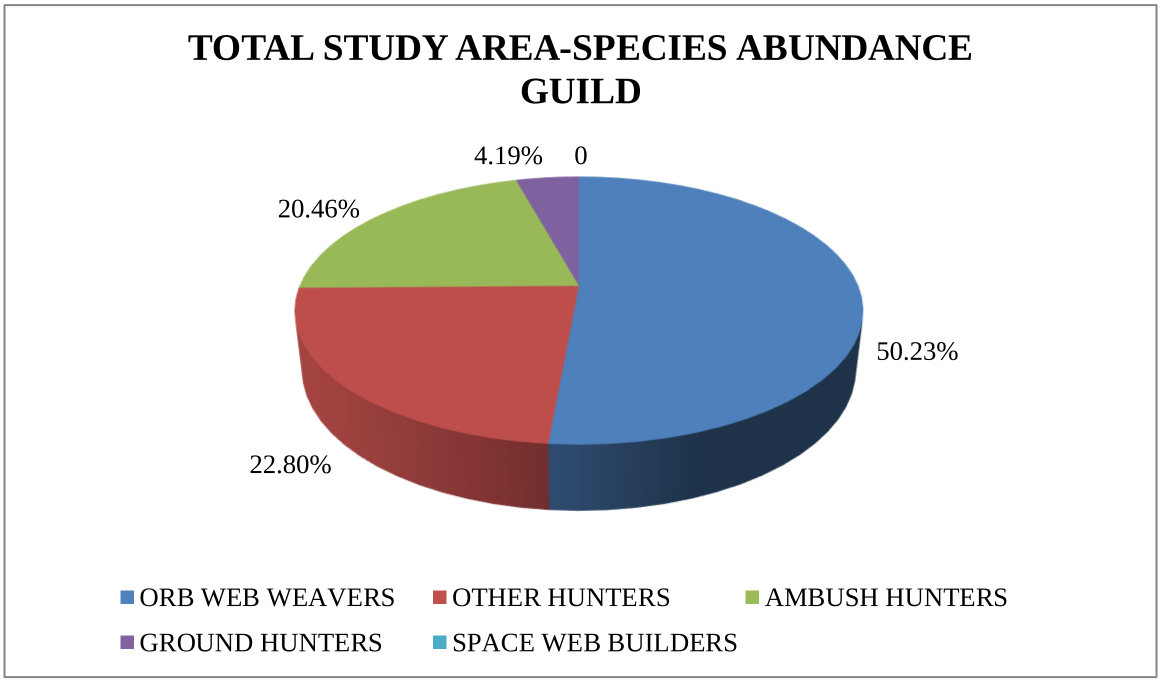


Fig5. Spider abundance among the guilds of total study area

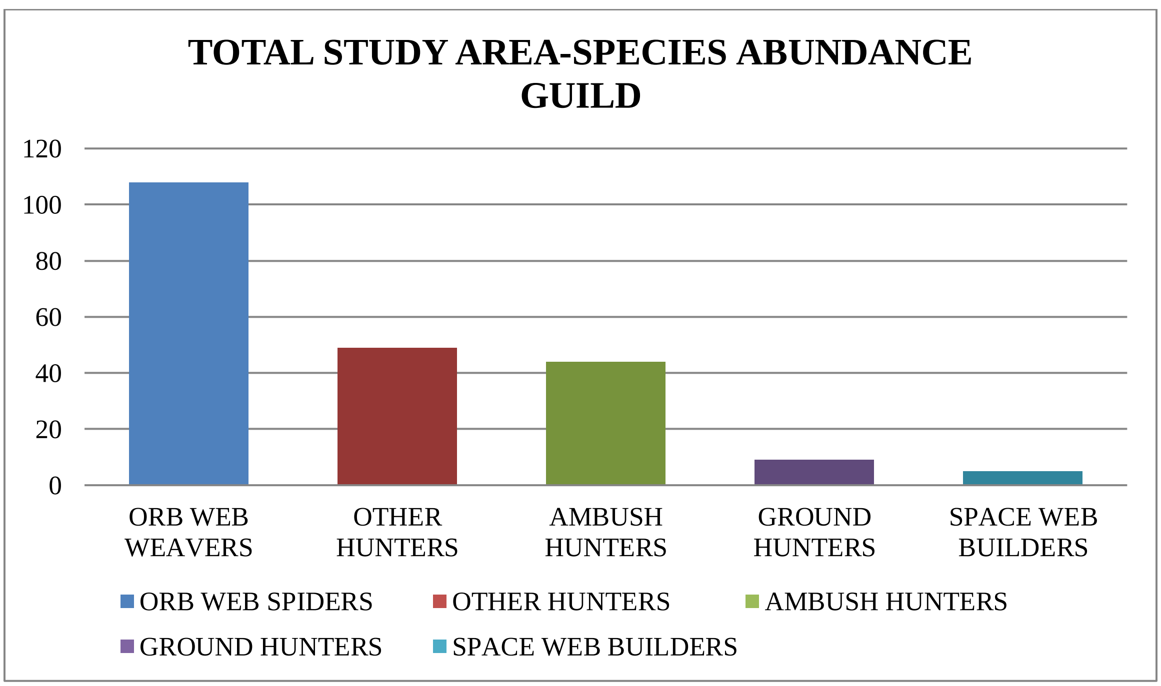


Fig6. Spider abundance among the guilds of total study area

4.5 SEASONAL VARIATION AMONG GUILDS

In the month of May orb web weavers and other hunters are the most abundant ones and ground hunters are absent. In June other hunters like Cheiracanthiidae, Oxyopidae like families are the abundant ones. In July, August and September orb web weavers marked the highest in abundance. In October and November other hunters like Salticidae, Oxyopidae marked the highest in abundance. In the remaining months of December, January and February orb web weavers were the abundant guild. Out of these datas collected we can come to a conclusion that orb web weavers and other hunters like species belonging to family Salticidae, Oxyopidae and Cheiracanthiidae were the abundant guilds in the study area.

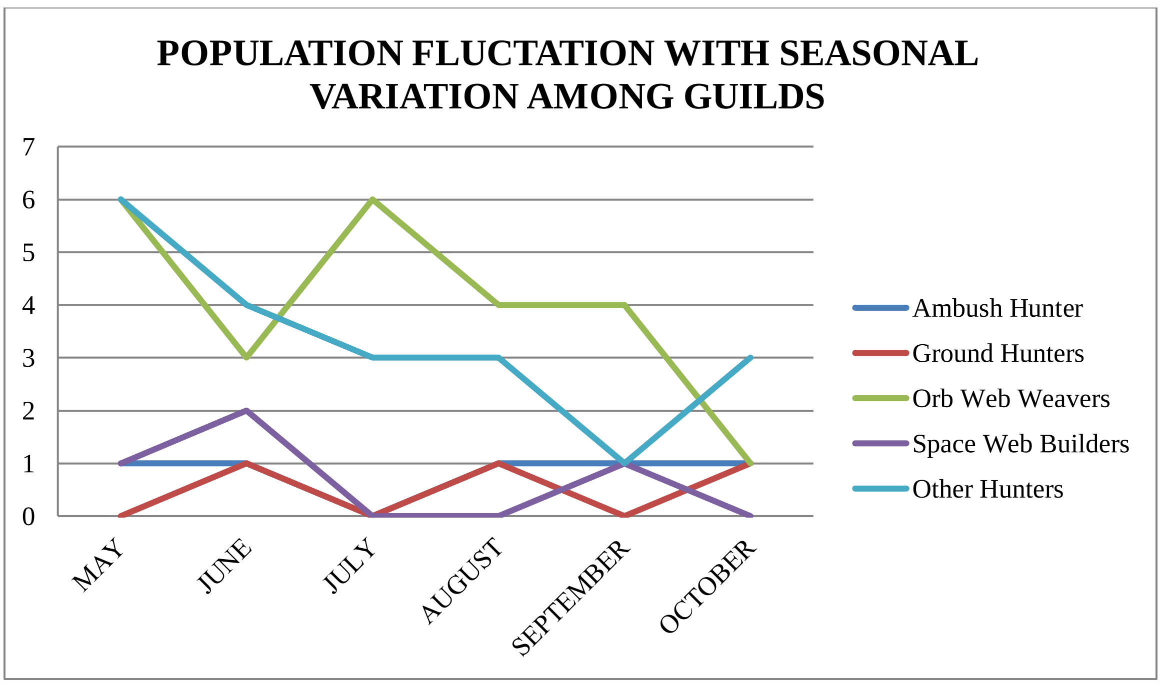


Fig7. Spider seasonal variation among guilds

4.6 DIVERSITY INDICES

Study area	No.of species (S)	No.of individual (N)	Species richness (d)	Shannon-Weiner index (H')	Simpson index (D)	Evenness (E)
Total study area	26	215	0.1860	2.8730	0.9019	0.7842

Table3. Diversity data on spiders of selected habitat of Mothirakkanny, Thrissur during the study period.

Species richness (d): The number of different species in an ecological community is referred to as species richness. Species richness is merely a count of species and it does not take into account the species abundance or their relative abundance distributions. Species richness was same for total study area have a value (0.1860) less than this for species richness.

Species diversity: Species diversity is defined as the number of different species that are represented in a given community and their relative abundance. Shannon -Weiner Index and Simpson Index were used to calculate species diversity. The Simpson index is sensitive to changes in the most abundant species in a community and the Shannon–Wiener index, is sensitive to changes in the abundance of rare species in a community (Solow et al., 1993).Typical values of Shannon - wiener species diversity generally lies between 1.5 -3.5. Total study area shown a value of 2.8730 for H'.

Evenness or Equitability Index: The evenness indicates uniform distribution of spiders in the study area. Here evenness is 0.7842.

5. DISCUSSION

The current study is the first to document the spider fauna of the nutmeg ecosystem of Mothirakkanny, Thrissur. The observation and collection of spider was made throughout a ten-month period, from May 2022 to February 2023. Spiders were collected once a month from May to February. Time of collection was in the evening from 4.00pm to 6.00pm. During the study period, a total of 26 species from 0 genera in 9 families were collected from the total study area. The Araneidae and Salticidae family was the most dominant of the 9 families studied, with 17 and 6 species belonging to 8 and 6 genera. With 4 species belonging to 3 genera, the Tetragnathidae family was the second most dominant. Thomisidae was the third dominant family, with and 1 species belonging to 1 genera. The purpose of this study was to determine the spider family composition, guild structure, and species abundance in selected habitat.

Araneidae and Salticidae was the two most dominant families in the entire study area. The Araneidae is the largest spider family that spins orb-webs. They are the most common builders of spiral webs in the shape of a wheel, which may be found in gardens, fields, and forests. Spiders belonging to the Salticidae family jump over their prey to consume them. There is a link between habitat structural complexity and species diversity, according to various studies (Andow, 1991). Uetz (1991), discovered that a more structurally complex shrub can host a more diversified spider community. The vegetational architecture is directly related to the dominance of these families in the study area. The distribution and occurrence of spiders are affected by habitat structure and vegetation factors, and anthropogenic activities that alter the ecosystem can result in habitat degradation and potentially local extinction of the species.

The average altitude of Mothirakkanny, Thrissur is about 25.9m above mean sea level. The temperature ranges between 24˚C to 35˚C, the humidity in the study area ranged from 75 to 85% in the entire study area. According to Noss (1990), Spiders have humidity and temperature preferences that confine them to places within their physiological tolerance range, making them suitable candidates for land conservation research. There have been numerous accounts of threats to spider diversity. Deforestation, habitat loss owing to intensive agriculture, and human settlement are all important threats to spider survival, as they are to other biological species. Thus, spider conservation will demand a broader knowledge of the relevance of spider conservation among the general public, scientists, land owners, and environmentalists (Sebastian & Peter, 2009).

Guilds are biological groups of species that use the same or similar resources in the same way (Root, 1967). Spiders have recently been subdivided into a finer guild system (Uetz, 1991). Spiders collected from the selected habitats of study area were divided into 6 guilds based on their foraging behaviour in the field (Cardoso et al., 2011):- (1) Ambush hunters (Family Thomisidae); (2) Ground hunters (Corinnidae and Lycosidae); (3) Orb web weavers (Araneidae and Tetragnathidae); (4)Space web builders (Theridiidae); and (5)Other hunters (Cheiracanthidae, Oxyopidae and Salticidae).

Highest species richness in the total study area was shown by the guild of orb web weavers (53.85%) followed by other hunters (28.20%). Other hunters are treated as either stalkers or foliage runners. The most abundant guild in the total study area was the guild of orb web weavers (50.23%) followed by other hunters (22.80%). Remaining were 20.46% ambush hunters, 4.19% ground hunters and 2.32% space web builders. The typical orb web weavers (Araneidae and Tetragnathidae) are the most common group of spiral wheel-shaped web builders found in fields, gardens and forests. Vegetation structure in the nutmeg ecosystem may have influenced the spider composition and favoured the orb web weavers leading to their abundance in the nutmeg ecosystem. Least abundance was shown by space web builders in nutmeg ecosystem.

Tracking spider diversity patterns can provide valuable insight into the biodiversity of tropical environments. In light of the current global biodiversity crisis, spiders as a group could be important conservation tools as ecological indicators in quick biodiversity monitoring; there is an urgent need to provide taxonomic resources for groups from tropical environments.

A diversity index is a single value that encompasses both species richness and evenness (Magurran 1988). Shannon-Wiener index (H'), which is sensitive to changes in the abundance of rare species in a community, and Simpson index (D), which is sensitive to changes in the most abundant species in a community, are two diversity indices employed here. The value of H´ is 2.8730 and value of D is 0.1860.

The use of a diversity index allows for comparisons between different environmental conditions. Species richness and evenness are provided as separate values, if values for diversity indices are often difficult to interpret. They provide vital insights on the ecological changes that occur over time or the differences between ecological communities in this manner (Bisby, 1995). The number of species found in a habitat is measured by species richness. The most widely used diversity measure is overall species richness. When all species in a sample are equally abundant, the evenness index reaches its maximum, then reduces to zero when relative abundance of species diverges from evenness. Evenness found was 0.7842. The number of species in the sample should have no influence on the evenness index.

6. CONCLUSION

The aim of the study was to determine the spider diversity, guild structure, and species abundance in selected habitat of nutmeg agroecosystem. During the study period, a total of 26 species from 25 genera in 9 families were collected from the study area. Out of the 9 families collected during the study, the family Araneidae and Salticidae was dominant family with 7 and 6 species belonging to 8 and 6 genera. Family Tetragnathidae was second dominant family with 4 species belonging to 3 genera. Spiders belonging to 5 ecological guilds were collected during this study. The family's ecological traits were used to determine the spider guild (Cardoso et al., 2011). Highest species richness and abundance in the total study area was shown by the guild of orb web weavers followed by the other hunters. Composition of species abundance in the guilds of total study area constitute 50.23% orb web weavers (108 individuals), 22.80% other hunters (49 individuals), 20.46% ambush hunters (44 individuals), 4.19% ground hunters (9 individuals) and 2.32% space web builders (5 individuals). The study indicates a more or less diverse and varied species composition in connection to selected habitat, emphasizing the impact of different vegetation types on spider fauna as well as baseline information on spider ecology, relevance, and risks faced by spider species. This study intends to generate primary data on the spiders in this region, laying the foundation for more research into the subject.

7. RECOMMENDATIONS

- ✓ The findings from this study can be used to modify future studies as well as be directly included into spider-inventory-based conservation efforts.
- ✓ The information gathered in the form of a checklist will be extremely useful to anyone interested in learning more about the region's spider variety.
- ✓ There is a scarcity of knowledge on Indian Spider ecology and taxonomy even though spiders can serve as indicator species (Kapoor, 2008).
- ✓ Future research may concentrate on additional essential elements such as environmental factors, habitat controlling microclimate variability, and anthropogenic disturbance factors, all of which have the potential to have a significant impact on spider diversity on a large scale.
- ✓ This study provides data on species distribution and diversity, guild structure, richness, and evenness in selected habitats.
- ✓ Finally, it is recommended that these findings can be used for additional refinement research as well as direct integration into spider-inventory-based conservation projects.

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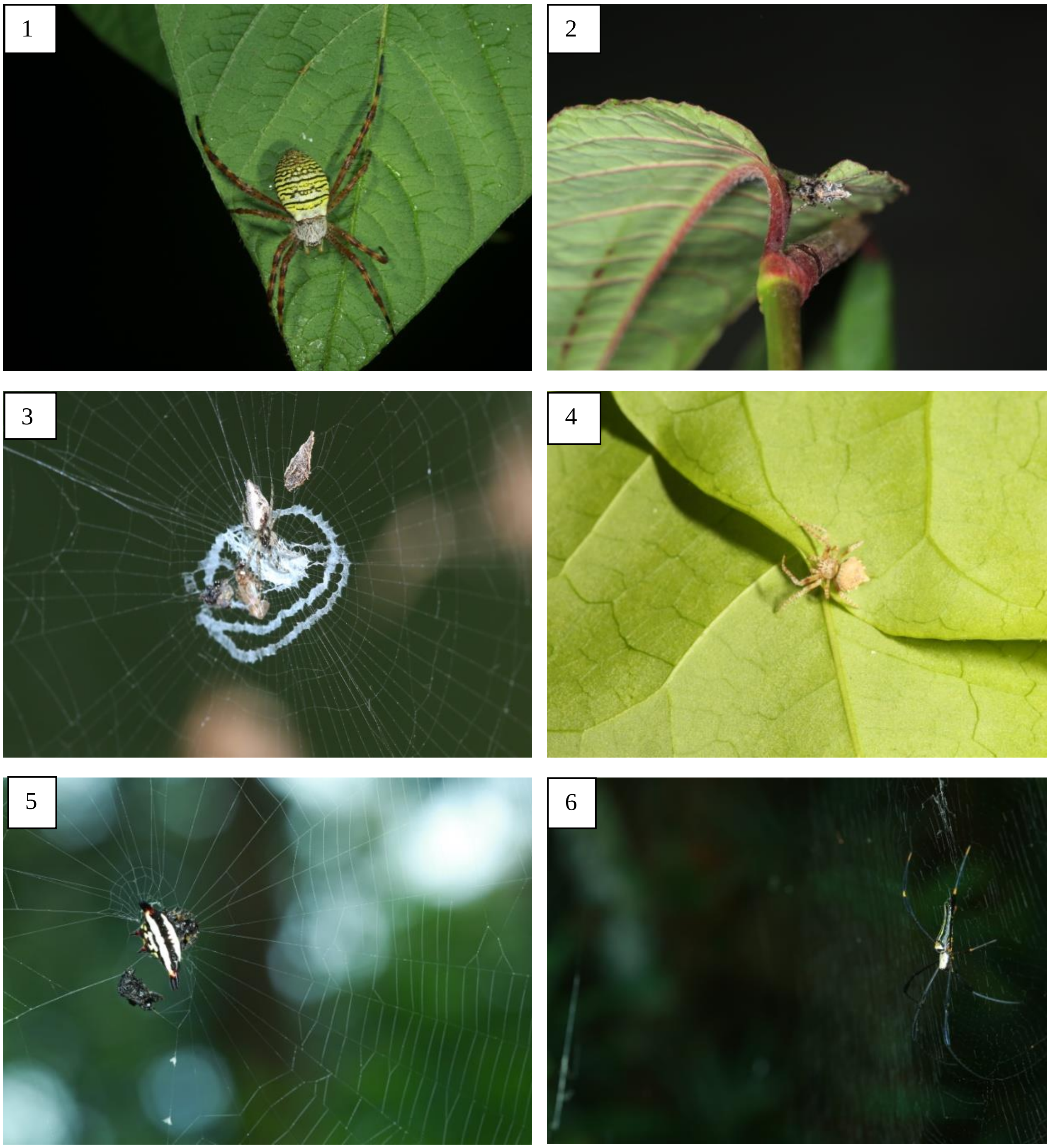
PLATE 4

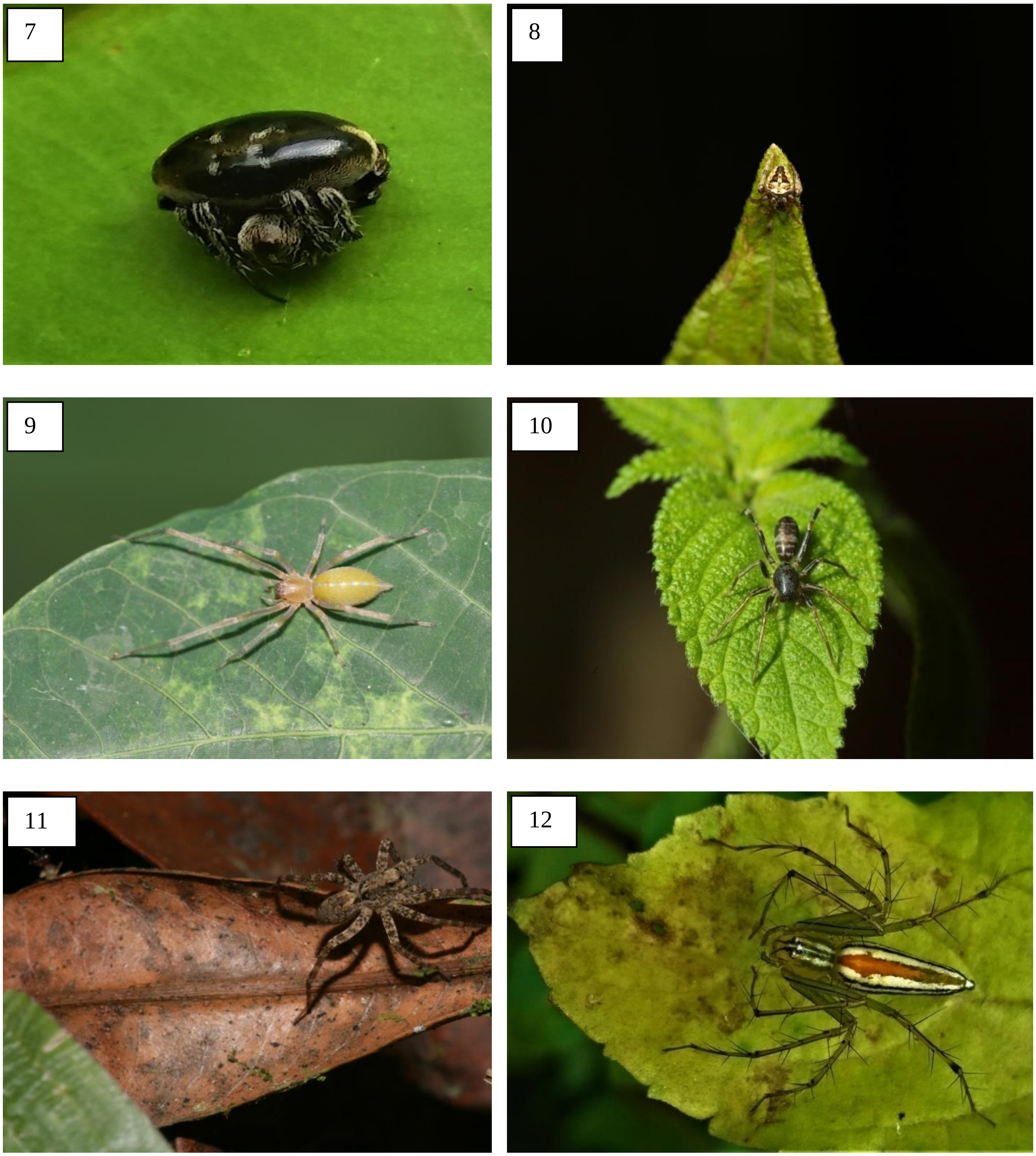
PHOTOGRAPHS OF SPIDER COLLECTED FROM THE STUDY AREA



Family: Araneidae – (1) *Ariope aemula*, (2) *Cyclosa hexatuberculata*, (3) *Cyclosa neilensis*, (4) *Eriovixia laglaizie*, (5) *Gasteracantha geminata* (6) *Nephila pilipes*

PLATE 5

PHOTOGRAPHS OF SPIDER COLLECTED FROM THE STUDY AREA



Family: Araneidae – (7) *Eriovixia sakiedaorum,* (8) *Neoscona mukerjie.* **Family: Cheiracanthidae** – (9) *Cheiracanthium danieli*. **Family: Corinnidae** – (10) *Castianeria zetes.* **Family: Lycosidae** – (11) *Pardosa sumatrana*.. **Family: Oxyopidae** – (12) *Oxyopes lineatipes*

PLATE 6

PHOTOGRAPHS OF SPIDER COLLECTED FROM THE STUDY AREA

Family: Salticidae – (13) *Carrhotus viduus*, (14) *Epeus tener*, (15) *Hyllus semicupreus*, (16) *Indopadilla insularis*, (17) *Stenaelurillus lesserti*, (18) *Telamonia dimidiata*

PLATE 7

PHOTOGRAPHS OF SPIDER COLLECTED FROM THE STUDY AREA

Family: Tetragnathidae - (19) *Leucage decorate*, (20) *Leucauge tessellate*, (21) *Opadameta fastigata*, (22) *Tetragnatha viridorufa.* **Family: Theriidiadae –** (23) *Meotipa multuma*, *(*24) *Nihnhimea mundula*

ANNOTATED LIST OF MOTHS (LEPIDOPTERA: HETEROCERA) FROM MADAIKONAM VILLAGE, THRISSUR DISTRICT WITH NOTES ON THE BIOLOGY OF *OLEPA RICINI* FABRICIUS AND *DYSPHANIA PERCOTA* (SWINHOE)

Dissertation submitted to the University of Calicut in partial fulfillment of the requirement for the

Degree of Master of Science in Zoology

ATHIRA V. T.

REG NO: CCAVMZL005

DEPARTMENT OF ZOOLOGY

CHRIST
COLLEGE (AUTONOMOUS)
IRINJALAKUDA, KERALA

MARCH 2023

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Place: Irinjalakuda | **Dr. Sudhikumar A.V.**
Date: 14-04-2023 | **Head of Department**

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I further certify that no part of the work has been presented before for the award of any other degree/ diploma.

Place: Irinjalakuda
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I hereby declare that this is an authentic record of the work carried out by me under the supervision of **Dr. Abhilash Peter, Assistant Professor, Department of Zoology, Christ College, Irinjalakuda** and no part of dissertation has previously formed the basis for the award of any Degree or Diploma as stipulated in the statutes of the University of Calicut.

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ACKNOWLEDGEMENTS

I feel the inadequacy of diction in expressing my sincere heartfelt thanks towards Dr. ABHILASH PETER, Assistant Professor, Post Graduate and Research Department of Zoology, Christ College, Irinjalakuda for suggesting me this topic and for encouragement throughout the course of my study. Without his expert guidance and dedicated involvement at each and every step, this research work would have never been accomplished in the present form.

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Finally, I recall with sincere gratitude to my loving parents, my friends and all those who have helped me in one way or the other in my endeavour and above all almighty god.

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CONTENTS

FREE RADICAL SCAVENGING ACTIVITY OF *Vernonia cinerea* (L.) LESS.

Dissertation submitted to

UNIVERSITY OF CALICUT

in partial fulfilment of the requirement for the award of

MASTER OF SCIENCE IN ZOOLOGY

BY

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ACKNOWLEDGEMENT

With great pleasure, I express my deep sense of gratitude and indebtedness to my supervising teacher **Dr. Leyon Varghese**, Department of Zoology, Christ College (Autonomous), Irinjalakuda for his selfless interest, constant help, guidance and continuous encouragement during the course of work.

I express my gratitude to **Dr. Sudhikumar A.V**, Head, Department of Zoology, Christ College (Autonomous), Irinjalakuda and other faculty members of the department, for their encouragement.

I am thankful to **Rev. Dr. Jolly Andrews CMI**, Principal, Christ College (Autonomous), Irinjalakuda, for providing necessary facilities to carry out the work.

Mrs. Jimsy Johnson, Research scholar, Immunology and Toxicology Research Laboratory, Department of Zoology, Christ College (Autonomous), Irinjalakuda was with me throughout my work and I am thankful to her for her sincere help and cooperation during the study.

I extend my sincere thanks to my classmates, non-teaching staff and friends for their help and cooperation. I am also grateful to my parents, siblings and relatives for their continuous encouragement, valuable prayers, love, consideration and moral support during the study period.

Above all, I render my sincere thanks to God, the Almighty for his enduring blessings showered upon me.

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I further certify that no part of the work has been presented before for the award of any other degree/ diploma.

Place: Irinjalakuda
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Project report submitted to the University of Calicut in partial fulfillment of the requirement for the award of the Degree,

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I further certify that no part of the work has not been presented for the award of any other degree/diploma.

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With great pleasure, I wish to express my deepest gratitude and indebtedness to my supervising teacher, **Dr Bijoy C**., Assistant Professor, Department of Zoology, Christ college (Autonomous), Irinjalakuda for his guidance, advise, encouragement, and insight throughout the project work.

I express my gratitude to **Dr Sudhikumar A.V.,** Head of the Department of Zoology, Christ College (Autonomous), Irinjalakuda, and other faculty members for their encouragement.

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I extend my sincere thanks to my Parents, classmates, non-teaching staff, and friends for their valuable support and co-operation.

Above all, I render my sincere thanks to God, for his blessings showered upon me.

LIST OF FIGURES AND TABLES

ABSTRACT

The present study explored the diversity and relative abundance of bees in the sacred grove of Thumboor, Thrissur district during May 2022 to April 2023. A total of 11 morphospecies of bees were collected from study area which belongs to three families, Apidae, Halictidae and Megachilidae. Maximum number of species recorded belongs to the family Apidae. There is seasonal variation in the abundance of bees which increases in the months of October, November, December and January and considerably declines in the months of June, July and August. Diversity indices such as evenness, Shannon, and Simpson indices have been studied on the habitat. The study deserves significance as a pioneering work conducted in the study area.

INTRODUCTION

Insects are important in all terrestrial ecosystems because of their abundance, diversity and ecosystem services they provide. The beneficial insects mainly include those which acts as pollinators, those which involve in mineral cycles and facilitate nutrient availability, soil formation, and some other hinders the survival of pest and act as biocontrol agents and ensure crop production. It forms a major source as consumption for other taxa (Scudder, 2017).

Bees are insects belonging to the order Hymenoptera, and includes in the superfamily Apoidea and further classified in to 7 families as Apidae, Halictidae, Megachilidae, Andrenidae, Colletidae, Melittidae and Stenotritidae (Michener, 2007). They are more complex than other insects due to their eusocial behaviour. Apidae is the family which is most familiar with members such as honeybee, carpenter bee, and bumble bees and this family also contain more tribes than any other in the world (Pannure, 2016). They are highly diverse in form, size, and in habits. Some are furry, some nearly hairless and slender like wasps, some exhibit different colour patterns as black or bright with or without spots and stripes (Batra, 1977). Bees have many similarities with wasp and the main difference includes the presence of branched hairs in which pollen sticks and wide body whereas wasps are usually with unbranched hair and slender body. The features of bees include their social behaviour, defence mechanism, division of labour, determination of sex and caste, and maintenance of nest structure (Michener, 1974).

Sacred groves are considered as remnants of evergreen forest patches, and they are examples for conserved and protected ecosystem based on religious beliefs and depicts an interrelation between human beings and nature. Together with cultural and religious belief, it owns great heritage of diverse species of both animals and plants (Khan *et al.*, 2008). Sacred groves are known in various names in different parts and mainly “Sarpakavu” or “Kavu” in Kerala. The sacred groves in Kerala can be classified according to their authority as managed by individual families, group of families and by agencies (Chandrashekara, 1998).

Among the pollinators, bees are considered as the most significant group. Almost 72.7 % crop species are pollinated by bees and it can be the possible pollinator of another 10.2 % crops (Nabhan and Buchman, 1997). The active collection of pollen is carried out by various structural and behavioural adaptations (Thorp, 2000). Honey bees use marks to guide and locate the position of sugar source by reference to the nearby landmarks (Menzel *et al*., 1996). The production of honey which is a highly nutritious item for consumption and a most widely used product in the ayurvedic medicines boosted bee keeping programmes. Collection of nectar and pollen by honey bees facilitates cross pollination in flowers, which leads to 30-80 % increase in agricultural crop productivity. In India about 80% of honey is used as medicine and 10% in ayurvedic and pharmaceutical preparations (Singh, 2000).

The foraging behaviour of bees can vary according to different factors that includes temperature, relative humidity, wind speed etc. The temperature and rainfall have a significant effect on foraging behaviour of stingless bees (Bharath *et al.*, 2000). Studies focussed on the abundance and diversity of bees throughout the year in an ecosystem help us to understand about the seasonal variation in bee diversity. From this study we can understand the influence of host plants and how the climatic conditions regulate abundance of bees in a selected ecosystem with least human intervention.

OBJECTIVES OF THE STUDY

1. Study the diversity, relative abundance and seasonal variation of bees visiting in the study area.
2. Floral association of bees in the study area.
3. Prepare a checklist of bees visiting the study area.

REVIEW OF LITERATURE

Bees are effective pollinators and studies about diversity of bee community helps for better management of ecosystems and various applications in agricultural sector. Studies related to bees in a particular ecosystem, specific bee species, their influence in effective pollination, various factors affecting their diversity, their conservation are carried out in different parts of the world. Majority of bees are solitary that inhabit in burrows, plant stems and in wood where nectar is stored as food for their young ones. As they collect pollen from specific plants, they become potential pollinator of that particular plant (Linsely, 1958).

Tepedino *et al*. (2008) studied about the dependence of solitary bees on invasive plants because of their nectar, pollen and attractive flower. Studies done by Kimoto (2012) on the bee community in North American bunchgrass prairie about the diversity and temporal variability, showed the diversity in grassland which is particularly vulnerable and marked seasonal and inter-annual variation. Klatt (2014) studied how the bee pollination helps in improving the quality of fruits and the study focussed on straw berries and resulted in increased redness and reduced sugar-acid ratio and thus increased commercial value by more heavier fruits. Klejin (2015) reported in a study of pollination services and pollinator conservation, found that crop pollinator bees which are restricted to a small fraction of all known bees, are easily enhanced by simple conservation strategies because they are present in agricultural sites. The conservation activities should be extended to rest of the threatened bees also for the actual conservation of biological diversity.

The studies in cash crops in Burkina Faso, West Africa by Stein (2017) showed that the pollinator presence increased the crop production with yield quantity and quality and also it helped to overcome the potential negative consequences of self-pollination by preventing inbreeding depression. Rasmussen (2021) done a study on national level in Denmark on a comparative basis of native bees and honey bees according to their foraging preferences. The study aimed to verify whether the release of large colonies of honeybees in to an area can cause any negative impact on wild bees due to sharing of same foraging plants. As per the result of the study, no relation was found between their foraging specialization and conservation, even though they shared almost 176 plants as their common forage plants.

There are studies in our country, one which is done in non-wind pollinated crops and wild plants, bees are the most effective pollinators (Batra, 1995). In sacred groves, as a site of rich diversity and considered as a patch of forest, many diversity studies were carried out (Chandrasekhara, 1998). Hymenopteran floral visitors from Agro-ecosystem near Bikaner, Rajasthan, found that there are almost 13 species and mainly include bees (Bhardwaj *et al.,* 2012). A study by Balina *et al.* (2012) reported pollination efficiency of native bee pollinators of bitter gourd revealed a total of nine bee species as visitors of bitter gourd. *Apis dorsata* was identified as the most efficient pollinator followed by *Halictus* and *Megachile.* The studies carried out by Rasmussen (2013), about stingless bees in Indian sub-continent concluded that except in the higher elevation or the drier interior region, rest of the parts of Indian subcontinent, stingless bees are present which are concentrated to particular conserved areas. In medicinal herb, *Leucas aspera,* hymenopteran visitors are more acceptable by the bilabiate corolla as pollinators (Prasad and Sunojkumar, 2014). The work done by Waykar (2014) on the diversity of nectariferous and polleniferous bee flora at Anjaneri and Dugarwadi hills of Western Ghats concluded 52 plant species were useful for honeybees and mid-December to February and mid-July to September is identified as major honey flow periods and based on this data, floral calendar was developed. Several studies for making floral calendar of a particular area by inspecting the presence and foraging activity of honeybees were conducted .Floral calendar development was also done in Paithan taluk of Maharashtra and identified mid-October to mid -December as honey flow period and also concluded that area is suitable for commercial bee keeping because of species richness (Waykar, 2015). The diversity study of solitary bees in oilseed crops by Navatha (2015) depicted that in niger, safflower, mustard and linseed, there is presence of 10 species of bees. Highest in niger while low in linseed and in the observation sweat bees was found to be the most abundant with a peak visitation time between 9.00 and 11.00 am in these 4 oil seed crops. In a study done by Sheeja and Jobiraj (2017) at Vanaparvam biodiversity park of Kerala revealed the presence of almost 21 species of bees, out of these, 18 species belong to 9 genera and 3 families. Foraging behaviour and relative abundance of insect pollinators on litchi, okra and sarson in Chandigarh showed that the pollinator visit is highly crop specific and among the insects, honeybees are the most effective pollinators (Singh, 2017). A five-year survey of stingless bees done by Rahman *et al.* (2018) in Northwest, North east and southern regions of India reported that area had two genera and six different species of Indian stingless bees. The study carried in one such organic farm of Hyderabad by Latha (2018), revealed the presence of 14 Species of bees. Five species were honey bees from family Apidae and the remaining 9 species were solitary bees. Study done by

Minz *et al.* (2020) showed the diversity of bees along elevational gradient in different agro-chemical zones of Chhattisgarh found out almost 396 individuals belong to 3 families out of which, 196 individuals from Apidae as the most abundant family then followed by halictidae and Megachilidae. The order of abundance of families seems to be Apidae, Halictidae, followed by Megachilidae. The study by Bhatta and Kumar (2020), concentrated to urban areas, about the bee diversity and abundance in urban green spaces of Bangalore and confirmed the presence of bees from families Apidae, Halictidae and Megachilidae. They detected the presence of cavity nesting species more than tree nesting species or ground nesting. Diversity studies are also conducted in ecologically engineered organic fields. Analysing the Macrohymenopteran diversity in Thommana kole wetland, Kerala revealed 36 species from 24 genera and 9 families which bees own the major share, and family Apidae with highest relative abundance of 30.50% (Anas *et al.,* 2021). Examples of studies conducted on specific bees include, the work conducted by Udayakumar *et al.,* (2021) on *Amegilla violaceae* a native bee showed its effect as a potential pollinator on egg plants which need vibratory motion for effective pollination. Because of the anther cone bruising and buzzes made by this native bee, the fruit set weight and number of seeds per fruit increased considerably. Prakash and Bijoy (2021) in a study reported 11 species of bees under 8 genera from the flowers of ash gourd from Malappuram district.

MATERIALS AND METHODS

STUDY AREA

The present study was carried out in a sacred groove near “Thumboor Ayyappankkavu”, Kombodinjamakkal(10°18′36″N,76°16′04″E) Thrissur, Kerala (plate 1and 2, figure 1 and 2) from 2^{th} May 2022 to 29^{th} April 2023. The sacred grove is spread over an area of 1.6 acres. The area is mostly shady, and the vegetation consists of members of herbs, shrubs, and trees with a few members of flowering plants. Most areas are covered by the canopy and within the area, grasses, flowering plants, other herbs and shrubs show distinct variations in distribution due to differences in the availability of sunlight.

MATERIALS

Sweep net for collection, collecting jar for keeping collected bees, 70% alcohol for wet preservation, killing jar for killing the specimens, ethyl acetate as the killing agent, incandescent bulb for drying specimens, insect box for dry preservation, and insect pins for spreading the specimens, Stereozoom microscope for identification of bees.

METHODOLOGY

The study site was divided into four plots according to the difference in their vegetation.

Plot 1 (Plate3, figure 1): Area 10x10 m wide. The vegetation consists of grass mainly *Megathyrsus maximus*

Plot 2 (Plate 3, figure 2): Area 20x20 m wide. The vegetation consists mainly of palms, *Corypha umbraculifera*

Plot 3 (Plate 4, figure 1): Area 15x15 m wide. The vegetation consists mainly of flowering plants, mostly *Chassalia curviflora*, *centrosema molle*

Plot 4 (Plate 4, figure 2): Area 15x15 m wide. The vegetation consists of trees and shrubs and includes *Artocarpus heterophyllus*, *Tamarindus indica.*

Sampling was carried out fortnightly from the selected 4 plots from May 2022 to April 2023. Bees were collected by using a sweep net. The net consists of a circular mouth frame, a handle, and a net bag. 15 sweeps were made while walking a distance of 10 m through the study area (Plate 9,figure1).Bees caught on the net were transferred to a killing jar with ethyl acetate.

Sweeping was done from 8.30 am to 12.30 pm, with an interval of 1 hour break in between collection time. The temperature in each interval is recorded and mean temperature of every month is calculated. The collected specimens were preserved in 70% alcohol. Later bee specimens were pinned using entomological pins and labelled with the locality and collection details (Plate 9, figure2)

The specimens were then dried properly under incandescent lights and stored in the insect boxes for further identification. Observations of specimens and their detailed taxonomy study were carried out under a high-resolution stereo zoom microscope, Labomed Luxeo 6Z. Diversity indices were calculated using the latest version of PAST software.

RESULTS

A total of 11 morphospecies of bees belonging to 9 genera were collected, out of which 6 genera belong to the family Apidae and 2 genera belong to the family Halictidae. Only 1 genus belong to family Megachilidae. The relative abundance of bees caught is given in figure 1. Among the species, *Amegilla zonata* dominated over others with a relative abundance of 34.51 percent followed by *Apis dorsata* with 19.21 percent. Overall month wise data of bees collected and relative abundance of bees during the entire study are represented in Table 1 and Table 2. Considering the seasonal variation in bee abundance, post monsoon season is recorded with highest species diversity with a presence of 9 different species, and abundance (144 individuals collected). *Tetragonula* sp and *Amegilla zonata* are most abundant two species in this season with 39 and 34 individuals respectively. Within the post-monsoon season, from December month most diverse no of species with members from all the observed 3 families were recorded. The abundance of bees in Pre monsoon, Monsoon, and Post monsoon season are showed in Table 3, 4 and 5 respectively and in the figures 2, 3, 4.

The temperature has an influence in the abundance of bees, as it varies in different time intervals according to change in temperature. The recorded mean temperature in 12 months at specific intervals of time are represented in table Table 6 and in figure 5.

Vegetation has a great influence in the diversity of a particular habitat and in this sacred grove, flowering plants were recorded as *Chassalia curviflora* during May to December, *Barleria prinoitis* during January to February, *Eranthemum capense* during January to February, *Centrosema molle* during November to January and *Clerodendrum paniculatum* during April to July. Among these *Chassalia curviflora* and *Centrosema molle* are identified as floral host of bees. The bees collected from these plants and their collected months were recorded in the Table 7 and 8. Table 9 represents the diversity indices for bees collected during the study. A list of bees visited in the study area is represented in the Table 10.

Figure 1. Relative abundance of bees during the entire study

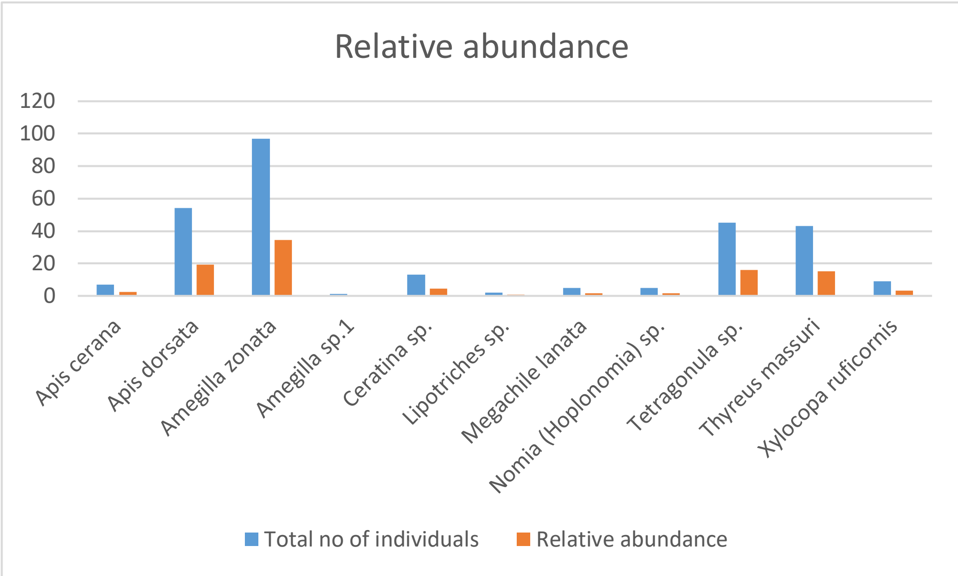

Figure 2. Month wise data of bees collected during Pre monsoon season

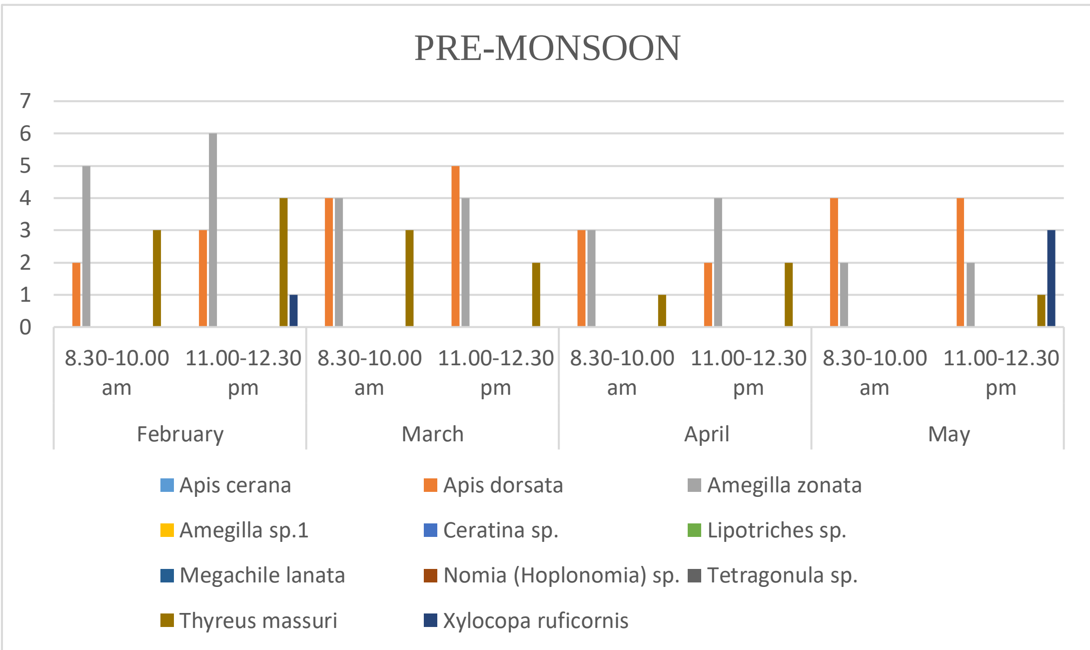

Figure 3. Month wise data of bees collected during Monsoon season

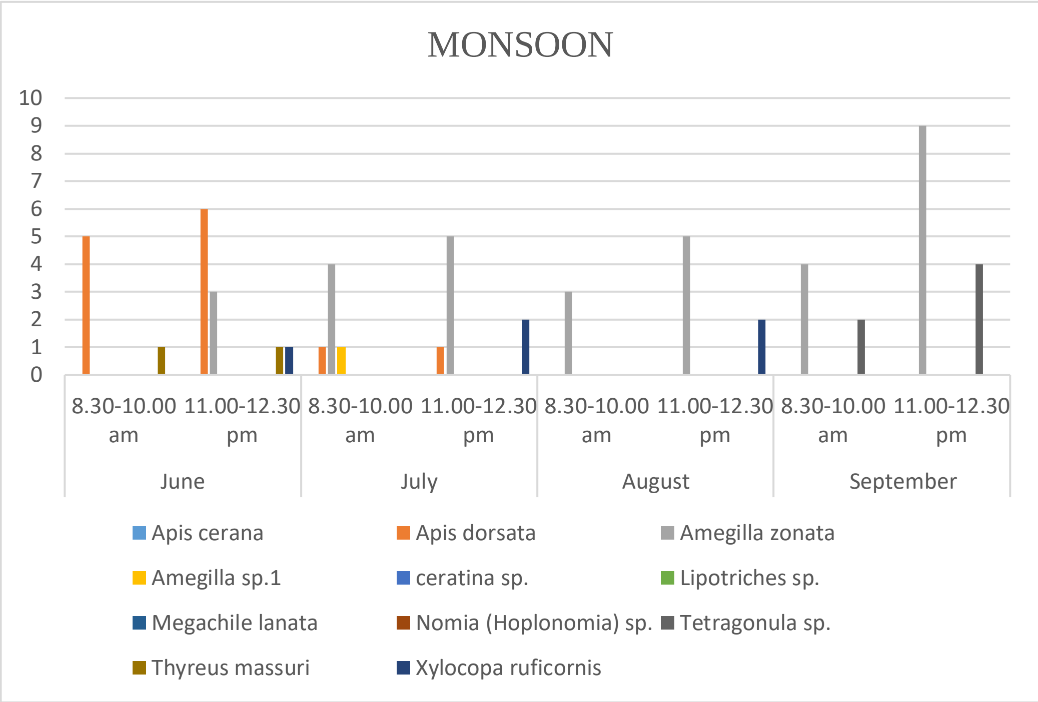

Figure 4. Month wise data of bees collected during Post Monsoon season

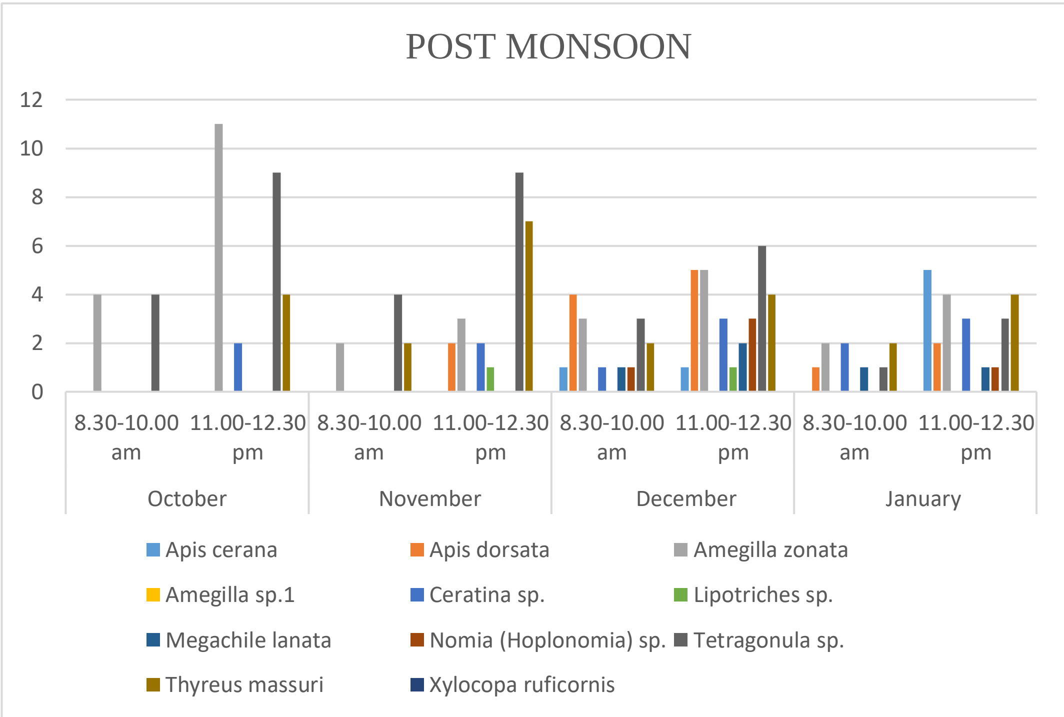

Figure 5. Month-wise data of mean temperature during study

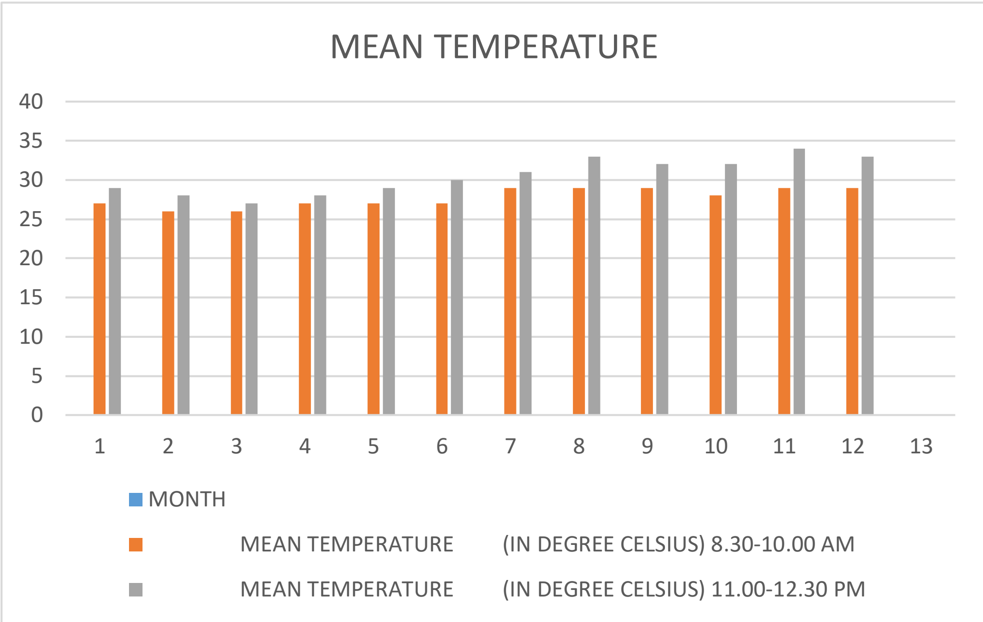

Table 1. Month-wise data of bees collected from study area

Species	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Apis dorsata	8	11	2	0	0	0	2	9	3	5	9	5
Amegilla zonata	4	3	9	8	13	15	5	8	6	11	8	7
Amegilla sp.1	0	0	1	0	0	0	0	0	0	0	0	0
Apis cerana	0	0	0	0	0	0	0	2	5	0	0	0
Ceratina sp.	0	0	0	0	0	2	2	4	5	0	0	0
Lipotriches sp.	0	0	0	0	0	0	1	1	0	0	0	0
Megachile lanata	0	0	0	0	0	0	0	3	2	0	0	0
Nomia (Hoplonomia) sp.	0	0	0	0	0	0	0	4	1	0	0	0
Tetragonula sp.	0	0	0	0	6	13	13	9	4	0	0	0
Thyreus massuri	1	2	0	0	0	4	9	6	6	7	5	3
Xylocopa ruficornis	3	1	2	2	0	0	0	0	0	1	0	0

Table 2. Relative abundance of bee species

Bee species	Total no of individuals	Relative abundance
Apis cerana	7	2.491103203
Apis dorsata	54	19.21708185
Amegilla zonata	97	34.51957295
Amegilla sp.1	1	0.355871886
Ceratina sp.	13	4.62633452
Lipotriches sp.	2	0.711743772
Megachile lanata	5	1.779359431
Nomia (Hoplonomia) sp.	5	1.779359431
Tetragonula sp.	45	16.01423488
Thyreus massuri	43	15.3024911
Xylocopa ruficornis	9	3.202846975

Table 3. Month wise data of bees collected during Pre-monsoon

PRE-MONSOON								
Bee species	**February**		**March**		**April**		**May**	
	8.30-10.00 am	11.00-12.30 pm	8.30-10.00 am	11.00-12.30 pm	8.30-10.00 am	11.00-12.30 pm	8.30-10.00 am	11.00-12.30 pm
Apis cerana	0	0	0	0	0	0	0	0
Apis dorsata	2	3	4	5	3	2	4	4
Amegilla zonata	5	6	4	4	3	4	2	2
Amegilla sp.1	0	0	0	0	0	0	0	0
Ceratina sp.	0	0	0	0	0	0	0	0
Lipotriches sp.	0	0	0	0	0	0	0	0
Megachile lanata	0	0	0	0	0	0	0	0
Nomia (Hoplonomia) sp.	0	0	0	0	0	0	0	0
Tetragonula sp.	0	0	0	0	0	0	0	0
Thyreus massuri	3	4	3	2	1	2	0	1
Xylocopa ruficornis	0	1	0	0	0	0	0	3

Table 4. Month wise data of bees collected during Monsoon

MONSOON								
Bee species	**June**		**July**		**August**		**September**	
	8.30-10.00 am	11.00-12.30 pm	8.30-10.00 am	11.00-12.30 pm	8.30-10.00 am	11.00-12.30 pm	8.30-10.00 am	11.00-12.30 pm
Apis cerana	0	0	0	0	0	0	0	0
Apis dorsata	5	6	1	1	0	0	0	0
Amegilla zonata	0	3	4	5	3	5	4	9
Amegilla sp.1	0	0	1	0	0	0	0	0
ceratina sp.	0	0	0	0	0	0	0	0
Lipotriches sp.	0	0	0	0	0	0	0	0
Megachile lanata	0	0	0	0	0	0	0	0
Nomia (Hoplonomia) sp.	0	0	0	0	0	0	0	0
Tetragonula sp.	0	0	0	0	0	0	2	4
Thyreus massuri	1	1	0	0	0	0	0	0
Xylocopa ruficornis	0	1	0	2	0	2	0	0

Table 5. Month wise data of bees collected during Post Monsoon

POST-MONSOON								
Bee species	October		November		December		January	
	8.30-10.00 am	11.00-12.30 pm	8.30-10.00 am	11.00-12.30 pm	8.30-10.00 am	11.00-12.30 pm	8.30-10.00 am	11.00-12.30 pm
Apis cerana	0	0	0	0	1	1	0	5
Apis dorsata	0	0	0	2	4	5	1	2
Amegilla zonata	4	11	2	3	3	5	2	4
Amegilla sp.1	0	0	0	0	0	0	0	0
Ceratina sp.	0	2	0	2	1	3	2	3
Lipotriches sp.	0	0	0	1	0	1	0	0
Megachile lanata	0	0	0	0	1	2	1	1
Nomia (Hoplonomia) sp.	0	0	0	0	1	3	0	1
Tetragonula sp.	4	9	4	9	3	6	1	3
Thyreus massuri	0	4	2	7	2	4	2	4
Xylocopa ruficornis	0	0	0	0	0	0	0	0

Table 6. Month wise Mean temperature

MONTHS	MEAN TEMPERATURE (In degree Celsius)	
	8.30-10.00 AM	11.00-12.30 PM
MAY	27	29
JUNE	26	28
JU LY	26	27
AUGUST	27	28
SEPTEMBER	27	29
OCTOBER	27	30
NOVEMBER	29	31
DECEMBER	29	33
JANUARY	29	32
FEBRUARY	28	32
MARCH	29	34
APRIL	29	33

Table 7. Bees collected from *Chassalia curviflora*

Sl.No.	Species	Collected Months
1	*Apis cerana*	Dec, Jan
2	*Apis dorsata*	May, Jun, Jul, Nov, Dec, Jan, Feb, Mar, Apr
3	*Amegilla zonata*	May, Jun, Jul, Aug, Sep, Oct, Nov, Dec, Jan, Feb, Mar, Apr
4	*Amegilla* sp.1	Jul
5	*Ceratina* sp.	Oct, Nov, Dec, Jan
6	*Lipotriches* sp.	-
7	*Megachile lanata*	-
8	*Nomia (Hoplonomia)* sp.	-
9	*Tetragonula* sp.	Sep, Oct, Nov, Dec, Jan
10	*Thyreus massuri*	May, Jun, Oct, Nov, Dec, Jan, Feb, Mar, Apr
11	*Xylocopa ruficornis*	May, Jun, Jul, Aug, Feb

Table 8. Bees collected from *Centrosema molle*

Sl.No	Species	Collected Months
1	*Apis cerana*	-
2	*Apis dorsata*	-
3	*Amegilla zonata*	-
4	*Amegilla* sp.1	-
5	*Ceratina* sp.	Oct, Nov, Dec, Jan
6	*Lipotriches* sp.	Nov, Dec
7	*Megachile lanata*	Dec, Jan
8	*Nomia (Hoplonomia)* sp.	Dec, Jan
9	*Tetragonula* sp.	-
10	*Thyreus massuri*	-
11	*Xylocopa ruficornis*	-

Table 9. Diversity indices of bees collected during study

Diversity indices	May	June	July	Aug	Sep	Oct
Taxa	4	4	4	2	2	4
Individuals	16	17	14	10	19	34
Simpson(1-D)	0.6917	0.5662	0.5824	0.3556	0.4561	0.6613
Shannon(H)	1.274	1.094	1.136	0.5504	0.65	1.191
Evenness	0.8938	0.7469	0.7783	0.867	0.9577	0.8227

Diversity indices	Nov	Dec	Jan	Feb	Mar	Apr
Taxa	6	9	8	4	3	3
Individuals	32	46	32	24	22	15
Simpson(1-D)	0.746	0.8734	0.872	0.6884	0.6797	0.6762
Shannon(H)	1.546	2.118	2.081	1.239	1.116	1.11
Evenness	0.7819	0.9234	1.001	0.8627	1.017	1.012

Table 10. Checklist of bees visited in the study area

Sl. NO	SPECIES	FAMILY	SUB FAMILY
1	*Apis cerana*	Apidae	Apinae
2	*Apis dorsata*	Apidae	Apinae
3	*Amegilla* sp.1	Apidae	Apinae
4	*Amegilla zonata*	Apidae	Apinae
5	*ceratina* sp.	Apidae	Xylocopinae
6	*Lipotriches* sp.	Halictidae	Nomiinae
7	*Megachile lanata*	Megachilidae	Megachilinae
8	*Nomia(Hoplonomia)sp.*	Halictidae	Nomiinae
9	*Tetragonula sp.*	Apidae	Apinae
10	*Thyreus massuri*	Apidae	Apinae
11	*Xylocopa ruficornis*	Apidae	Xylocopinae

TAXONOMIC ACCOUNT

Genus *Apis* (Linnaeus, 1758) (Plate 6, figure 3 and 4)

Family: Apidae

Common Name: Common honeybee

DIAGNOSIS

Consists group of small (7 mm long) to large (19 mm long) moderately hairy bees. Some species have red or brown with black bands and orange-yellow rings on the abdomen. They have hair on thorax and less hair on abdomen. The wings have complete strong venation. Stigma is small and slender. Honey bees have pollen basket on their hind legs.

Apis cerana and *Apis dorsata* are the identified species in the study. *Apis cerana* and *Apis dorsata* are found in 2.4 % and 19.2% in the study site respectively.

Genus *Amegilla* (Friese, 1897) (plate 6, figure 1 and 2)

Family: Apidae

Common Name: Banded bee

DIAGNOSIS

Characteristic black and pale blue abdomen with a golden-brown head. Bands may differ with sex, male having more bands than female. The face of both sexes contains yellow or white markings. The tibial scopa includes a band of plumose hairs near the upper margin of tibia. The pygidial plate of the male is absent.

Amegilla zonata and one more *Amegilla* species are identified from the study. Most abundant species in the study was *Amegilla zonata* with abundance 34%.

Genus *Ceratina* (Latreille, 1802) (plate 7, figure 1)

Family Apidae

Common Name: Small carpenter bee

DIAGNOSIS

Slender body usually small generally shining, superficially hairless body varies from black to metallic green, rarely with metallic red. Males of many species have white markings on the face. Concave lateral margins of the clypeus, the clypeus shaped like a thick inverted T shape of the mandible are broad at the base and abruptly narrowed medially

One *Ceratina* species are identified in study site with an abundance of 14.6%.

Genus *Lipotriches* (Gerstaecker, 1858)

Family: Halictidae

Common Name: Sweat bee

DIAGNOSIS

They are solid looking medium sized bees (7-12 mm in length). Most species are banded on the abdomen (dark coloured with narrow lighter bands on the abdomen or yellow black bands on the abdomen). Pronotum with continuous or medially or laterally notched transverse carina in both sexes. Basitibial plate of female with a carina only along the posterior margin.

One species of *Lipotriches* was identified with a very low abundance of 0.71%.

Genus *Megachile* (Latreille, 1802) (plate 7, figure 2)

Family: Megachilidae

Common Name: Leaf cutter bee

DIAGNOSIS

They are medium sized bees having pale bands of hair across the abdomen. Female of most species have large mandibles for cutting leaves and flowers. They have long stigma and prestigma. They don't have sticky pads (arolia) between their claws and therefore cannot climb smooth surfaces. Scopa is underside of abdomen.

Megachile lanata is the identified species with an abundance of 1.77%.

Genus *Nomia* (Latreille, 1804) (plate 7, figure 3)

Family: Halictidae

Common Name: Alkali bee

DIAGNOSIS

They are small to medium sized (7-12 mm) in length, solid looking hairy bees. They vary in colour but are mostly dark with contrasting bands on the abdomen which are glossy.

Nomia species was seasonal in occurrence with an abundance of 1.77%.

Genus *Tetragonula* (Moure, 1961) (Plate 7, figure 4)

Family: Apidae

Common Name: Stingless bee

DIAGNOSIS

Mostly black and body is trigoniform to apiform. Claws of female are simple, arolia present. Wing venation is reduced and marginal cells being open apically. Stigma is large to moderately Sized.

Tetragonula species are identified with 15.3% relative abundance.

Genus *Thyreus* (Panzer, 1806) (Plate 8, Figure 1)

Family: Apidae

Common Name: Cuckoo bee

DIAGNOSIS

Body is less robust. Body has striking pattern with pale to bright blue or greenish areas of appressed hairs. Wings are light brown with a purple sheen. Scutellum is flattened as a plate projecting posteriorly.

Thyreus massuri is the species identified with a relative abundance of 15%.

Genus *Xylocopa* (Latreille, 1802) (Plate 8, Figure 2)

Family Apidae

Common Name: Carpenter bee

DIAGNOSIS

Large robust bees. Reduced stigma and very long prestigma and marginal cell. Strongly papillate distal parts of the wing. Short proboscis being strongly sclerotized. Post palpal part of the galea is blade like and used to cut the corolla of tubular flowers to take honey.

Xylocopa ruficornis is observed with a relative abundance of 3%.

DISCUSSION

A total of 11 morphospecies of bees were collected from the study area which belongs to 9 genera, out of which 6 belongs to the family Apidae and 2 genera belong to Halictidae family. Only one genus belong to the family Megachilidae. In the estimation of relative abundance of bees during the entire study, *Amegilla zonata* dominated over others with an abundance of 34.5 %. Followed by *Apis dorsata* with an abundance of 19.21%. In the overall study, family Apidae dominated over other observed families in abundance. Total out of 281 individuals recorded, 97 individuals were *Amegilla zonata*. 54 individuals were *Apis dorsata*. Family Apidae is one of the largest bee families in the world (Kelber and Somanathan, 2019). There is variation in the seasonal diversity and abundance of bees. Pre monsoon includes the months from February to May. Monsoon includes the months from June to September. Post monsoon includes the months from October to January. From the study, it is evident that most diverse number of bee species were recorded during the month of December relative to all other months, with a presence of 9 morphospecies with members representing all the observed 3 families. Studies by Pannure and Chandrasekhara (2013) also shows that there is an evident relation between season and composition of bee community. There is difference in the trends of occurrence of bees that the *Apis* genus has its presence generally in all seasons whereas, *Megachile* and *Nomia* genus members are restricted to post monsoon. *Apis* genus is generally abundant in most of season, but *Megachile* are found active mainly during months of October to January (Pannure and chandrasekhara, 2013). Monthly differences in bee species abundance can be seen in all ecosystems (Kazenel *et al*., 2020).

The influence of abiotic factors is highly important in the bee composition. The mean temperature of every month and its variation in different time intervals are recorded in the Table. 6. In the time interval between 11.00-12.30 pm are recorded with high temperature and the highest temperature of 34 degree Celsius is recorded in the month of March. There is a high correlation between the maximum daily temperature and the honey bee visit (Puskadija *et al*., 2007). Monsoon season is comparatively having lower bee assemblage because of the rainfall. Studies also proved precipitation had negative impact to honey bee visit (Puskadija *et al.*, 2007). Rain had negative impact on bee activity and pollination. The positive temperature influence is generally applicable for species like *Apis dorsata*, *Tetragonula* etc. and in some species, there is a positive but not much significant effect for temperature (Battacharyya, 2016).

In the Table.1, it is represented as in march with a temperature of 34 degree Celsius, the recorded species are only from Apidae family. Weather conditions have significant affect in bees and different species respond differently to similar weather conditions (Abou shaara *et al*., 2012).

The availability of flowering plants is another factor that causes variation in the abundance of bees. The two flowering plants which are identified as floral host of bees influences the abundance of bees in that habitat. November to January is the time period where the presence of *Centrosema molle* was identified and that is the post monsoon season in which *Lipotriches, Megachile, Nomia* etc. were recorded. Rest species were collected from *Chassalia curviflora* which were present during the period of May to December. Naupane and Thapa (2015) through their study stated that the foraging activity of bees are in accordance with the flowering vegetation of that habitat. Thus, the availability of flowers and weather conditions together influence the bee abundance of a habitat.

Diversity indices were determined for bees collected in Table 9. Simpson index was found higher in December (0.8734) and lower in August (0.3556). The Shannon diversity index and Simpson index were found to be lower in August possibly because of weather.

CONCLUSION

The study was focussed on the seasonal variation and influence of abiotic factors and vegetation on bee diversity and abundance. A total of 11 bee morphospecies were collected from the sacred grove. They belong to 9 different genera which belongs to 3 bee families as Apidae, Halictidae, and Megachilidae. Among these families, species from Apidae are the most abundant over the other families followed by Halictidae and Megachilidae. Because of the shady environment, the availability of flowering plants is restricted to specific areas of the study site. The main floral host of bees are identified as *Chassalia curviflora* and *Centrosema molle*. *Amegilla zonata* is identified with the highest relative abundance as 34.5% and this species was highly dependent on *Chassalia curviflora*. The species of Apidae shows presence in all the 3 seasons studied whereas, species from genus *Lipotrichus, Megachile* and *Nomia* shows a restricted presence in the post monsoon season and they are dependent on plant *Centrosema molle*. There is seasonal variation in the abundance of bees. In the seasonal study of bees, the December month contains more diverse species and in the study post monsoon season with higher availability of flowering plants are season with the highest abundance.

The influence of abiotic factors is studied with the help of temperature and it has an influence in the foraging activities of bees. Most of them respond positively to the temperature and shows greater foraging activity during period of high temperature. The diversity indices are calculated, Simpson index is highest in the month December (0.8736) and Lowest in the Month August (0.3556). Shannon index is highest in the month December (2.118) and lowest in the month August (0.5504). Through the study, the abundance and seasonal variation of bees in a sacred grove which is a conserved ecosystem with religious belief was found. How temperature and limited vegetation contribute to the overall diversity of bees in the habitat is also revealed.

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PLATE 1.

SATELLITE VIEW OF STUDY AREA

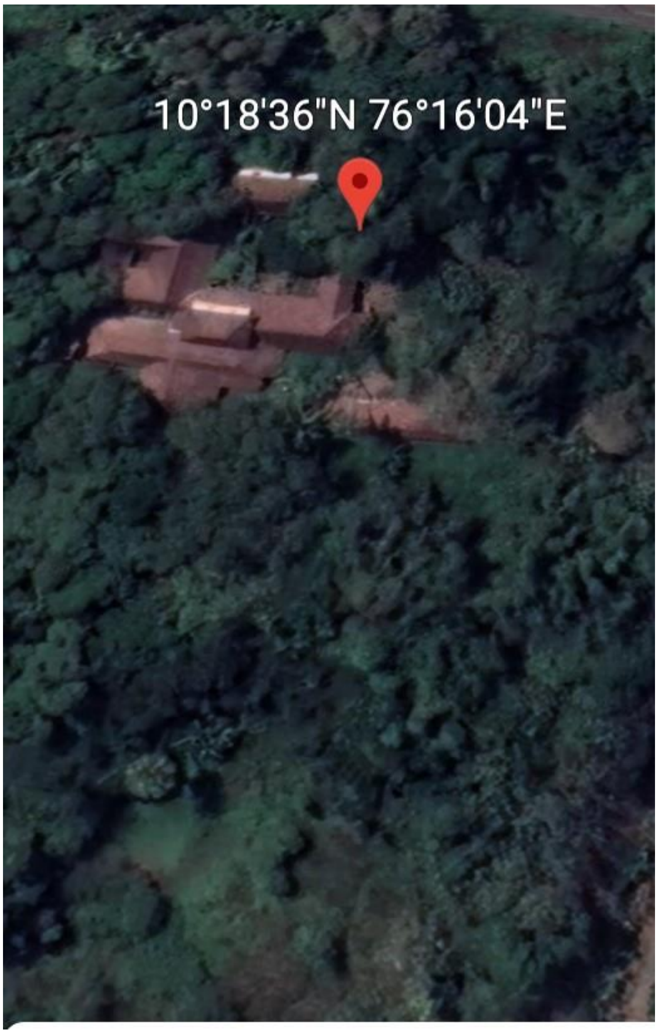

PLATE 2.

STUDY AREA

PLATE 3.

STUDY PLOTS

1. PLOT 1

2. PLOT 2

PLATE 4.

1. PLOT 3

2. PLOT 4

PLATE 5.

1. *Chassalia curviflora*

2. *Centrosema molle*

PLATE 6.

1. *Amegilla* Sp.1

2. *Amegilla zonata*

3. *Apis dorsata*

4. *Apis cerana*

PLATE 7.

1 .*Ceratina* sp.

2. *Megachile lanata*

3. *Nomia* sp.

4. *Tetragonula* sp.

PLATE 8.

1. *Thyreus massuri*

2. *Xylocopa ruficornis*

PLATE 9.

1. Collection method

2. Preservation of collected specimen

38

DIVERSITY AND ABUNDANCE OF LONG-JAWED SPIDERS (ARANEAE, TETRAGNATHIDAE) IN SELECTED ECOSYSTEMS IN THRISSUR, KERALA

DISSERTATION SUBMITTED
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF

MASTER OF SCIENCE IN ZOOLOGY

UNIVERSITY OF CALICUT

By
GREESHMA T S
CCAVMZL009

DEPARTMENT OF ZOOLOGY
CHRIST COLLEGE (AUTONOMOUS)
IRINJALAKUDA, THRISSUR, KERALA- 680125

JULY 2023

DIVERSITY AND ABUNDANCE OF LONG-JAWED SPIDERS (ARANEAE, TETRAGNATHIDAE) IN SELECTED ECOSYSTEMS IN THRISSUR, KERALA

Dissertation submitted in partial fulfilment of the requirement for the award of the degree of

MASTER OF SCIENCE IN ZOOLOGY

UNIVERSITY OF CALICUT

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JULY 2023

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Place: Irinjalakuda **Dr. Sudhikumar A.V.**

Date: 19-07-2023 **Head, Department of Zoology**

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I further certify that the work has not been submitted either partly or fully to any other University or Institution for the Award of any Degree or Diploma.

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DECLARATION

I hereby declare that the dissertation entitled **"DIVERSITY AND ABUNDANCE OF LONG-JAWED SPIDERS (ARANEAE, TETRAGNATHIDAE) IN SELECTED ECOSYSTEMS IN THRISSUR, KERALA"** is a genuine record of project work done by me under the guidance of Dr Sudhikumar A.V., Department of Zoology, Christ College, Irinjalakuda, and has not been submitted to any university or institution for the award of any degree or diploma.

I further declare that the results presented in this work and considerations made therein contribute to the advancement of knowledge in science in general and Arachnology in particular.

Place: Irinjalakuda GREESHMA T S

Date: 19-07-2023

ACKNOWLEDGEMENT

I would like to express my heartfelt appreciation to everyone who directly and indirectly assisted me in successfully accomplishing this project. First, I want to convey my profound gratitude to the Almighty, whose infinite offerings have improved my thoughts and behaviour.

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Last but not least, I want to thank all of my M.Sc. Zoology classmates and non-teaching staff for offering their support.

ABSTRACT

The long-jawed spiders (Family Tetragnathidae) play a significant role in the population control of insect pests. This study was carried out to document the species composition and abundance of the family Tetragnathidae in three different habitats of the Thrissur district: Muriyad Kol Wetland, Thumboor Ayyappankavu Sacred Grove, and Thekkinkadu teak plantation. The study was conducted from January 2023 to May 2023. A total of 475 Tetragnathid specimens, belonging to 18 species and 5 genera, were recorded from all three habitats. Diversity, species composition, richness, and abundance were different for different habitats. Muriyad Kol Wetland has high Tetragnathid diversity and abundance, followed by Thumboor Ayyappankavu Sacred Grove. The Thekkinkadu Teak plantation has the least diversity and abundance. The diversity of Tetragnathidae may be affected by the differences in climate, vegetation type, and disturbance levels in three different habitats. The analysis using a Venn diagram gives the unique and shared species of all three habitats. The diversity of Tetragnathidae was observed to be high during the months of January and February.

CONTENTS

STUDY ON THE CONGREGATION BEHAVIOUR OF FIREFLIES IN SELECTED SITES OF THRISSUR DISTRICT

Project report submitted to the

UNIVERSITY OF CALICUT

in partial fulfilment of the requirement for the award of the Degree,

MASTER OF SCIENCE IN ZOOLOGY

BY

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THRISSUR, KERALA – 680125

JULY 2023

Examiners

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2.

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This is to certify that the project work entitled **"STUDY ON THE CONGREGATION BEHAVIOUR OF FIREFLIES IN SELECTED SITES OF THRISSUR DISTRICT** "is an authentic record of the study carried out by **JITHIN JOSE (Reg. No. CCAVMZL011)** as the part of M. Sc. practical during the year 2022-2023 and the results of this work have not been presented for the award of any other degree/diploma in any university.

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I further certify that no part of the work has not been presented for the award of any other degree/diploma.

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Date: 10.07.2023

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I further declare that the results presented in this work and considerations made there in contribute to the advancement of knowledge in science in general and Entomology in particular.

Jithin
JITHIN JOSE

Place: Irinjalakuda

Date: 10.07.2023

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I would like to express my heartfelt sincere gratitude to all the individuals who have supported me throughout this project. I consider myself incredibly fortunate to have received such unwavering support and that moves me to seize this opportunity to thank each and every one of them.

First and foremost, I am deeply grateful to the Almighty God whose blessings have enriched my thoughts, actions, and health, giving me the strength and self-confidence to complete this project.

I am indebted to Rev. Fr. Dr. Jolly Andrews CMI, the Principal of Christ College, Irinjalakuda, for providing me with the necessary facilities and resources to carry out this work. His invaluable assistance and support were instrumental in the successful completion of this project.

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CONTENTS

ABSTRACT

The congregation behaviour of fireflies was studied from 6 different sites of Thrissur district. Study revealed that firefly congregation peaks by 7 pm and starts declining before it reaches its lower count by 11 pm. This is because of the increase in the value of abiotic factors such as humidity, wind speed and atmospheric pressure, but decrease in temperature. Two genera of fireflies belonging to the Family Lampyridae were identified from 6 different study sites. *Abscodita,* Ballantyne, Lambkin & Fu, 2013 was the dominant firefly during the entire study followed by *Asymmetricata,* Ballantyne, 2010. More firefly count was observed in Thumburmuzhi and Palappilly and less count observed from Karikulam. Mainly 3 display trees were observed; *Havea brasiliensis*, *Bombax ceiba* and *Terminalia catappa* in six different sites.

PREDATORY BEHAVIOUR OF *ARGIOPE PULCHELLA* THORELL, 1881

Dissertation submitted to

UNIVERSITY OF CALICUT

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ABSTRACT

Spiders are major predators that prey on a wide range of insects, maintaining the ecological equilibrium and stabilizing the ecosystem. *Argiope pulchella* is an araneid spider that weaves a quintessential orb web to capture prey. This is an experimental and observational study of the predatory behaviour of *Argiope pulchella* towards different categories of prey. The study is done in caged adult female conspecifics of the species. Prey belonging to three insect orders, Hymenoptera, Lepidoptera and Orthoptera which constitute three major categories of prey for *A. pulchella* in natural conditions and have distinct physical features are used for analysis. The sequential order and the duration of behavioural units, starting from prey location and discrimination to feeding by the spider are recorded and analyzed. Prey discrimination is peculiar and the spider decides the attack strategy based on this discrimination. The sequence of predation is specific to each prey type. Even though variations are reported, the majority follow a general pattern. The behavioural units have adaptive significances that enhance the survival value of the species. In all predatory sequences, the behavioural units fall into five functional categories; prey location, prey discrimination, prey immobilization, prey transportation and prey manipulation, similar to the predatory pattern shown by other araneids; *Argiope argentata* (Robinson, 1969; Robinson & Olazzari, 1971) and *A. aurantia* (Harwood, 1973), investigated for predatory behaviour before. A model of predatory behaviour of the species is constructed based on the data obtained from the study.

KEY WORDS: Araneidae, *Argiope pulchella*, hymenoptera, lepidoptera, orthoptera, predatory behaviour, prey

A study on the binding affinity of different investigational new drug (INDs) to various MMPs

Dissertation submitted to

UNIVERSITY OF CALICUT

in partial fulfilment of the requirement for the award of

MASTER OF SCIENCE IN ZOOLOGY

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2023

A study on the binding affinity of different investigational new drug (INDs) to various MMPs

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UNIVERSITY OF CALICUT

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MASTER OF SCIENCE IN ZOOLOGY

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2023

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DECLARATION

I, LIKHITHA K AKHILESWARAN do hereby declare that this dissertation entitled **"A study on the binding affinity of different investigational new drug (INDs) to various MMPs"** is a genuine record of dissertation done by me under the guidance of **Dr.Leyon Varghese**, Asst. Professor, Department of Zoology, Christ College (Autonomous), Irinjalakuda, and the results of this study have not previously formed the basis of the award of any degree in any university**.**

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This is to certify that, the dissertation entitled **"A study on the binding affinity of selected investigational new drugs (INDs) to various MMPs "** is an authentic work carried out by **LIKHITHA K AKHILESWARAN (Reg. No.CCAVMZL013),** Department of Zoology, Christ College, Irinjalakuda, and is in partial fulfillment of the requirements for the degree of **Master of Science in Zoology** of the **University of Calicut** and the results of this work has not formed the basis for the award of any degree or diploma.

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LIKHITHA K AKHILESWARAN

CONTENTS

SPIDER DIVERSITY AND GUILD STRUCTURE IN THE NUTMEG AGROECOSYSTEM, KADUPUKARA, KERALA, INDIA

Project report submitted to the University of Calicut in partial fulfillment of the requirement for the award of Degree of

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Dr. Sudhikumar A.V.

Head of the Department

Submitted for the university examination

held on ……………….

Internal Examiner:

External Examiner:

<u>CERTIFICATE BY THE GUIDE</u>

This is to certify that the contents of this project entitled ***'SPIDER DIVERSITY AND GUILD STRUCTURE IN THE NUTMEG AGROECOSYSTEM, KADUPUKARA, KERALA, INDIA'*** is the original work of Mariya Rose Davis carried out under my supervision and guidance in the Department of Zoology at Christ College (Autonomous), Irinjalakuda.

Dr. Sumesh N V

Department of zoology

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CANDIDATE’S STATEMENT

I hereby declare that the work incorporated in the present project is original and has not been submitted to any other university or institution for the award of a degree. I further declare that the results presented in the thesis and the considerations made there in, contribute in general to the advancement of knowledge in science.

PLACE-IRINJALAKUDA

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MARIYA ROSE DAVIS

REG NO: CCAVMZLO14

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ACRONYMS AND ABBREVIATIONS

Ha	Hectare
MS Office	Micro Soft Office
WSC	World Spider Catalogue

CONTENTS

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LIST OF TABLES

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ABSTRACT

Spiders are one of the most diverse groups of terrestrial predators and are found in various environments such as agroecosystems and neighbouring areas.It's crucial to do research on the variety of spiders in agroecosystems in order to track changes in fauna brought on by management.This work evaluated spider richness, abundance, and species composition and the effect of seasonal variation in population fluctuation. The study area was nutmeg plantations situated at Kadupukara, Thrissur district, Kerala. The study was conducted during the period of June 2022 to March 2023.Sampling methods such as ground hand collection, aerial hand collection, vegetation beating, litter sampling and visual search were used to collect spider samples. The collected specimens were preserved in ethyl alcohol and identified upto genus or species level using available literature.During the study period, a total of 33 species from 26 genera in 11 families were collected from the total study area.The Araneidae and Salticidae was the most dominant of the 15 families studied in the total study area, with 8 species belonging to 7 and 6 genera respectively.A guild structure analysis revealed six feeding guilds viz.: Ambush hunters Ground hunters Orb web weavers, Space web builders, Sheet web builders andother hunters.

Keywords: Spider, Diversity, Guild structure, Nutmeg, seasonal variation

1. INTRODUCTION

Spiders are cosmopolitan terrestrial arthropods and although they are usually abundant predators (Turnbull 1973; Nyffeler and Benz 1987; Wise 1993).Spiders are found throughout the world and live in almost every habitat on earth, except Antarctica. Spiders belongs to largest order Araneae of class Arachnida and they are the members of the phylum, Arthropoda. They rank 7th positon in total species diversity and account for 18% of all animal variety. Currently spiders consists of over 51,000 species in 132 families.

Spiders are the ancient animals with a history going back over 400 million years during the Devonian period. Spiders usually have 1 year life span, but some lives around 20 years. And their size ranges from barely visible (0.017 inches) to huge (11inches). In most of the cases, females are dominant ones.

Spiders are unique among arthropods in their body construction. Body segments are merged into two tagmata, anterior cephalothorax and posterior abdomen, which are linked together by a short pedicel.The cephalothorax constitutes the head and the thorax which are fused into a single unsegmented unit and protected dorsally by a hard chitinous carapace and ventrally by sternum.And four pairs of segmented legs attached to the cephalothorax. Abdomen is usually the largest portion of the body and varies greatly in shape, size, shape, colouration and markings in different species. But abdomen is relatively smaller in adult males than females. And four pairs of segmented legs attached to the cephalothorax.Spiders are also unique by the presence of spinnerets, situated at the posterior end of the abdomen, the external organs used for spinning silk or webbing.

Spiders are carnivorous and they feed almost exclusively on living prey. These successful predators prey on different organisms and employ a wide range of strategies to capture prey. And their amazing way of prey catching strategies ranging from simple ambushing to the use of complex silk snares. Prey detection is done withsense vibrations, but active predators have excellent vision. They may trap prey in sticky webs, mimic to avoid detection, or chase and tackle it.Spiders are known to be sensitive to fine changes in temperature with the tips of the legs and the spinnerets. Spiders usually have eight eyes arranged in two rows. Some with exceedingly good vision powers and other nocturnal ones more dependent on tactile and chemical stimuli than on visual stimuli.

They eat and digest anything they catch but have an inconspicuous mouth opening through which they can only eat liquefied food due to thelack of specialized intestines and mandibles. And they crush food with the pedipalps and liquefy their meal with digestive enzymes. Spiders kill their prey by injecting the venom secreted by the pair of venom glands located near chelicera of cephalothorax.The web-building spiders wrap their victims in a sheet of silk.

Camouflage and mimicry adaptations are exhibited by spiders to catch their prey and to avoid predators.Diurnal spidersare cryptically coloured and their body patterns make them difficult for their predators to find.Nocturnal spiders are shabbily coloured.Ant-mimicking also very popular among spiders like *Castianeira*

In spite of being predators themselves, due to their smaller appearance spiders have many predatory enemies such as certain mammals, birds, reptiles, wasps, centipedes and other larger spiders. And man has also become, indirectly, a predator of spiders through destruction of their habitats and poisoning with harmful pesticides and chemicals.

Spiders exhibits great sexual dimorphism, with the females much larger than the males in most cases. In some cases spiders with poor eyesight the larger females may attack and kill small spiders including individuals of their own species.Thus the male spider often displays some unique courtship ritual to attract the attention of the female for survival and mating. In the cases ofspiders with good vision such as jumping spiders (Salticidae), the courtship displays are elaborate and the males possess bright colours.

Spiders have already established themselves as model organism for biochemical, ethological and ecological research purposes (Sebastian & Peter, 2009) Spiders serve an important ecological role to maintain the food wed in perfect equilibria as they feed on several insects and even small vertebrates (Sumesh & Sudhikumar, 2020). Spiders are also considered as bio-indicators of the health of the ecosystem (Mathew et al. 2009). Thus it is necessary to conserve these natural pest regulating factors for maintaining ecosystem sustainability and conservation of biodiversity.

Spiders form the primary predators of any terrestrial group (Gertsch, 1949). Spidersact as a potent biological pesticide by predating on almost all insects (Nyffeler & Birkhofer, 2017). By collectively consuming large quantities of prey and occasionally being immune to some insect-specific agrochemicals, spiders act as one of best biological insect control (Pékar and Kocourek, 2004; Michalko et al., 2018). Additionally, there is a wealth of pharmaceutical and medicinal potential in some spider species and their venom, and silk shows tremendous promise for engineering purposes, from clothing to industrial applications (Foelix, 2011; Ko and Wan, 2018; Pineda et al., 2018). Spider venom possess various potent and target peptide molecules which will be beneficial in medical, agricultural and pharmacological activities (Saez & Herzig, 2019).

These slow moving creatures are also sensitive to disturbances across the feeding network and unable to escape environmental changes. Habitat loss and land degradation due to deforestation, agroforestry, climate change, urbanisation, grazing andpollution forms major threats to the to the spider population.

In agroecosystems, the distribution pattern, abundance and diversity of spiders is usually negatively affected by high external input farming systems (Butt and Sherawat, 2012). Species abundance of spider communities in agricultural and horticultural ecosystem can be as high as in undisturbed natural ecosystem. Now research studies shows that organic farming is more beneficial to spider abundance than conventional agriculture. But these also effects depend on the complexity of the landscape. A reduction in mechanical alterations to the land, such as harvesting, ploughing and grazing and the use of biopesticides, botanicals and organic manure would enhance the spider population in different ecosystems. Spiders remain under-represented across the world's endangered-species conservation plans and groups and governments don't act enough to protect them.

The most diverse and abundant spider group (Marshall et al.1994) forms an excellent indicators of biodiversity due to their extreme Sensitivity to natural conditions and disturbances. Their presence or absence in a region provide information about the present state of the environment and provide an early warning signal of environmental changes (Sumesh, 2021).

Globally, agriculture is becoming one of the main threats to biodiversity, especially in tropical countries.Spiders occurring in high abundance and richness in agricultural ecosystems (Caprio et al., 2015; Sunderland and Samu, 2000; Wise, 1993) but they are also little studied in environments like agroecosystems and nearby lands. Spiders provide an ecosystem service by feeding on pest insects (Riechert and Lockley, 1984, Symondson et al., 2002) and through this provide a sustainable agriculture system. Thusfor efficient pest suppression, a large regional species pool is needed (Symondson et al., 2002). In spite of this, they have not been treated as an important biological control agent (Fahad et al, 2015). Despite their size, ecological importance of spiders is undeniable as they are abundant predators of Arthropods group (Scharff et al., 2003).

Farmers spend billions of dollars annually on pesticides designed to destroy weeds and insect pests. Unfortunately, pesticide use has also been shown to impact spider abundance in fields this indirectly result in an unintentional resurgence of pests after the pesticides action period.

Detailed knowledge of the biodiversity of spider communities on agricultural land is important both in terms of enhancing pest control and also in nature conservation by acting as bio-indicators. Thisresearch on spider aims to finds its diversity from a nutmeg agroecosystem in Kerala. And to find ways to preserve and enhance spider density and species richness in agricultural fields by maintaining a diverse fauna in the agroecosystems.

Nutmeg is one of the important spice commodities in Kerala. Nutmeg trees (*Myristica fragrans Houtt)* are large evergreen tree spice belonging to the family 'Myristicaceae' and genus 'Myristica'. It grows to a height of about 10 to 18 m. Nutmeg requires a hot, humid climate withhumidity range of 75-90 percent and annual rainfall about 150cm and above. The tree takes preference for partial shades and areas with clay loam, sandy loam and red laterite soils. Organic rich soil with water stagnation conditions are ideal for its growth.Nutmeg is relatively easy to maintain and harvest as compared to other labour intensive crops like vanilla.

In India, nutmeg is broadly grown in the southern states of Kerala, Karnataka and Tamil Nadu, and has now spread to the eastern states and to the north eastern part of India. The dry, humid climate conditions of Kerala was more suitable for nutmeg production andwere grown in a multi crop mode along with other spices and crops. This cash crop contributes a substantial income to the farmers. In Kerala alone about 5000 farmers are engaged in nutmeg production.

Nutmeg starts bearing fruit from eight to nine years after planting andcontinues to yield well for 10 to 20 years and sometimes even longer.A fully grown nutmeg tree produces about 2,000 to 3,000 fruits per year and its seed forms the economically valuable commercial part of nutmeg spice. Harvesting is done in different areas at different times of the year and it heavily dependent on rain patterns and fruit ripening. In India it’s usually done in April to July months.

Nutmeg plantations are considered as an environmentally friendly crop. As their shallow roots makes them relatively resistant to drought, it protects the soil, allows proper water drainage and sequestrates carbon.Nutmeg production is moderately sustainable and eco-friendly. Aside from high water consumption, there is no significant damage to air, water, land, soil etc. as long as pesticides have not been used. Nutmeg is a perennial agricultural ecosystem with a rich arthropod diversity including pests and natural enemies.Ants and spiders are the most abundant predators of ecosystem.

The site selected for the study is the nutmeg ecosystems situated at Kadupukara, Thrissur district. The focus of this study was on determining the diversity of spiders,their abundance on seasonal variations and guild structure. In general, there are only few and limited taxonomic investigations on spiders in man-made agroecosystems. There have been no comprehensive studies of the selected region's spider faunal diversity have been published. The present study will help to improve the understanding on spider diversity and seasonal occurrence and thereby help in developing a future integrated pest management strategy (IPM) in nutmeg.

1.1 OBJECTIVES OF THE STUDY

This study was carried out with the primary goal of getting the approximate representation of the spider fauna from selected habitats of nutmeg plantations in Kadupukara, Thrissur, India within the limited time period.

1. Conduct an exploratory survey of spiders from the selected habitats in Kadupukara and identification of spiders up to genus or species level
2. Study the guild structure of spiders within each habitat
3. Estimate the species abundance, seasonal diversity and richness of spider population in selected habitats.

1.2 RELEVANCE OF THE STUDY

Spiders play a fundamental role in natural ecosystem. They support a large proportion of 'insectivorous' animals by serve as a food source. Few vertebrate species feed almost exclusively on spiders alone.They’re also generalist consumers, they prey on a variety of organisms, including other spiders, very rarely vertebrates, and their most common prey type insects.These obligate predators are crucial in controlling these plant feeding insect populations in every ecosystem they’re a part of. It is estimated that one spider can eat as many as 2,000 insects in a year (Dustin Wilgers, 2016).

In the study area, containing man-made ecosystems of nutmeg plantation, no specific extensive studies on spider faunal diversity have been done and published.It is the first attempt to examine the spider fauna in this area. Focus of the study was to find out the diversity and abundance of spiders in the selected habitats in the study area.This study provides data on species distribution and diversity, guild structure, richness, and evenness in selected habitats based on seasonal variation. The goal of this study is to look into the spider fauna in this area in order to provide a baseline for future research.

2. REVIEW OF LITERATURE

Spiders belongs to the order Araneae are one of the most fascinating and diverse invertebrate animals in the world. Since 18th century the studies and classifications based on spider diversity and abundance were conducted by naturalists in various regions of the world. Spiders belongs to the largest phylum Arthropoda, and it comprises all the insects, arachnids, crustaceans etc. Spiders are divided into two suborders: Mesothelae (about 100 species) and Opisthothelae.

Many researchers have undertaken extensive research on the diversity of spiders from various countries. Currently More than 5100 spider species are divided among 132 families and 4314 genera (WSC, 2023). About 1200 new spider species are described in recent year. Since the publication of the updated checklist of Indian spiders (Siliwal et al., 2005), there has been an incredible increase in the number of spider fauna all over the world. After that in 2007, Siliwal&Molur provide a comprehensive checklist of spiders of South Asia with eight countries. And the estimated number is about 2,299 spider species divided into 552 genera and 67 families.

India is one of the mega diversity countries in the world with only 2.4% of the world's land area. Even though it comprises about 7 to 8% of all recorded species including all plants & animals (Pande& Arora, 2014). British explorers began studying spiders in India in the latter half of the 19th century. The earliest contribution on the taxonomy of Indian spiders is that of European arachnologist Stoliczka (1869). From that period the contributions from Blackwall (1867); Karsch (1873); Simon (1887); Thorell (1895) &Pocock (1900), Tikader(1980), Malhotra (1980), Biswas (1981) forms the pioneer works of Indian spiders. Currently from India 1947 species under 493 genera in 61 families are known (Caleb et al.

2003, Araneae of India). Although spiders are one of the most widely distributed and diverse groups of organisms in Kerala, their study has been largely neglected.

Spider diversity assessment is difficult, particularly in tropical environments where dozens of species can coexist (Privet et al., 2020). The status of spider diversity is a major constraint to evaluate the community level of biological organization. Higher species diversity and species richness in an area is an indicator of a healthier and complex community. A greater variety of species allows for more interactions, thereby increasing the stability of the system, indicating good environmental conditions (Hill, 1973).

Studies have demonstrated that the selection of spider habitat is affected by a variety of biotic abiotic factors as well as architectural features of the habitat. And this attributes include size, shape and spatial arrangement of substrate used by spiders (Utez, 1991; Hawksworth&Kalin-Arroyo 1995). Studies of Ried& Miller (1989) suggest that structurally more complex habitat types can support more diverse spider community. Spiders generally have preferences for moisture and temperature and these factors limit their range of physiological tolerance zones (Pandit&Pai, 2017).

Hore & Uniyal's study (2008) deals with the comparison of spider diversity and composition in a complex landscape of the Terai Conservation Area (TCA). A mosaic of five vegetation types was sampled for spiders and a total of 3666 adult spiders representing 22 families, 60 genera, and 160 species were found. PhalgunChetia&Dilip Kumar Kalita (2012), conducted a study describes the identification of the spider assemblages with respect to their diversity and distribution in the semi evergreen forest, Gibbon Wildlife Sanctuary, Assam, India. . A total of 95 species of spiders belonging to 56 genera and 18 families were recorded, that represent 30% of the total families reported from India. In it Salticidae and Araenidae are the commonest families. Nautiyal et al. (2017) found out the Diversity and Distribution of

Spiders in Gogi, Yadgir District, Karnataka. This study was undertaken as baseline to understand the status, population, and distribution of spiders in different ecosystems viz., natural, agro, and domestic ecosystems of a semiarid region in southern India. And the spider studies in yogi enables further investigation of the contribution of ecosystem services by these invertebrates in semi-arid landscapes dominated by agricultural practices. Jose et al. (2018) made the first attempt to document spider diversity in a lateritic biotope of Southern India. There were 112 spider species in all, divided into 81 genera and 21 families. Araneidae family was the most abundant one, accounting for nearly 21.5% of all spider species.

Western Ghats, being one of the global hotspots of biodiversity, supports an enormous plant and animal species. Anthropogenic factors cause serious threats to the biodiversity of Western Ghats, mainly by agricultural expansion. Conversion of land to plantations and infrastructural projects have resulted in loss of forests and grasslands (Pius et al., 2015). Studies looking at the effects of forest fragmentation and disturbance have mostly tended to focus on higher vertebrate groups especially plants, aves and mammals. (Rahman et al., 2011; Korad, 2014; Jhenkhar et al., 2016). There was a scarcity of research on invertebrates among Western Ghats especially in terms of habitat disruption and fragmentation (Kapoor, 2008; Mubeen&Basavarajappa, 2018). And this poorly studied group play an important role in the regulation of other invertebrate populations in most ecosystems (Russell-Smith, 1999). As part of conservation planning, maintaining the diversity of spiders requires an understanding of diversity on an appropriate regional scale (Uniyal&Shrivastava, 2012).

Sruthi et al. (2019) carried out studies on spider diversity in the selected habitats in the Western Ghats of North Wayanad region. A total of 150 species belonging to 73 genera under 20 families were recorded from the selected habitats. The results of the present study and several other observations led them to the conclusion that habitat structure and environmental factors crucial in determining the composition of spider community of the area. Thus, documenting spider diversity patterns can provide important insights to justify the importance of ecosystem conservation (Sruthi et al., 2019).

Spiders are abundant predators in agroecosystems and they play an important role in natural pest control (Marc et al., 1999). Recent studies have emphasised the significant influence that predators play on the composition of communities. (Bruno &Cardinale, 2008). The intensive use of land and natural resources for agricultural uses has resulted in a 10% decrease in the potential of land and also caused species extinctions (sensu, 1995; Pimm& Raven, 2000; Vitousek et al., 1997). In addition to that land transformation into agroecosystems has often entailed a simplification of the landscape which may reduce the possibility of maintaining a high number of species (Benton et al., 2003, Donald, 2004, Green et al., 2005, Tscharntke et al., 2005). Spider diversity decreases due to anthropogenic activities such as grazing (Bell et al., 2001), heavy trampling (Bell et al., 2001), cutting (Bell et al., 2001), herbicide spraying (Bell et al., 2001), pesticide use (Luczak, 1979, Riechert, 1998), field improving (Bell et al., 2001) or agricultural treatments (Luczak, 1979), as well as grassland burning (Bell et al., 2001). The effects of agricultural diversification on spider abundance in relation to the potential role of spiders as biological control agent have been reviewed by Sunderland &Samu (2000). Agroecosystems were dominated by a few ‘agrobiont’ spider species (Luczak, 1979) and habitat diversification within and around the crops increases spider density (Sunderland &Samu, 2000).

Straub & Snyder (2006) found that predator species identity was more important for effective pest suppression than increased species richness. A study conducted by Öberg et al. on the Influence of habitat type and surrounding landscape on spider diversity in Swedish agroecosystems based on the species composition, richness and abundance of the two spider families, Lycosidae and Linyphiidae. And the results shows that the abundance of lycosids, in contrast to linyphiids, would vary among habitat types and that they would be more common in the field margin due to their mode of dispersal. So species richness and composition of both spider families would be influenced by habitat type as well as the structure of the surrounding landscape (Öberg, 2007).

Pathummal Beevi & Mahapatro (2008) conduct an investigation to gain insight into species-spectrum and inter-relationship between ant and spider fauna in cashew agro-ecosystem. Positive correlations were observed between ant and spider populations in different crop-phenophases - flushing, flowering and fruiting. 35 spider species were identified. Their predatory potential and web making patterns in laboratory were studied. There are a growing number of investigations in which spiders in agro-ecosystems are used as tools to gain fundamental insights into the role of generalist predators in community and ecosystem function. Samiyyan (2014) made a paper on Spiders – The Generalist Super Predators in Agro-Ecosystems. And he explains spider's contribution to biological control through predation in various agroecosystems.

SeemaKeswani (2014) identified the spider species from citrus agro-ecosystem. In a total of 6975 spider specimens, family Thomisidae dominates. It's the first attempt to list out the spider populations in citrus agroecosystem. Nagrare et al. (2015) made spider diversity studies in transgenic and non-transgenic cotton in rainfed agro ecosystem of central India. 15 species of spiders belonged to 6 families were recorded and family Araneidae contributed one third of spider population (34.56%). They found out that spider population was negatively correlated with all the weather parameters in transgenic cotton while positively correlated in non-transgenic cotton.

Research on spiders in Kerala has changed significantly in recent years, through better knowledge of ecosystems and the importance of spiders in ecosystem processes. Sudhikumar et al. (2005), made an attempt to study the spider population and their abundance and richness in seasonal variations in the rice agroecosystem of Kuttanad, Kerala. Sampling was done in four cropping seasons and found out that spiders shows population fluctuations in different seasons. Sebastian et al. (2005) listed out the spider fauna of the irrigated rice ecosystem in central Kerala, India across different elevational ranges. Spiders were collected from rice fields of high ranges, midland and low land areas in two cropping seasons and a total of 92 species, 47 genera and 16 families were recorded.

Mathew et al. (2014) carried out investigations on the vertical stratification of spiders in the rice agroecosystem of Kuttanad. Spiders collected from the field were classified into five main functional groups based on the activity and foraging behaviour related to average height of the rice plant. Ambily& Anju (2016) conducted a study on diversity and distribution of spiders in agro ecosystem of Ernakulum district, Kerala. 40 species from 14 families are being reported and Aranidae and Salticidae were the most commonly occurred families. Smitha&Sudhikumar (2020) conducted a study to document spider fauna in cashew orchards of the Cashew Research Station, Madakkathara, Kerala. A total of 63 species of spiders under 52 genera belonging to 14 families were recorded. Spider abundance was maximum during the monsoon season with 59 species.

In recent years, there has been an increase in research on spiders. Spiders represent the largest biomass of predatory arthropods in different agroecosystems. Their presence during all phases of the crop development allows them to act as effective natural pest control agent and act against different phytophagous insects. The knowledge of the spider community can be used to become new information resources for the environmental certification of agricultural practices and helps to reducing farmers the indiscriminate use of pesticides and improving natural biota (Marco Antonio Benamú P, 2020).

3. MATERIALS AND METHODS

3.1 STUDY AREA

The area selected for this study was agroecosystem of nutmeg plantations situated at Kadupukara, Thrissur district, Kerala. It is located 10˚ 20′ 10.5″North latitude &76˚ 18′ 7.884″East longitude with an area of 10 ha. The average altitude of collection area is about 42m above mean sea level.

This is a warm, humid region and the seasonal variation in the temperature ranges from 25°C to 38°C. Humidity is also showing seasonal fluctuation and is about 75% to 85%.

3.2 STUDY PERIOD

The observation and collection of spiders was made during the period of 10 months from June 2022 to March 2023. A total of 10 samples were collected from the study areas. The time of collection was in the evening time from 4.30 pm to 6.30 pm.Study area was examined thoroughly to find possible spiders and an all-out search method was used for spider collection.

Figure 1. Map showing the study area

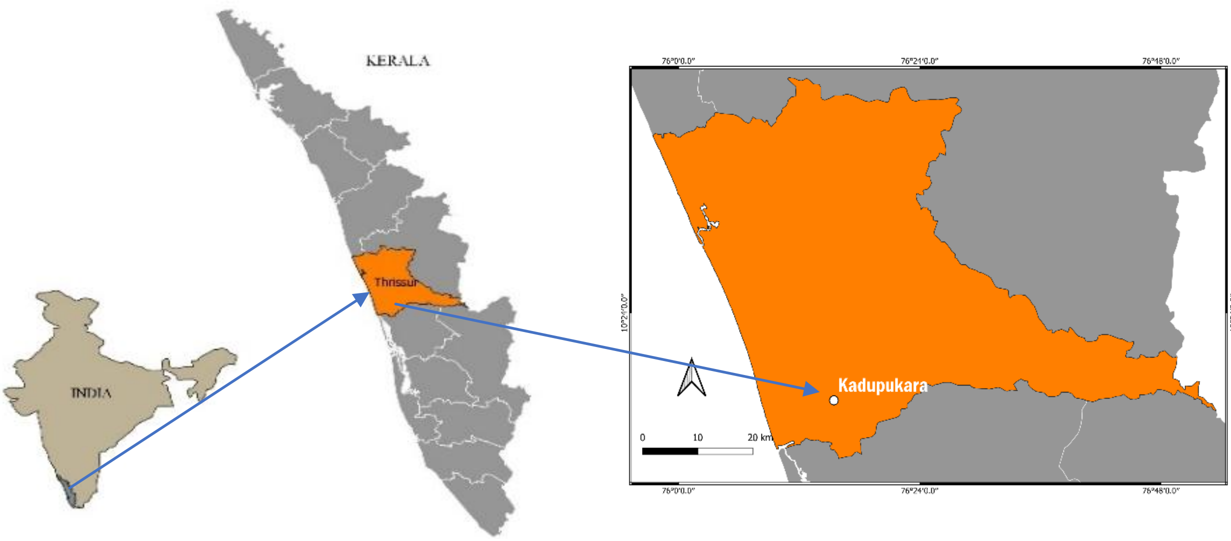
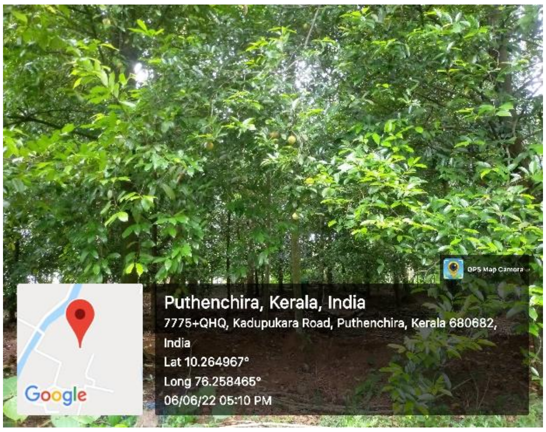
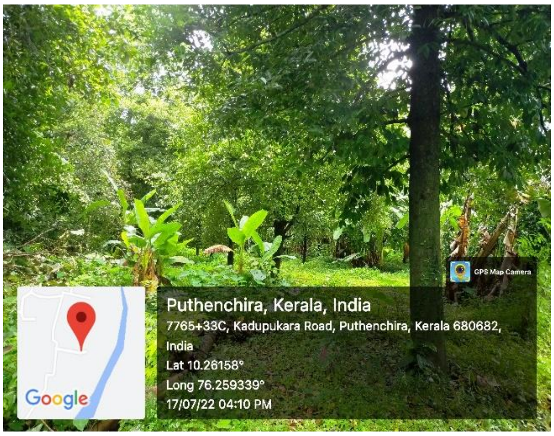


PLATE 1

PHOTOGRAPHS OF SAMPLING SITES IN THE STUDY AREA

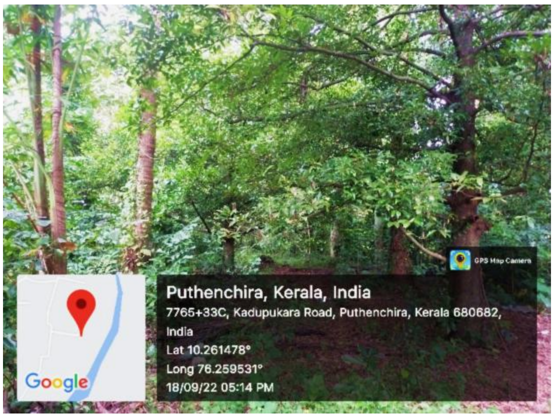


(a)

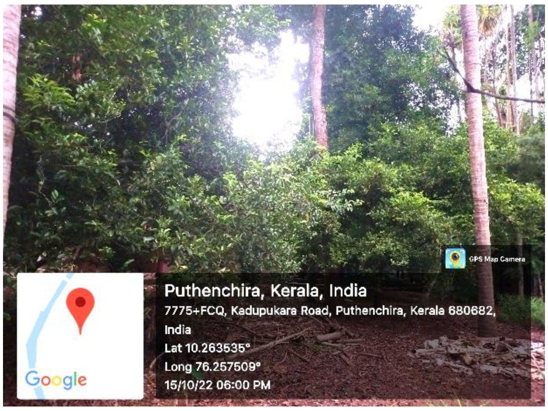


(b)

(c)



(d)



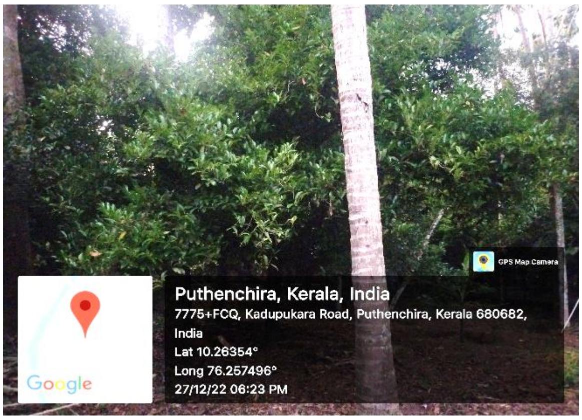
(e)

(f)

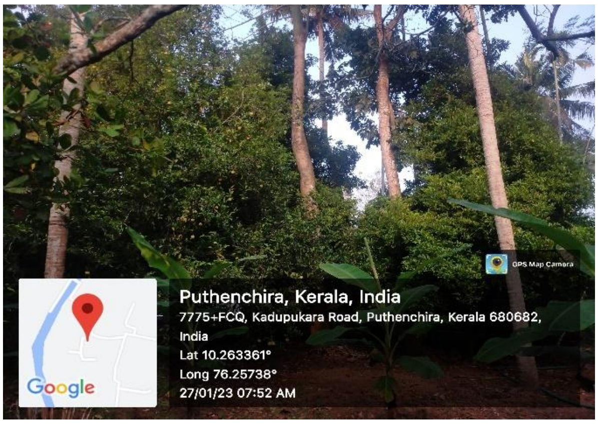
Sampling sites in the Nutmeg plantations - (a), (b), (c), (d), (e), (f)

PLATE 2

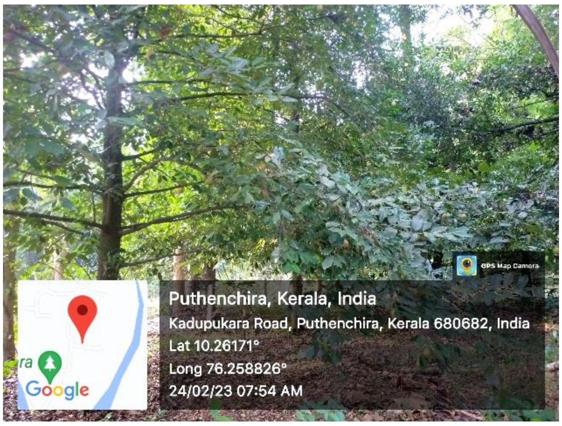
PHOTOGRAPHS OF SAMPLING SITES IN THE STUDY AREA



(g)



(h)



(i)

(j)

Sampling sites in the Arboretum – (g), (h), (i), (j)

3.3 SAMPLING METHOD

Line transect method of sampling was used for spider collection. Spiders were collected throughout the 100-meter transects, which were sampled for about 2 hours. The collection was conducted mainly by handpicking andvegetationbeating methods. Spider microhabitats like fallen logs and leaf litters were thoroughly checked for ground-dwelling spiders while leaves of trees and visible webs were searched for arboreal spiders. Smaller spiders were collected by leading them into tubes containing alcohol with the help of brush dipped in alcohol.

The detailed descriptions of the collection techniques are as follows,

3.3.1 Collection by hand

It is the commonest method employed for spider collection. This method is available for collection of spiders from a wide variety of environments.In this method,gently knock the specimen using a brush and lead into a collecting vial. The specimens can also be gently picked off by hand.

Ground Hand Collection - Ground Hand collection involves the collection of spider samples from ground to knee level. This method is used to collect the spiders, which are found in the ground, litter, in broken logs, rocks etc.

Aerial Hand Collection –This method involves the collection of samples from knee level to arm length level. The specimens carefully picked by hand and this method accessed web-building and free-living spiders on the foliage and stems of shrubs, high herbs, trees etc. Spiders found on the webs were caught in the jar by holding it open beneath them and by tapping these spiders into it with the lid.

3.3.2 Litter sampling:

Undisturbed grounds are the perfect hunting ground of spiders. Litter was collected from ground by hand and transferred it to a big tray. Spiders were sorted from litter in the tray.

3.3.3 Vegetation Beating: This method is suitable for studying vegetation like trees, bushes and shrubs.Since the nutmeg plantations mainly constitutes trees and shrubs, this is the most effective method to collect spiders. First place an inverted umbrella or sheet beneath the shrub or tree.Then firmly beat the vegetation with a stick. Collect the fallen spiders instantly.

3.4 PRESERVATION AND IDENTIFICATION

Once collected, spiders can be identified from either live or preserved specimens. First kill and preserve spiders by put them directly into containers with 80% alcohol. Locality, habitat, collection date, collectors name were recorded on each bottle using paper label. Identification was done at the Centre for Animal Taxonomy and Ecology (CATE), Dept. of Zoology, Christ College, Irinjalakuda. Preserved specimens were examined under a stereo zoom microscope (Leica-MS5) in the laboratory for taxonomic identification. Spiders were identified up to species level with the help of available literature (Sebastian & Peter, 2009, WSC 2022, Caleb &Sankaran, 2022).Field record was maintained throughout the study period. The field collection data also used to calculate the species richness, evenness, species diversity and relative abundance of dominant spiders present in different location.

PLATE 3

TECHNIQUES USED FOR SPIDER SAMPLING IN THE STUDY AREA

(a)

(b)

(c)

(d)

Aerial hand collection – (a),Ground hand collection – (b),

Litter sampling – (c), Vegetation beating – (d)

3.5 DIVERSITY INDICES

The diversity indices like the Shannon-Wiener index (H′), which is sensitive to changes in the abundance of rare species in a community, and the Simpson index (λ), which is sensitive to changes in the most abundant species in a community, Species Richness index (R) and Evenness index (E) of spider communities were calculated using the MS Office standard Excel 2013 programme.

The diversity of species in a community can be measured using the Shannon-Wiener Index.Denoted as *'H'*, this index is calculated as:

$$\mathbf{H'= -\sum_{I=1}^{S}\left(\frac{ni}{N}\right)\ln\left(\frac{ni}{N}\right)}$$

Where, pi = the observed relative abundance of a particular species (ni /*N*).

The diversity of species in a given community increases with increasing H value. The diversity decreases as H value increases. A community with a value of H = 0 is composed of just one species.

Simpson's Diversity Index is a diversity index that considers both the total number of species in addition the relative abundance of each species. Diversity rises along with species richness and evenness. And the value ranges from 0 to 1. The higher the value, the lower the diversity.

Simpson index is defined as: $\mathbf{D = 1 - \sum_{i=1}^{S}\frac{ni(ni-1)}{N(N-1)}}$

n = the total number of organisms of a particular species

N = the total number of organisms of all species

The evenness index shouldn't be affected by the number of species in the sample. **E= H/ln(S)** is probably the evenness index which ecologists use the most frequently. An evenness index should simply remain constant regardless of the number of species present, it would appear.

The species richness index (d) was calculated using the formula, **d = S/ N.**

N= the total number of individuals summed over all species.

3.6 GUILD STRUCTURE STUDIES

Environmental factors such family-level daily activity patterns, prey species, web structure, and foraging behaviour were all submitted to guild categorization. Graphs were used to organise the analysis's results. Based on the families gathered for the study, the habitat-based spider guild categorization was created. In the present study, guild classification was done using Cardoso et al. (2011)'s findings.

4. RESULTS

4.1 SPIDER DIVERSITY IN THE STUDY AREA

The study was carried out during a period of 10 months, from June 2022 to March 2023. During the study period, a total of 33 species from 26 genera in 11 families were collected. List of spiders collected is provided, as well as general explanation of the spider families in the collection. Photographs of the spiders collected from the study area is also provided.

Out of the 11 families collected during the study, Salticidae and Araneidae were the dominant families with 8 species. Salticidae spiders belonging to 6 genera and Araneidae with 7 genera. Family Tetragnathidae was the second dominant family with 5 species belonging to 2 genera. The family Oxyopidae represented the third dominant family with 3 species belonging to 2 genera. The famiies Uloboridae and Sparassidae was the fourth, which reported 2 species 2 genera. The families such as Corinnidae, Theridiidae, Thomisidae, Lycosidae and Linyphiidae had 1 species each. 85% of the specimens collected from the total study area were identified up to species level and remaining 15% were identified to genus level.

Table 1. Representation of genera and species in different spider families of the entire spider assemblage recorded in the study area.

FAMILY	NO OF GENERA	NO OF SPECIES
ARANEIDAE	7	8
CORINNIDAE	1	1
LINYPHIIDAE	1	1
LYCOSIDAE	1	1

OXYOPIDAE	2	3
SALTICIDAE	6	8
SPARASSIDAE	2	2
TETRAGNATHIDAE	2	5
THERIDIIDAE	1	1
THOMISIDAE	1	1
ULOBORIDAE	2	2
	26	**33**

Figure 4. Graph showing the distribution of genera and species in different spider families of the entire spider assemblage recorded in the study area

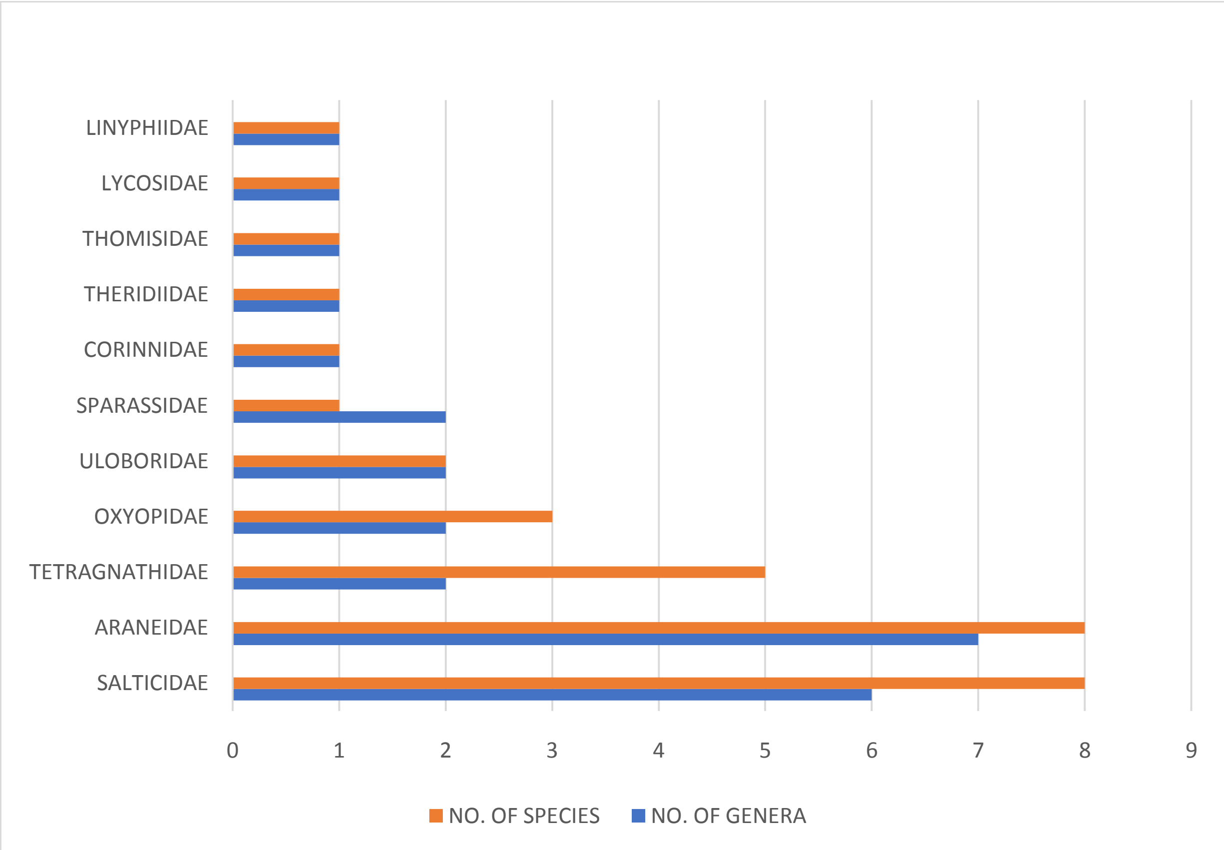


Table 2. Checklist of spiders collected from entire study area

SI NO	FAMILY/GENUS/ SPECIES	SPECIES ABUNDANCE
	1. ARANEIDAE	
1.	*Argiopepulchella*Thorell, 1881	6
2.	*Argiopeaemula*(Walckenaer, 1841)	5
3.	*Anepsionmaritatum*(O. Pickard-Cambridge, 1877)	12
4.	*Achaerania sp.*	1
5.	*Cyrtophoracicatrosa*(Stoliczka, 1869)	1
6.	*Cyclosaneilensis*Tikader, 1977	1
7.	*Eriovixiapoonaensis* (Tikader& Bal, 1981)	10
8.	*Neoscona theisi* (Walckenaer, 1841)	2
	2. CORINNIDAE	
9.	*Castianeirazetes*Simon, 1897	4
	3. LINYPHIIDAE	
10.	*Lyniphia sp.*	1
	4. LYCOSIDAE	
11.	*Pardosasumatrana*(Thorell, 1890)	32
	5. OXYOPIDAE	
12.	*Hamadruassikkimensis* (Tikader, 1970)	3
13.	*Oxyopesjavanus*Thorell, 1887	4
14.	*Oxyopes Shweta* Tikader, 1970	3
	6. SALTICIDAE	
15.	*Epeustener*(Simon, 1877)	5
16.	*Epeusindicus*Prószyński, 1992	4
17.	*Epeus sp.*	1
18.	*Hyllus semicupreus*(Simon, 1885)	9
19.	*Indopadillainsularis*(Malamel, Sankaran& Sebastian, 2015)	4
20.	*Portia fimbriata*(Doleschall, 1859)	2
21.	*Phintellavittata*(C. L. Koch, 1846)	1

22.	*Stenaelurilluslesserti*Reimoser, 1934	3
	7. SPARASSIDAE	
23.	*Thelcticopis sp.*	3
24.	*Oliosmilleti* (Pocock, 1901)	2
	8. TETRAGNATHIDAE	
25.	*Tylorida ventralis*(Thorell, 1877)	22
26.	*Tetragnatha viridorufa*Gravely, 1921	7
27.	*Tetragnathacochinensis*Gravely, 1921	4
28.	*Tetragnathakeyserlingi*Simon, 1890	4
29.	*Tetragnathamandibulata*Walckenaer, 1841	1
	9. THERIDIIDAE	
30.	*Chrysso sp.*	1
	10. THOMISIDAE	
31.	*Oxytate virens*(Thorell, 1891)	2
	11. ULOBORIDAE	
32.	*Miagrammopesextensus*Simon, 1889	1
33.	*Zosis geniculate* (Olivier, 1789)	1

4.1.1 Details of the families collected from the study area

1. Family: Araneidae, Clerck, 1757 (Orb web spiders)

This spider family exhibits a wide variation in size, colour, shape and behaviour andshows cosmopolitan distribution. Majority of this group spin perfect orb webs to catch prey. These spiders are sit-and-wait predators and use the “spin-wrap-attack” method to subdue their prey. The web can be considered as the spider’s home territory and its general shape, number of radii, spirals, shape of hub and decorations of the web vary between genera and subfamilies. The size, weight as well as the web site can influence web design.

Flat variable cephalothorax.An oblique depression at the junction between cephalic and thoracic region.Their 8 eyes are arranged in two rows, with lateral eyes spread considerably apart from middle eyes.Lateral eyes widely separated from medians. Medians forms a quadrangle and laterals usually close and often projecting on angular tubercles.Heart shaped or triangular sternum narrowing towards the posterior side.Fovea may present or absent.

Strong chelicerae provided with lateral condyle on both. Two rows of strong teeth on fang burrows. Long strong legs with hairs and spines,three tarsal claws and auxiliary foot claws. Trichobothria present on all leg segments except tarsi. Pedipalp with single claw in female but in the case of males it is complex.

Abdomen variable in size and shape, usually bulbous like an overhanging portion of the cephalothorax. Six simple spinnerets are present at the posterior end provided with aggregate silk gland spigots and colulus. Sclerotized, complex epigyne.

Shows sexual dimorphism with males smaller than females.

List of species in the present study: - 7 Genera and 8 species

1. *Argiopepulchella*Thorell, 1881
2. *Argiopeaemula*(Walckenaer, 1841)
3. *Anepsionmaritatum*(O. Pickard-Cambridge, 1877)
4. *Achaerania sp.*
5. *Cyrtophoracicatrosa*(Stoliczka, 1869)
6. *Cyclosaneilensis*Tikader, 1977
7. *Eriovixiapoonaensis* (Tikader& Bal, 1981)
8. *Neoscona theisi* (Walckenaer, 1841)

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

Corinnids are free-living ground dwellers, mostly located on the forest floor in shady regions among woody debris, litter, or humus. This group spiders are very much similar to ants, except they have eight legs. Even their walking patterns are matching with the ants. They move their abdomen in up and down fashion and also hold their first pair of legs in an upright fashion which closely resembles the ant's antennae.

The colour of these spiders range from dark to metallic, or dark to yellowish brown with a shiny red to reddish brown carapace and a pale abdomen.They flee quickly when startled, making them incredibly challenging to trap. These spiders also make silky retreatsin rolled up leaves and plant debris.

Cephalothorax is usually ovoid and elongated, sometimes heavily sclerotised. Eyes arranged in two rows either widely or closely spaced. Posterior row of eyes may straight or curved.Slightly convexlabium usually depressed transversely.Tough, convex chelicerae with strong curved setae on upper edge. Long and slender legs with two claws and claw tufts, variable setae on front legs.

Abdomen is ovoid and elongatesometimes with scutum or patches.Integument with prostrate feathery setae, which frequently form lines or other patterns.Anterior spinnerets sturdy and contiguous, posterior spinnerets a little bit farther apart than the front pair. In females median spinnerets with three and posterior spinnerets with two large cylindrical glands called spigots is present.Epigyneis complex and variable.

List of species in the present study: - 1 Genus and 1 Species

1. *Castianeirazetes*Simon, 1897

3. Family: Linyphiidae, Blackwall, 1859 (money spiders or dwarf spiders)

Linyphiids are Small, three-clawed, ecribellate spiders.Eight heterogeneous eyes are arranged in two rows, in which anterior medians slightly darker.Strong, typically tooth-equipped chelicerae with lateral stridulating files and fang furrows. Slender three clawed legs, and provided with setae especially on tibiae and metatarsus; Female palps usually possess tarsal claws.Longer abdomen, sometimes with characteristic pattern. Three pairs of spinnerets are present at the posterior abdomen; short, conical anterior and posterior pair. Epigyne is complex.

They are known as sheet web spiders, because they form compact sheet webs in green vegetation and often are found in large numbers on the surfaces of lawns.The sheet webs may be flat, rounded, or curved like a hammock, isolated threads create a scaffolding web above the sheet.These spiders does not make any retreatbesides it hangs upside down under the sheet.The spider waits for its meal below the funnel's entrance on the web.When disturbed the spider rapidly escapes into the foliage.

List of species in the present study: - 1 Genera and 1 Species.

1. *Lyniphia sp.*

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

Lycosidae is a widespread family of ground-dwelling spiders. Because they chase after their prey, they are commonly referred to as wolf spiders.They are the spiders that are most likely to be seen in the field in broad, somewhat undisturbed places.Larger lycosids create burrows or tunnels in the ground or beneath stones. Some of the smaller species do not produce any webs at all, while others spin silky webs and hide in the grass.And adopt a sit and wait strategy for feeding.

Many little lycosid species' females carry their egg sacs underneath their abdomens by fastening them to their spinnerets. These egg sacs are frequently white or pale in color and bigger than the female's abdomen.After hatching from the egg sac, the young spiderlings cling up onto their mothers' backs, where they reside until the second moult. They restrict from eating while the young are bound to their mother's body.

These spiders have good eyesight and are excellent predators.The spider attacks their prey fiercely, smashing it with her powerful chelicerae. Most of them carried out hunting during diurnal period, but some active at night. Despite of their keen vision powers they also possess highly developed sense of touch.

Longer cephalothorax, narrower and higher in cephalic region. Carapace covered with dense setae. Oval shaped sternum. Eight dark eyes are arranged in three rows of 4, 2, 2. They are of unequal in size, four little eyes in the front row, two large eyes in the second row, and two intermediate-sized eyes in the third row.Powerful chelicerae with condyles and a toothed furrow.Three clawed legs, usually with scopulae and spines; trochanters notched.Oval shaped abdomen,brownish or greyish in colour, covered with dense setae.Peculiar hairs over the abdomenallows the mother spider to carry her spiderlings.

List of species in the present study: - 1 Genera and 1 Species

1. *Pardosasumatrana*(Thorell, 1890)

5. Family: Oxyopidae, Thorell: 1869 (Lynx spiders)

Oxyopids are distinguished easily by their long spiny legs,two small anterior median eyes and hexagonal eye configuration.The body colourvaries from brilliant green to yellowish brown, or dark brown. These foliage dwellers appear in size ranges from small-to-large sized, with three claws.

Cephalothorax is longer, high and convex in the front, sloping in the back, usually with conspicuous stripes and spots. The wide, very high and vertical clypeus attached with this also possess stripes and spots. Eight eyes arranged in a hexagonal shape with by slightly procurved posterior row and strongly recurved anterior row.Thin setae cover the integument, occasionally with iridescent scales.

These plant dwelling spiders, popularly known as lynx spiders because of the method of prey capturing. Diurnal or nocturnal spiders with good eyesight.The size of males and females are nearly the same.The eggs are guarded by the female and the eggs sac is protected with twig or leaf with a small irregular web.

List of species in the present study: - 2 Genera and 3 Species

1. *Hamadruassikkimensis* (Tikader, 1970)
2. *Oxyopesjavanus*Thorell, 1887
3. *OxyopesShweta* Tikader, 1970

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

They are very small to medium sized spiders, popularly known as ‘Jumping spiders’. This is because these active, hunting spiders capable of jumping or leaping to a distance to capture prey. Prey mainly includes insects. They are more active at the diurnal period.

Most characteristic feature is the ocular clad on the cephalothorax. Eight eyes arranged in three or four rows, in which the anterior median eyes are very large and prominent.The two anterior laterals,two posterior mediansand two posterior lateralseyes together provide excellent eyesight to about 360 degrees.With this perfect eyesightjumping spiders are capable of recognising colours and distinguishing the preyfrom a considerable distance.

The segmented legs are usually long and stout ending in hairy tuft having two claws. Structure of legs especially that of the first pair vary in some genera.They have a square-shaped carapace. The anterior cephalic regioncovered with setae with attractive patterns and colours.Abdomen is generally small, oval or round but insome elongated. Its dorsal side usually covered with hairs forming attractive colour patterns and designs. This colour patterns helpful in distinguishing species. Usually they do not construct webs for capturing the prey. But often makes a silken retreat in the form of tube or sac fastened to various substrata and they are used to the retreat to moult, sometimes to mate, egg-laying or as night shelter.

Many shows sexual dimorphism, male with attractive colour patterns and smaller size. Courtship behaviour varies according to species. Maxillary palps are simple in female but very complex in male and act as copulatory organs and helps in reproduction.

List of species in the present study: - 6 Genera and 8 Species.

1. *Epeustener*(Simon, 1877)
2. *Epeusindicus*Prószyński, 1992
3. *Epeus sp.*
4. *Hyllus semicupreus*(Simon, 1885)
5. *Indopadillainsularis*(Malamel, Sankaran& Sebastian, 2015)
6. *Portia fimbriata*(Doleschall, 1859)

7. *Phintellavittata*(C. L. Koch, 1846)
8. *Stenaelurilluslesserti*Reimoser, 1934

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

These nocturnal crab like spiders appear in medium to large sized forms. Usually they not made webs, only silk retreats are constructed. In certain species of this family, the female carries the egg sac beneath the body by securing it with her pedipalp and hiding during daytime. They usually appeared in green, grey, brown or black colours, often matches with their hiding places in the bark or green leaves.

Broad, oval cephalothorax, longer than wide. Cephalothorax gets narrower towards the eye region, covered with a dense layer of fine setae. Fovea present. Eight eyes are arranged in two rows. Larger median eyes and evenly spaced posterior eyes.Size of anterior eyes varies between genera. Sternum almost circular, with apex pointed.

Two rows of teeth on fang furrow and boss of the chelicerae.Male palp with strong tibialapophysis. Female palp also possess claw. Long laterigrade legs, Laterigrade only allows sideways movements, resembles the crabs motion. First two pairs are larger than the rest. Round to oval shaped abdomen covered with a layer a fine setae. A dark, median, heart-shaped mark is present at its centre. Sclerotized complex epigyne.

List of species in the present study: - 2 Genera and 2 Species.

1. *Thelcticopis sp.*
2. *Oliosmilleti (Pocock, 1901)*

8. Family: Tetragnathidae, Menge, 1866 (Long jawed orb weavers)

They are long jawed orb weavers and their size ranges from small to very large. They have lengthier body.

Cephalothorax is longer with monotonous brown or grey coloration with silvery patterns.Size of abdomen is highly variable; it may be elongated,round to ovoid in shape.Sternum also longer, pointed posteriorly. Eight eyes are arranged in two rows,which are sometimes attached to tubercles. Lateral eyes contiguous or apart.

Chelicerae have a row of massive teeth and powerful protruding spurs. Legs long and slender, three clawed, with or without spines.In some species, abdomen may be extending back to spinnerets virtually in straight manner.

They weave asticky orb web that is nearly horizontal. Their male genitalia comparatively simple and female genitalia without external structures. Unsclerotised complex epigyne. They occupying a variety of habitats.

List of species in the present study: - 2 Genera and 5 Species.

1. *Tylorida ventralis*(Thorell, 1877)
2. *Tetragnatha viridorufa*Gravely, 1921
3. *Tetragnathacochinensis*Gravely, 1921
4. *Tetragnathakeyserlingi*Simon, 1890
5. *Tetragnathamandibulata*Walckenaer, 1841

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

Popularly known as comb footed Spiders or cobweb spiders, because of their three dimensional webbing patterns.

Cephalothorax and abdomen is variable in shape, may be round or oval and high to elongate. Some species develops modifications in the frontal region of cephalothorax. Eight eyes are arranged in two rows, more or less parallel. Usually the eyes are encircled by a brownish ring, anterior medians in dark and the rest in pale colour. Sometimes very long chelicerae can been seen. Cheliceral teeth are few in number or absent. Generally legs are long and curved with three claws. Tarsi IV on large theridiids has a row of bristles known as the tarsal comb.It helps to extend the throw of sticky silk threads over the prey, and is reduced or absent in smaller species and males. Male palp without apophysis and female palp with a claw.

Some webs, made of crisscross viscid strands, allow the spider tocatch flying insects. The sticky threads are thin and easily breakable, more entangled during escape activities of the prey. Some spiders use plant or soil particles to make retreats near or inside it to hide the web.Some other species prefer to find shelter in a dark or debris-filled silken refuge built into the edge of the web.Few members of this family do not build webs at all and can be observed wandering among fallen leaves on the ground or, in the case of cryptic species, lying on exposed branches or sticks.

List of species in the present study: - 1 Genera and 1 Species

1. *Chrysso sp.*

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

Thomisidans represents the second dominant diverse family in India. Most of them have a peculiar crab like appearance. These nocturnal creatures usually do not spin webs, and hunting is done by stealth and ambush using their powerful and spinous legs.They occur more commonly onleaves, in flowers or under bark or rocks. The body colour may be brown, green or white to match with their surroundings to improve the camouflage. Their movement pattern is sideways like crabs, hence the name ‘crab spiders’.

Cephalothorax shapes range from round to ovoid to elongated,usually with simple erect setae. Some species have tough, roundedeye tubercles. Eight dark and homogenous eyes with white outline are arranged in two rows.The medians are often bigger than the others, and the lateral eyes are typically raised on tubercles that may be connected.Heart shaped sternum. Chelicerae is free, cheliceral teeth absent. Retromargin ambiguous and unarmed, promargin sometimes with cusps or tiny denticles. Despite having weak chelicerae, they are able to attack large insects with regard to the highly potentvenom they release.Prey is sucked dry rather than being crushed because there are no cheliceral teeth present.

Two clawed legs enables laterigrade motion. The first two pairs have paired ventral spines and are larger and much stronger than the others, used for seizing the prey.

Abdomen is much larger and more varied in form than the cephalothorax, ranging from spherical to oval or elongated and normally covered in sporadic simple setae and extends caudally ahead of the spinnerets.Short, conical, and closely spaced anterior spinnerets with colulus. Atrium and hood on the epigyne complex are typical features.

List of species in the present study: - 1 Genera and 1 species

1. *Oxytatevirens*(Thorell, 1891)

11. Family: Uloboridae, Thorell: 1869 (Hackled web spider)

They are cribellate web builders. Cephalothorax vary in shape and having a pair of lateral swellings near to the posterior lateral eyes.Long, oval to triangular shapedsternum.In some species two separate sternitesare present and they surrounded by a sternal plate. Narrow and elongated abdomen with one or two ridges and sometimes expands beyond spinnerets. Long or semicircular and distally pointed labium. Dull, grey or brown in coloured anal tubercle usually large and two segmented.Eight homogenous dark eyes arranged in two well separated rows.

Three segmentedanterior spinnerets with ring shaped short second segment and domed third segment. Median spinneretsunsegmented and posterior spinnerets with two cylindrical segments. Undivided cribellum is placed in front of spinnerets. And this modification helps them to make cribellated silk. During prey capturing spidertugged the web forcefully to locate and entangle the prey. The longer first pair of legsused for tugging.Spider uses the fourth pair of legs to cast silk onto the prey to subdue it. Uloborids lack a venom glands, but they use digestive enzymes onto the prey to kill it.

List of species in the present study: - 2 Genus and 2 Species

1. *Miagrammopesextensus* Simon, 1889
2. *Zosis geniculate* (Olivier, 1789)

4.2 GUILD STRUCTURE STUDIES

A guild is a group of organisms that utilize the same resources in comparable ways.The idea that species were constrained by ecological niche limits by competing species was initially put out by Hutchinson.The currently most accepted definition characterizes ecological guilds as ecological guilds are non-phylogenetic groupings of organisms that share one or more significant resources.

Regardless of the precise taxonomic makeup, guilds respond approximately the same way to similar changes in the environment, then the definition and study of guilds is particularly valuable. Numerous additional areas, like the control of habitat disturbance and the investigation of assemblage responses to climate change, might benefit from the study of ecological guilds.

Ecological traits related to foraging methods, web structure, prey species, usage of microhabitats, site tenacity, and daily activity were classified according to guilds. The data collection's output was arranged in tabular format.Based on the families gathered during the survey, the spider guild classification was created. According to Young and Edwards (1990), the family's established ecological trait served as the basis for spider guild designation.

In the present study, guild classification was done with the Pedro Cardoso’s work on Global Patterns of Guild Composition and Functional Diversity of Spiders.Guild composition was more consistent than taxonomic composition, indicating family turnover in various locations using the same resources.

Among the members of 11 families of spiders collected during the study were classified into 6 ecological guilds based on the foraging mode of the spiders.

(1) Ambush hunters (Family: Thomisidae); (2) Ground hunters (Family: Lycosidae & corinnidae); (3) Orb web weavers (Family: Araneidae, Tetragnathidae & Uloboridae);

(4)Space web builders (Family: Theridiidae); (5)Sheet web builders (Family: Linyphiidae); (6) Other hunters (Family: Sparassidae, Salticidae & Oxyopidae).

(1)Ambush hunters

Ambushers exhibit "sit-and-wait" behaviours in order to capture their prey. Family Thomisidae is included in this guild type, consisted of 1 species from the total study area.

(2) Ground hunters

Ground running spiders mostly hunt their prey on the field's bottom layer, rarely moving up into the foliage or canopy. This guild includes the families Lycosidae (1 species) and corinnidae (1 species).

(3) Orb web weavers

The "orb weavers" guild of spiders makes exquisite orb webs for catching prey. This group includes the families Araneidae (8 species), Tetragnathidae (5 species), and Uloboridae (3 species).

(4) Space web builders

This guild spiders spins irregularly spread webs to catch prey. Family Theridiidae (1 species) fall under this category.

(5) Sheet web builders

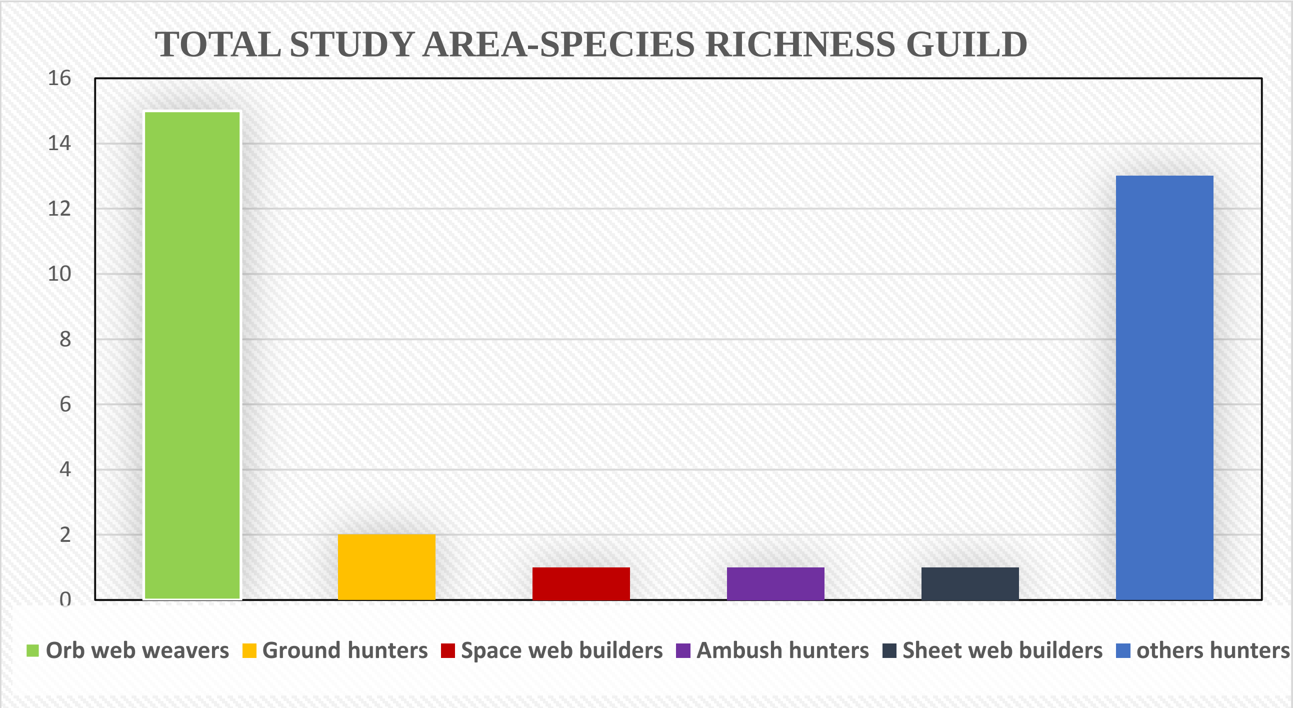
The guild of sheet web builders' spiders weave sheet-like webs for capturing prey. This category only includes one species from the Linyphiidae family

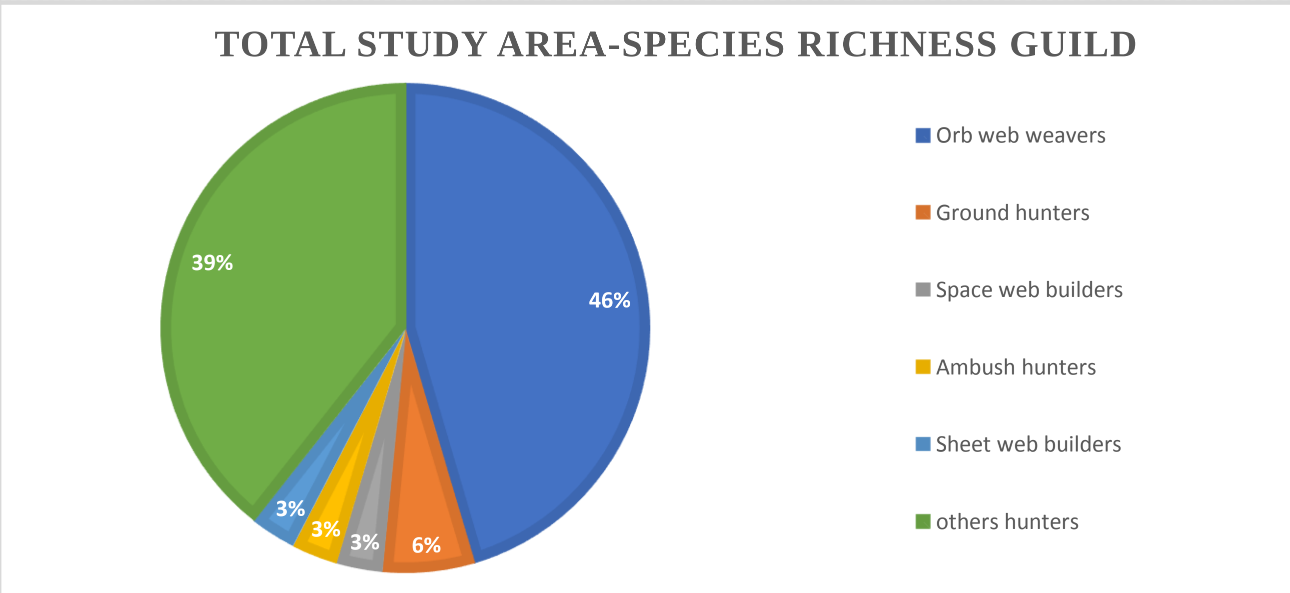
(6) Other hunters

This group of spiders wisely jump over its prey to feed. This kind of feeding habit is found in the families Oxyopidae (3 species), Sparassidae (2 species) and Salticidae (8 species).

4.3 SPECIES RICHNESS AMONG GUILDS

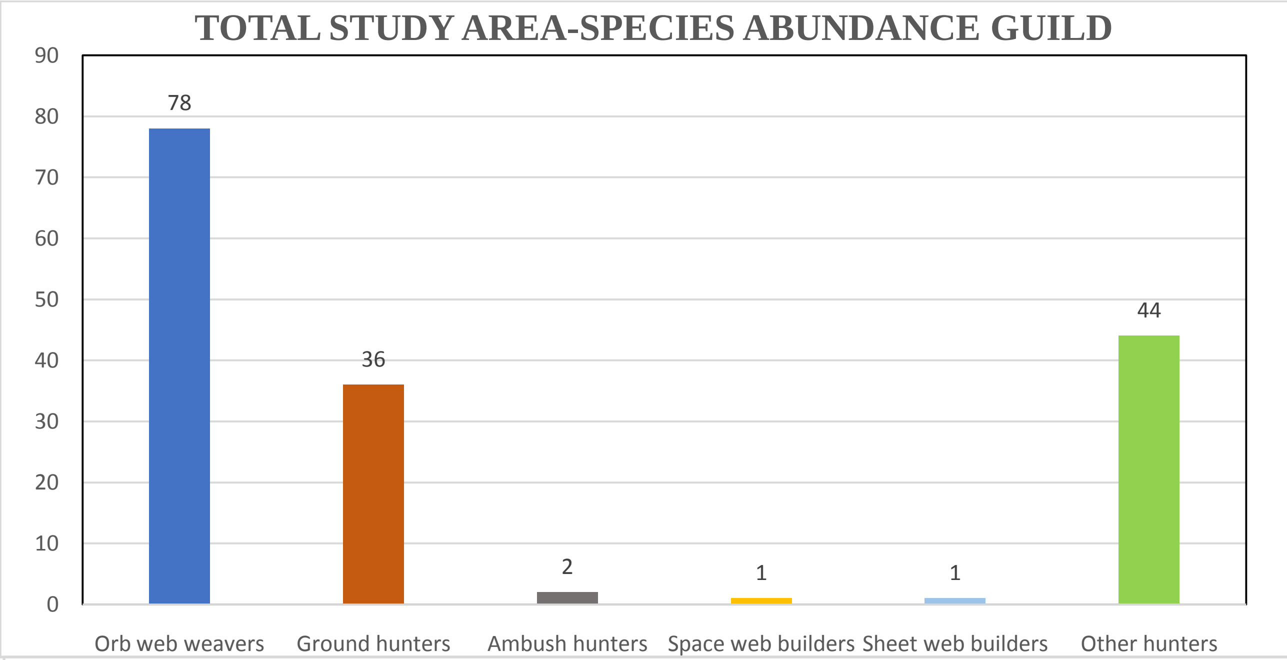
Results of spider species richness among guilds in the total study area shows that the guild of orb web weavers showed the highest species richness with 46% (15 species) followed by other hunters with 39% (13species). There are remaining 6% of ground hunters with 2 species, 3%of sheet web builders (1 species), 3% of ambush hunters (1 species) and 3% of space web builders with 1 species.

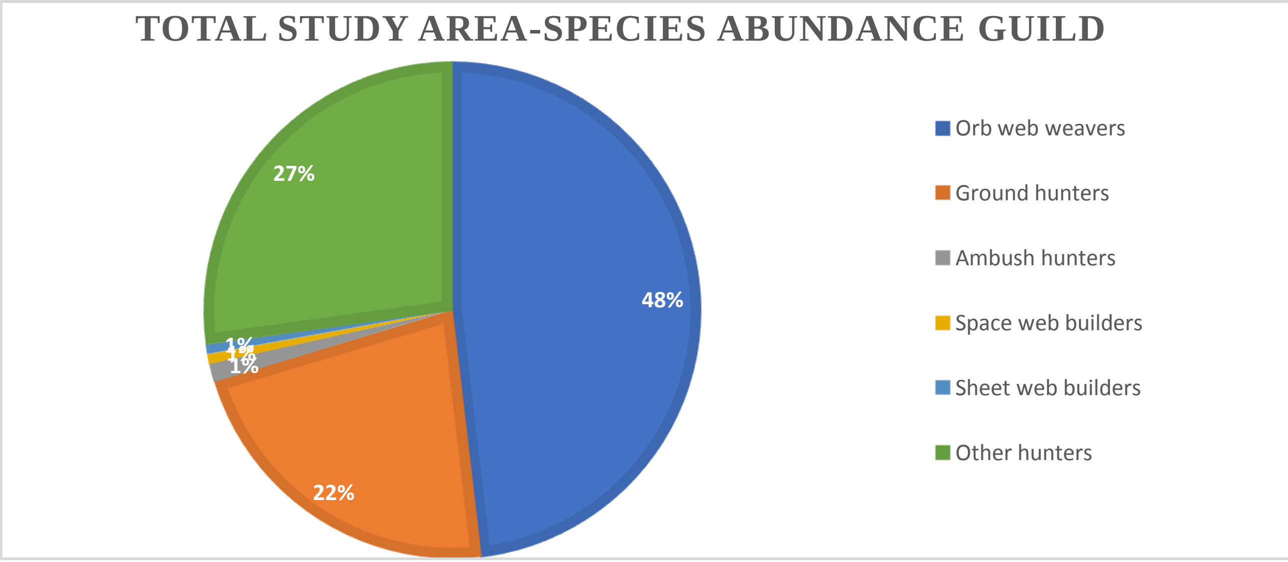




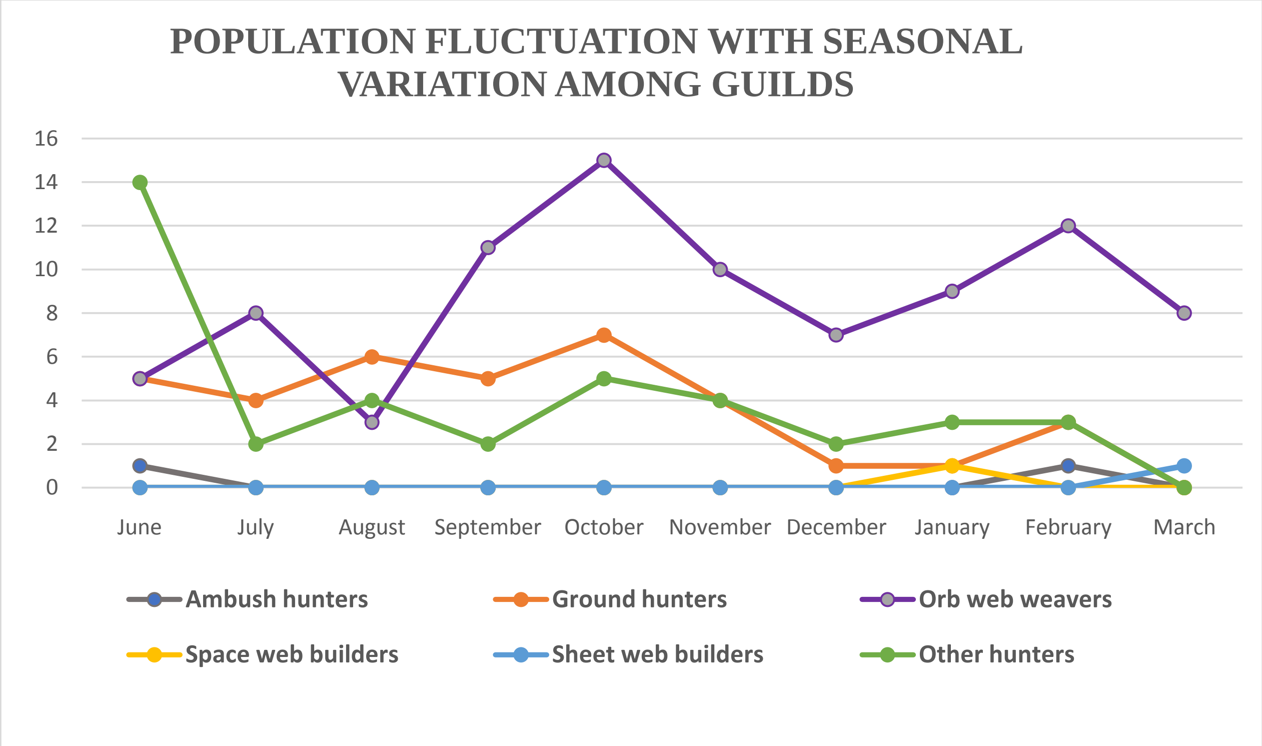
4.4 SPECIES ABUNDANCE AMONG GUILDS

Composition of species abundance in the guilds of total study area constitute 49% orb web weavers (78 individuals), 27% other hunters (44 individuals), 22% ground hunters (36 individuals), 1% ambush hunters (2 individuals), 1% space web builders (1 individuals) and 1% sheet web builders (1 individual). Highest abundance was shown by the guild of orb web weavers followed byother hunters and the least abundance by space web builders, sheet web builders and ambush hunters.





4.5 SEASONAL VARIATION AMONG GUILDS



This graph shows the population variations during different seasons from June to March. The fluctuation in the population density showed a difference between the web builders and the non-web builders. There was a slight drop in the spider population of non-web weavers during the study period.

High abundance of orb weaver spider species results from dense canopy of tall nutmeg trees, prevails year round.These ecosystems have a significant degree of vertical stratification and might provide more physical structures for web attachment. But there was a drop in orb weavers from June to August and November to December. This is probably because of the rainfall, such that the wind and raindrops made it difficult for them to construct and maintain the webs.

Maximum diversity index during the month of October and minimum at the month of December. Humidity and average temperature from September to November provides a way for gradual increase in both population number and diversity of the species. This climacteric condition is favourable for the prey species like insects to flourish and indirectly increase the spider population by providing suitable feeding availability.

Spiders usually prefer low temperature and humid conditions, which confines them to areas that are within the tolerance range of their physiology. In the last four months there was a huge loss in spider population.Temperature fluctuations in this period also cause a reduction in bothnumber of individuals and diversity of them.Seasonal fluctuation and alterations in the climate can both affect the diversity index readings.

4.6 DIVERSITY INDICES

Table 7. Diversity data on spiders of selected habitats of nutmeg plantations in Kadupukara, Thrissur during the study period.

	No.of species (S)	No.of individual (N)	Species richness (d)	Shannon-Weiner index (H')	Simpson index (D)	Evenness (E)
Total study area	**33**	**162**	**0.204**	**2.955**	**0.925**	**0.845**

Species diversity: Species diversity is defined as the number of different species present in an ecosystem and relative abundance of each of those species.Diversity is greatest when all the species present are equally abundant in the area. The Simpson Index and Shannon-Weiner Index were used to determine species diversity. The Shannon-Wiener index is sensitive to changes in the abundance of rare species in a community, while the Simpson index is sensitive to changes in the most abundant species in a community (Solow et al., 1993).

Shannon-Weiner Index value is 2.955, a moderate diversity index value. Simpson index shows a value close to 1, and is 0.925, indicates high diversity.

Diversity is greatest when all the species present are equally abundant in the area. There are two constituents of species diversity:

Species richness: Number of different species present in an ecosystem. Tropical areas have greater species richness as the environment is conducive for a large number of species.Species richness of study area have a value less than 1 and that is 0.204.

Species evenness: Relative abundance of individuals of each of those species. If the number of individuals within a species is fairly constant across communities, it is said to have a high evenness and if the number of individuals varies from species to species, it is said to have low evenness. High evenness leads to greater specific diversity. Species evenness value is 0.845. The study area shows low species richness, but high species evenness.

5. DISCUSSION

The current study is the first attempt to document the spider fauna of the nutmeg plantations located in, Kadupukara, Thrissur District. The observation and collection of spider was made throughout a ten month period, from June 2022 to March 2023. Spiders were collected once a month from June to March. Time of collection was in the morning from 4:30pm to 6:30pm. During the study period, a total of 33 species from 26 genera in 11 families were collected from the total study area.

This study aimed to determine species abundance, guild organisation, and the spider family composition in selected habitats. The Salticidae and Araneidae were the most dominant of the 11 families studied, with 8 species belongingto 6 genera in Salticidae and 7 genera in Araneidae. Tetragnathidae family was the second most dominant with 5 species belonging to 2 genera. Oxyopidae was the third dominant family, with 2 genera and 3 species.

The timing and sample technique have an impact on the amount and quality of the spider fauna. The diversity of species might be affected by a variety of environmental factors, including seasonality, geographic heterogeneity, competition, predation, habitat type, environmental stability, and productivity (Riechert 1990).Research by Russell-Smith (2002) demonstrated the significance of rainfall for local spider diversity.The environment has a certain influence on the majority of spiders. Generally speaking, various species have distinct preferences for humidity and temperature and are constrained to those seasons that provide a microclimate within the parameters of their physiological tolerances. Therefore, the change in rainfall and temperature between the two seasons is probably what causes the variance in species diversity between them.

Two diversity indices used here are Shannon-Wiener index (H), which is sensitive to changes in the abundance of rare species in a community, and Simpson index (D), which is sensitive to changes in the most abundant species in a community. Simpson index is more easily interpreted than other diversity indices.Shannon-Wiener index got a value 2.955, a moderate diversity value. Simpson index shows 0.925, a value close to 1 also indicates a superior good diversity. Species richness is 0.204 and species evenness value is 0.845. These values altogether indicates a perfect balanced ecosystem.

Spiders were grouped into guilds based on their hunting behavior similarities. The relative abundance of guilds based on the number of individuals changed significantly, which could be an indication of the resources that are available for a given crop variety. Similar patterns in guild composition imply that plant habitat layout may have an impact on the spider community.

This study results revealed that, spiders often exhibit seasonal patterns of abundance, peaking in the early rainy season and declining throughout and after the rainy season.In June, the early rainy season guild group ‘other hunters’ were able to maintain their populations, perhaps because there was little disturbance caused by an abiotic factor such as rainfall.The fine sheet-webs of linyphiids that attached to ground vegetation layers and, space webs of theridiidae irregular mesh of strands may be damaged during the rainy season when rainfall reaches a peak. The number of orb web builders also decreased during the rainy season as web destruction can affect the source of food.

Turnbull (1973) asserts that the majority of spider webs have certain attachment and space requirements.It would be expected that structurally complex crops, which offer a larger range of resources, would sustain a more diversified spider assemblage, increasing the possibility of the "best" match between spiders and insect pests.According to Uetz (1991), more structurally complex plants may be able to support a wider variety of spider communities.Similar families tend to aggregate within a similar habitat type, suggesting that vegetation structure influences spider family establishment.As a result, vegetation structure may be a more significant factor than just seasonal change. This offers important explanations for why particular species may predominate at different periods of the season.

The vertical stratification method of niche portioning is used by orb-weaving spiders, who do not actively compete with one another (Tahir et al.2012).Orb-web weavers can effectively reduces niche overlap by targeting different prey at different heights due to differences in web structure.Therefore, spiders can form several guilds pest prevalence, microhabitat and feeding strategies and they coexist depending on their plant structure primary habitat.

Another important point related to the species composition is the vegetation structure of the habitat.The structural variety of the ecosystem was correlated with relative spider and prey concentrations (Kajak 1965). In this nutmeg plantations the habitat consists of the same vegetation type, tall nutmeg trees. Thus the expected spider composition was comparatively low in this region.

The current study's findings and several other observations lead to the conclusion that, habitat structure and environmental conditions may play a significant role in defining the composition of the local spider community. Therefore, studying spider diversity patterns can give valuable information to support the ecosystem's functioning.

More research should be done to determine the impact of these habitats on the presence of spiders in the nutmeg plantations itself because no data were gathered from the nearby habitats.

6. CONCLUSION

The aim of the study was to determine the spider diversity, guild structure, and species abundance in selected habitats of nutmeg plantations situated at Kadupukara, Thrissur District.During the study period, a total of 33 species from 26 genera in 11 families were collected from the total study area. Out of the 11 families collected during the study, the family Araneidaeand Salticidaewere the dominant families with 8 species belonging to 7 and 6 genera. Spiders belonging to 6 ecological guilds were collected during this study.Composition of species abundance in the guilds of total study area constitute 48% orb web weavers (78 individuals), 27% other hunters (44 individuals), 22% ground hunters (36 individuals), 1% ambush hunters (2 individuals), 1% space web builders (1 individuals) and 1% sheet web builders (1 individual). Highest abundance was shown by the guild of orb web weavers followed byother hunters and the least abundance by space web builders, sheet web builders and ambush hunters.The study indicates a more or less diverse and varied species composition present in the nutmeg agroecosystems of Kerala, Thrissur district and also their seasonal abundance among guilds.This gives an essential knowledge of the ecology, importance, and challenges faced for the existence by spider species. The primary objective of the study is to collect data on the spiders found in this area, which will serve as a starting point for further research on this topic.

7. RECOMMENDATIONS

- ✓ The findings from this study can be used to modify future studies as well as be directly included into spider-inventory-based conservation efforts.
- ✓ The information gathered in the form of a checklist will be extremely useful to anyone interested in learning more about the region's spider variety.
- ✓ There is a scarcity of knowledge on Indian Spider ecology and taxonomy even though spiders can serve as indicator species (Kapoor, 2008).
- ✓ Future research may concentrate on additional essential elements such as environmental factors, habitat controlling microclimate variability, and anthropogenic disturbance factors, all of which have the potential to have a significant impact on spider diversity on a large scale.
- ✓ This study provides data on species distribution and diversity, guild structure, richness, and evenness and also about the population fluctuations due to seasonal variations among guild in selected habitats.
- ✓ Finally, it is recommended that these findings can be used for additional refinement research as well as direct integration into spider-inventory-based conservation projects.

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PLATE 4

PHOTOGRAPHS OF SPIDERS COLLECTED FROM THE STUDY AREA

(1)

(2)

(3)

(4)

(5)

(6)

Family: Araneidae– (1) *Argiope pulchella* (2) *Argiope aemula* (3) *Anepsion maritatum* (4) *Cyrtophora cicatrosa* (5) *Cyclosa neilensis (6) Neoscona theisi*

PLATE 5

PHOTOGRAPHS OF SPIDERS COLLECTED FROM THE STUDY AREA

(7)

(8)

(9)

(10)

(11)

(12)

Family corinnidae – (7) *Castianeira zetes*

Family linyphiidae – (8) *Lyniphia sp.*

Family lycosidae – (9) *Pardosa sumatrana*

Family oxyopidae – (10)*Hamadruas sikkimensis* (11) *Oxyopes javanus* (12) *Oxyopes Shweta*

PLATE 6

PHOTOGRAPHS OF SPIDERS COLLECTED FROM THE STUDY AREA

(13)

(14)

(15)

(16)

(17)

(18)

Family salticidae – (13) *Epeus tener* (14) *Hyllus semicupreus* (15) *Indopadilla insularis* (16) *Portia fimbriata* (17) *Phintella vittata* (18) *Stenaelurillus lesserti*

PLATE 7

PHOTOGRAPHS OF SPIDERS COLLECTED FROM THE STUDY AREA

(19)

(20)

(21)

(22)

(23)

(24)

Family sparassidae – (19) *Thelcticopis sp.* (20) *Olios milleti*

Family tetragnathidae – (21) *Tylorida ventralis* (22) *Tetragnatha viridorufa*

(23) *Tetragnatha cochinensis* (24) *Tetragnatha keyserlingi*

PLATE 8

PHOTOGRAPHS OF SPIDERS COLLECTED FROM THE STUDY AREA

(25)

(26)

(27)

(28)

Family tetragnathidae – (25)*Tetragnatha mandibulata*

Familythomisidae - (26) *Oxytate virens*

Family uloboridae - (27) *Miagrammopes extensus* (28)*Zosis geniculate*

A COMPARATIVE STUDY OF ODONATES IN FOUR SELECTED PONDS IN IRINJALAKUDA, THRISSUR DISTRICT, KERALA

Project report submitted to the University of Calicut in partial fulfillment of the requirement for the award of the Degree,

MASTER OF SCIENCE IN ZOOLOGY

By

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(Reg. No. CCAVMZL015)

DEPARTMENT OF ZOOLOGY

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Examiners

1.

2.

CERTIFICATE

This is to certify that the project work entitled "**A COMPARATIVE STUDY OF ODONATES IN FOUR SELECTED PONDS IN IRINJALAKUDA THRISSUR DISTRICT, KERALA.**" is an authentic record of the study carried out by **Merin Joseph (Reg. No. CCAVMZL015)** as the part of M. Sc. practical during the year 2022-2023 and the results of this work have not been presented for the award of any other degree/diploma in any university.

Place: Irinjalakuda
Date:

Dr. A.V SUDHIKUMAR,
Head, Department of Zoology,
Christ College, Irinjalakuda.

DECLARATION

I, **MERIN JOSEPH** do hereby declare that this dissertation entitled **"A COMPARATIVE STUDY OF ODONATES IN FOUR SELECTED PONDS IN IRINJALAKUDA, THRISSUR DISTRICT, KERALA"** is a genuine record of dissertation done by me under the guidance of **Dr BIJOY C.,** Assistant Professor, Department of Zoology, Christ College (Autonomous), Irinjalakuda and has not formed the award of any degree in any college or university.

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ABSTRACT

A comparative study of diversity of Odonates was conducted in four selected ponds scattered in Irinjalakuda, Thrissur district, among which two ponds were occupied with invasive plant species, *Eichhornia crassipes*. The study period was between September 2022 and May 2023. During the study period, 11 species of dragonflies under 9 genera and 5 species of damselflies under 3 genera were recorded.

CONTENTS

LIST OF FIGURES AND TABLES

INTRODUCTION

The term Biodiversity is derived from the Greek word *bios* meaning life and the Latin word *diversitas* meaning variety. Therefore, as a whole, the term biodiversity means "variety of life". It refers collectively to variation at all levels of biological organizations specifically the genetic, species and the ecosystem level (Gaston *et al*., 2004).

Insects are considered to be the most abundant, the most diverse and the most successful animal group on earth (Huis, 2014). Even if they look different, they share similar key features. Taxonomy is responsible for identifying and organizing the different species of insects. The Odonata, an insect order comprises dragonflies (suborder Anisoptera), damselflies (suborder Zygoptera) and the suborder Anisozygoptera which is a living fossil. About 6000 extant species of Odonates are found globally and more than 500 known species are found in India (Subramanian, 2005). Since the odonates are first appeared during the Carboniferous era they are considered to be one of the most ancient orders of the Insecta. Odonates are commonly used as ecological indicator to examine the habitat quality and to check the integrity of freshwater ecosystem (Vilenica *et al*., 2020).

Dragonflies and damselflies have aquatic larval phases which are closely connected with freshwater ecosystems. The odonates in both larva and adult stage are predatory. Odonates are considered to be the sit and wait predators because, until an insect or a small fish approaches the larva, they remain immobile (Bouchard *et al*., 2004). The odonata are one of the most dominant animal taxa of freshwater habitat specifically staying in ponds, and where they are considered as top predators (Carchini *et al*., 2005).

A pond is a small area, still, land-based body of freshwater which is smaller than lake and usually is artificially made. In many parts of world, the pond had put up greatly to the regional diversity (Simaika *et al*., 2016). Pond has a high conservation value for biodiversity (Minot *et al*., 2021). When compared to streams and river, pond accounts for a sizeable amount of the biodiversity of a given landscape (Marco *et al*., 2013). The assemblage pattern of adult dragonflies is influenced by both pond age and pond size. The distributional pattern of species is based according to pond area. The species richness was matched up with the pond age is in association with floral life which cover within the pond (Kadoya *et al*., 2004).

MORPHOLOGY OF ODONATA

The morphological characteristics of an adult odonate which includes a large head, well developed compound eyes, a pair of minute antenna, two pairs of long transparent wings which can move independently with many small veins, an elongated abdomen, and legs that make it easy for catching prey in flight. Dragonflies are distinguishable from damselflies in several easily recognisable traits; dragonflies are strong fliers, they have fairly tough bodies and have wings that are broad near base and at rest, wings are held out to the side whereas damselflies are weak fliers, they have less tough bodies and their wings are narrow near the base and when perched, wings are held folded back over the abdomen (Subramanian, 2005).

LIFE CYCLE

The life cycle of odonates consists of 3 stages: Egg, larva (naiad) and adult

EGG STAGE: Odonates lay their eggs in an extensive reach of aquatic habitats, from damp soil to waterfalls. Visual cues play a significant role in egg laying. Many dragonflies lay their broad and elliptical eggs either in air or by perching on an overhanging vegetation or rock whereas damselflies place their elongate and cylindrical eggs into aquatic plants. Eggs are laid in consecutive batches. A damselfly lays about 100-400 eggs per batch whereas a dragonfly lays about several hundred to thousands per batch.

LARVA STAGE: The aquatic larva or naiad is a sophisticated and ambush predator, they wait for their prey to approach closer before striking. The larva has an enigmatic colouration and sharp eyesight which makes them effective predator. The larva, moult into adult just before sunrise. The newly emerged adults are wet and fragile and they becomes dry when the day rises.

ADULT STAGE: The newly emerged male and female odonates vacate their emergence site and inhabit close by landscape. Damselflies complete their maturation stage in about a week by which successive changes occur in the colour of body and wings. Whereas dragonflies take nearly two weeks (Subramanian, 2005).

REPRODUCTION

Male species mature earlier than female species. Mature male holds territory and shows aggressive behaviour such as wing warning and display of abdomen, towards conspecific males which enter their territory. Males when sexually matured, gain bright colouration. Among odonates multiple mating is common in both males and females. The territoriality and courtship are based on the colours and patterns of wings and body. Courtship is more noticeable in damselflies than in dragonflies. The reproduction of odonata is very special with tandem and wheel position.

FEEDING

Adult dragonflies are aeriform predators. They catch insects like mosquitoes, butterflies. They can feed in the air, using the legs to catch the prey and transfer into jaws.

FLIGHT SKILLS

Almost all the dragonflies are day fliers, but a few are active during twilight hours. Their flight speed could be maximum upto 10-45 m/s. They have a high-powered flight capacity due to their powerful thoracic muscle.

SIGNIFANCE OF THE GROUP

The dragonflies and damselflies being predators both at larval and adult stages, play an important role in wetland ecosystem. For the harmful insects such as blood-sucking flies, odonates acts as an important biocontrol agent. The most of the species of odonates inhabiting in agro ecosystems plays a pivotal role in controlling pest populations. The larva of container breeding dragonfly, Granite ghosts (*Bradinopyga geminata*) which is found in urban areas of Thailand was capably used to control *Aedes* mosquito, an important vector of dengue fever (Subramanian, 2005). Besides the direct role of predators in ecosystems, the value of odonates as indicators of quality of biotope is now being increasingly esteemed (Subramanian, 2005).

CONSERVATION

The Larval stages of only 76 Indian odonate species are well-known and the full life history is recorded for only 15 species. A detailed understanding of larval ecology is critical for odonate conservation. Prolonged conservation of odonates and other freshwater biota can only be guaranteed through relevant national level policy interventions and definite freshwater biodiversity conservation programmes. The upcoming studies on dragonflies may be directed to have all-inclusive understanding of their ecology and their value as biomonitoring tool.

OBJECTIVES OF THE STUDY

- To observe and compare the odonata diversity in four selected ponds of Irinjalakuda and Thrissur districts in Kerala.
- To compare the odonata diversity month wise and to calculate the various diversity indices.
- To observe the behavioural study of Odonate depending on their habitat.

REVIEW OF LITERATURE

Linnaeus (1758) was the Swedish naturalist who had published several species of odonates in his famous book named 'Systema Naturae'. This was the base for classification and modern taxonomy. The encyclopaedic study of dragonflies of North America was made by Eaton (1877). Clausnitzer (2004) studied about the critical species of Odonata in eastern Africa ranging from Somalia and Ethiopia south to Mozambique and Zimbabwe and west to eastern Democratic republic of Congo and Botswana. McCreadie *et al.* (2005) conducted the one-year duration study of biodiversity of larval Odonata in lower Mobile-Tensaw Delta at Albama and recorded 16 species of odonates constituting 9.2% of Albama's odonate fauna. The diversity of odonates and habitat attributes in mountain ponds of Italy was prepared by Carchini *et al.* (2005) and they proved that it was considered as an important habitat for the conservation of dragonflies.

Rashid *et al.* (2008) provided the status of odonates of Singapore based on the historical records and museum collections of Raffles Museum of Biodiversity Research in National University of Singapore and listed 117 species of dragonflies and damselflies including 11 new records. The biodiversity of odonata of Iberian wetlands of Corrientes province in Argentina was studied by Muzon *et al.* (2008) and collected 75 species under 33 genera and 7 families, out of which 3 genera and 10 species are new report for the country. Gutierrez and Ananya *et al.* (2009) conducted a parallel study of Odonata assemblages along an altitudinal gradient in the Sierra de Coalcoman Mountains, Michoacan in Mexico and recorded 116 species, 44 genera and 9 families along with 5 new species and the results prioritized the area for conservation and related research.

The distributional patterning of species richness of adult Odonata assemblage present in the Adolpho Ducke Forest Reserve in Manaus, Brazil was studied by Juen and Marco (2011) and recorded a total of 17 species. Sheikh and Douglas (2012) studied the biodiversity, phenology and thermoregulatory scheme of Odonates at Pierce Cedar Creek institute in Michigan and recorded 43 species of dragonflies belonging to 5 families and 16 species of damselflies belonging to 3 families. The Odonata diversity of the middle and lower reaches of Red River Basin, Yunnan in China were studied by Chen and Yu (2013) and 86 species of Odonata were recorded along with new reports of 5 genera and 5 species to Yunnan Province.

Khan and Zia (2016) studied the biodiversity of dragonflies and their life mortal factors in Tehsil Chamla and Daggar of district Buner, Khyber Pakhtunkhwa in Pakistan and 11 species were recorded. Seidu *et al*. (2017) conducted the study of Odonata community structure and patterns of land use across 3 different land use types in a Nature Reserve in Ghana and recorded a total of 6940 individuals belonging to 53 species in which 23 species belongs to Zygoptera and 30 species belongs to Anisoptera in 8 families recorded. The effects of anthropogenic disturbances and riverine conditions on Odonata assemblages in eastern Amazon basin streams were studied by Oliveira *et al*. (2017) and they recorded 1769 specimens representing 11 families, 41 genera and 97 species and among these, 56 species come under Zygoptera and 41 come under Anisoptera. The biodiversity of larval and adult Odonata of Interdunal Wetlands at Saugatuck Harbor Natural Area in Michigan was studied by Volz (2017).

Dalzochio *et al*. (2018) conducted a comparative study on how each vegetation type affects the selection of species attributes and which elements are responsible for the presence of the species in environment in Highlands of southern Brazil and recorded 36 odonate species covering 14 functional groups. Cai *et al*. (2018) studied the habitat features, diversity, distribution of dragonflies in Nee Soon freshwater swamp forest in Singapore and a total of 1706 odonate specimens were recorded consisting of 49 species of 34 genera which comes under 11 families. The distributional patterning of odonate assemblage in connection with environmental factors in streams of South Korea were studied by Lee *et al*. (2018) and a total of 83 taxa belonging to 10 families of Odonata were noted. Among them, 8 species exhibited high incidence and over-abundance. Rodrigues *et al*. (2018) studied the diversity of odonates in palm swamps of Cerrado hotspots of South America and reported 56 species of odonates, out of which 10 were latest records. Aziz and Mohamed (2018) conducted the study of diversity and species make-up of odonates of Hutan Lipur Bukit Soga Perdana, the Green Lung for Batu Pahat which is regarded as the 2nd largest industrial town in Malaysia and 22 species of odonates grouped into 17 genera and 7 families are noted.

Chein *et al*. (2019) studied the adult odonate biodiversity in association with pond management applications and environmental factors in a swiftly urbanized landscape for that they selected 24 farm ponds in Taoyuan city and collected 21 species of odonates under 17 genera and 6 families and the results suggested that pond management methods can either increase or reduce odonate species richness depended on the alteration of pond microhabitat features. Barbosa *et al*. (2019) studied the odonate community of Sucupira Reservoir, Rio Uberabinha, Minas Geralis, Brazil and recorded the species make-up of odonate fauna during both the dry and rainy seasons and noted 860 individuals of 43 species grouped into 26 genera and 6 families.

Bobrek (2020) studied to check whether there was a high diversity of odonata fauna in an old limestone quarry with completely developed aquatic habitats occupying in an urban environment in Central European city of Krakow and 37 species were noted which were grouped into 7 families of Odonata in the quarry which represented 50% of Poland's Odonata fauna, out of which 33 species were regarded as endemic to the quarry, out of which 30% were urbanophobic taxa. Mafuwe and Moyo (2020) investigated the diversity and possible drivers of dragonfly distribution in a biodiversity hotspot of southern Africa, Eastern highlands, Zimbabwe and noted 27 species which are associated with dams and ponds and 4 species are associated with swamp forests. The checklist of odonates of Amazonas state in Brazil was presented by Koroiva *et al*. (2020) and 324 species under 101 genera which makes the state the most odonate species recorded from Brazil. The highest number of species were grouped in family Coenagrionidae with 32 genera and 101 species followed by Libellulidae with 28 genera and 100 species and Gomphidae with 12 genera and 45 species. Ilhamdi *et al*. (2020) studied the diversity of Odonata and community structure in Suranadi Natural Park, West Lombok, Indonesia and noted 16 species of odonates consisting of the family Libellulidae with 11 species, Platycnemididae with 1 species and Coenagrionidae with 3 species. Perez and Bautista (2020) studied the diversity, species richness and evenness, relative abundance and the effective number of dragonflies in selected areas of Davao city, Philippines and a total of 962 individuals of dragonflies were observed comprising 6 species of dragonflies under 6 genera which comes under a single family. *Orthetrum sabina* was the most abundant species among 6 species noted.

. Rafique *et al*. (2021) studied taxonomic study and the biodiversity of Odonata from district Multan, Punjab, Pakistan and as a result 20 species were identified depending upon their morphology and physiology. Buczynski *et al*. (2021) studied the distribution and diversity of Odonata in an upland storage reservoir and its feeder rivers occupying in South-east Poland and recorded a total of 25 species including 22 in reservoirs.

Mairif *et al*. (2023) studied the biodiversity of odonates in Theniet EI Had National Park of Algeria and recorded 240 individuals of odonates which is grouped into 18 species.

STUDIES FROM INDIA

Shinde and Sathe (2007) studied the biodiversity of dragonflies of Koyna dam and nearby area which were easily affected by earthquake. Dinesh Kumar *et al*. (2010) studied the biodiversity of odonates of 6 dominant lakes in and near by the Bangalore and 20 species of dragonflies under 15 genera and 6 species of damselflies under 4 genera were collected. *Orthetrum sabina* and *Trithemis aurora* were present copiously almost throughout the year.

Das *et al*. (2012) studied the distribution, diversity and species make-up of odonates in buffer areas of Similipal Tiger Reserve, Eastern Ghats in India and recorded 58 species. The suborder Zygoptera was expressed by 23 species and 35 species represents suborder Anisoptera and Libellulidae was the most abundant family.

Andrew *et al*. (2013) studied the odonate diversity at Wena dam of Nagpur district, Maharashtra in India during post-monsoon period and recorded a total of 52 odonates, 34 species belonging to Anisoptera and 18 to Zygoptera.

The studies on the habitat priority and diversity of odonates in Deepor Beel Bird Sanctuary, Kamrup in Assam were worked by Kalita and Ray (2015) and a total of 39 species belonging to 5 families and 22 genera were recorded. In case of suborder Anisoptera, family Libellulidae was the most dominant family and in case of Zygoptera, *Rhyothemis variegata* was the most dominant species. Boruah *et al*. (2015) studied the diversity of Odonata in Padmatola wetland, Balasore in Odisha and prepared a checklist of total 51 species of Odonata. The suborder Anisoptera represented by 33 species with 22 genera from 4 families and suborder Zygoptera represented by 18 species with 9 genera from 3 families. The biodiversity of odonates in rice ecosystem of Titabar in Assam were studied by Saikia *et al*. (2016) and the study reported 40 species of damselflies and 28 species of dragonflies.

Palita *et al*. (2016) studied the odonate diversity along different habitats of Koraput district in Odisha and recorded 64 species representing 45 genera under 9 families. Family Libellulidae was the dominant group representing 32 species and maximum species were collected along hill streams. The biodiversity of odonates of Acharya Prafulla Chandra college campus, West Bengal with duration period of both monsoon and winter seasons was studied by Baidya (2017) and a total of 19 species of odonates coming under 6 families were recorded. Harisha and Hosetti (2017) conducted the study of diversity of odonates in Kuvempu University campus, midWestern Ghats, Shivamogga district in Karnataka and a total of 43 species of Odonata in 31 genera grouped into 7 families have been noted.

Sonawane *et al*. (2020) studied the biodiversity of Odonates of Akola city in Maharashtra and collected a total of 24 species grouped into 4 families, out of which family Libellulidae represented 15 species. The study of diversity and distribution of odonates in Rani reserve forest in Assam were worked by Thakuria and Kalita (2021) and a total of 67 species belonging to 44 genera, representing 11 families were noted. Sawant *et al*. (2022) prepared the updated checklist of odonates of Amboli-Chaukul-Parpoli region of Maharashtra and noted 93 species grouped into 12 families and also reported 6 new records for the state of Maharashtra with a total of 144 species. The diversity of odonates from Gondia district in Maharashtra were studied by Bharathi and Koparde (2021) and noted 35 species, comprising around ¼ of total Odonate diversity in Maharashtra.

STUDIES FROM KERALA

Palot *et al*. (2005) studied the odonata diversity of rice field habitat in Palakkad district kerala.Varghese *et al*. (2014) studied the odonata diversity of Salim Ali bird sanctuary and its adjacent areas in Thattekad kerala and recorded 82 species of odonata which included 51 species of Anisoptera and 31 species of Zygoptera. Chandran *et al*(2020) studied the odonates of Irinjalakuda ponds of central Kerala and recorded 30 species of odonata which included 19 species of dragonflies and 11 species of damselflies. Bose *et al*. (2021) studied the diversity and abundance of riparian odonata fauna of midstream Chalakkudy river, Kerala and recorded 25 species of odonates and among them, 10 species are dragonflies and 15 species are damselflies .Chandran *et al*. (2021) studied the dragonflies and damselflies of kole wetlands ,central Kerala and reported a total of 44 species belonging to 33 genera and among them , 30 are dragonflies and 14 are damselflies. Benjamin *et al*. (2022) studied the diversity of Odonates in All Saints college campus,Thiruvananthapuram,Kerala and recorded overall, 36 species from which 26 species are dragonflies and 10 are damselflies belonging to 29 genera and 5 families.Rodrigues *et al*. (2022) studied the odonata of Kattampally wetland,Kerala and recorded a total of 66 species of odonates from 42 genera including 4 species endemic to the Western Ghats.Muneer *et al*. (2023) studied the odonata of Wayanad Wildlife Sanctuary,Kerala and recorded 84 species from which 49 are dragonflies and 35 damselflies.

The present study was conducted at Irinjalakuda, Thrissur district and specimens were observed from four selected ponds which are scattered over Irinjalakuda region of Thrissur district, Kerala.

STUDY SITE 1: MANNATHIKULAM (Plate A, Figure 4)

It is a clear water pond surrounded by a calm and quite environment. It is situated near the Koodalmanikyam temple. The average temperature in and around that pond is 29.95 °C. The pond is surrounded by bund vegetation. The camera used for clicking photos of Odonata is Canon EOS 1200D.

STUDY SITE 2: KALLANKULAM (Plate A, Figure 1)

It is a pond with aquatic plants which makes it more beautiful and with some invasive plant species which is the *Eichhornia crassipes*. At times, there are aquatic birds like ducks. It is situated in Combara. The average temperature in and around that pond is 18.8°C..

STUDY SITE 3: ANDANIKULAM (Plate A, Figure 2)

It is pond which is situated in Nadavaramba. It is also an open-air swimming pool. The average temperature in and around pond is 24°C.The area upto which the odonata species are clearly visible is only taken as study area.

STUDY SITE 4: ONGICHIRA (Plate A, Figure 3)

It is pond with calm and quite environment. It is well maintained for swimming practice for public. It is located in Velukara panchayat. The average temperature in and around pond is 26°C.

MATERIALS

Canon EOS 1200D digital camera for imaging Odonates, field guide for identification and data sheet for data collection

METHODOLODY OF OBSERVATION

The sampling technique was adopted for evaluating the diversity of Odonata. The sampling was conducted for 9 consecutive months starting from September 2022 to May 2023. The pond visits were made in the morning between 10.30am to 12.30 pm. Each pond site was visited twice a month. A fixed sampling area The area choosen as the observer was clearly able to identify and take photographs of species was opted for every pond site.

Odonates under the sampling area were well scrutinized and their identifying unique features were noted down in a notepad and recorded the encountered species. The species were identified with the help of field books and those species which cannot, have been identified with the help of experts. The species were photographed using Camera EOS 1200D 55-250 mm. lens. The observations were tabulated and kept for future study and comparison and calculated the diversity indices such as Taxa, Individuals,Simpson(1-D),Shannon(h), and Evenness.

The odonata species were grouped into five relative frequency classes,vbased on the number of ponds and their frequency of occurrence.The categories include very common(80-100%), common(60-80%),Occasional(40-60%), rare(20-40%), and very rare(<20%).

OBSERVATION AND RESULTS

TOTAL ODONATA DIVERSITY

Overall, 16 species of Odonata, among which 11 species of dragonflies (Anisoptera) are belonging to 9 genera and 2 different families, Libellulidae and Gomphidae and 5 species of damselflies (Zygoptera) are belonging to 3 genera and to a single family, Coenagrionidae. They were identified from four selected ponds in and around Irinjalakuda in Thrissur district during the study conducted from 18th September 2022 upto 21st May 2023.

Dragonflies leads the collection with 11 species, among which 10 species belongs to family Libellulidae and 1 species belongs to family Coenagrionidae. *Brachythemis contaminata* (240) was the most abundant species of the study followed by *Rhyothemis variegata* (168), and *Rhodothemis rufa* (124). *Archibasis oscillans* was the most abundant species of damselfly which belongs to the family Coenagrionidae. Among 16 odonates observed from study, based on frequency of observation, four species are very common, one species is common, three species are occasional, five species are rare, three species are very rare.

The study area was divided into four selected ponds in and around Irinjalakuda, Thrissur district. They are Ongichira, Mannathikulam, Andanikulam and Kallanakulam. Andanikulam and kallankulam were occupied with invasive plant species, *Eichornia crassipes* author name only for a few months and it was cleared later and the vegetation along the pond usually occupies grass, shrubs and rarely trees which the odonates used for thermoregulation, resting, and thermoregulation.

ODONATA DIVERSITY DISTRIBUTION IN VARIOUS STUDY SITES

ONGICHIRA: 3 species of dragonflies under 3 genera belonging to 2 families were collected from Ongichira. No damselflies were found here. Out of 3 species, 1 species is under the family Gomphidae and the remaining 2 species are belonging to the family Libellulidae. Among 3 species, most abundant species is *Brachythemis contaminata* (195) and the lowest number is

Brachydiplax chalybea (3) and second dominant species in dragonflies *is Ictinogomphus rapax* (10).

MANNATHIKULAM: 6 species of dragonflies under 6 genera belonging to 2 families were collected from Mannathikulam. No damselflies were found here. Out of 6 species, 1 species is under the family Gomphidae and the remaining 5 species are belonging to the family Libellulidae. The most abundant species are *Ictinogomphus rapax* (34) followed by *Rhodothemis rufa* (28), *Brachythemis contaminata* (12), *Rhyothemis variegata* (8), *Neurothemis tullia* (7) and *Brachydiplax chalybea* (4).

ANDANIKULAM: 15 species under 12 genera belonging to 3 families were collected from Andannikulam. Out of 16 species, 10 species are dragonflies under the 2 families Gomphidae and Libellulidae. *Rhyothemis variegata* was the most abundant species with 117 individuals, second dominant species is *Rhodothemis rufa* with 64 individuals. *Archibasis oscillans* dominate with 51 individuals in damselflies. *Pseudagrion microcephalum* is represented by lowest number of individuals (3) in damselflies.

KALLANKULAM: 11 species under 10 genera belonging to 3 families were collected from Kallankulam. Out of 11 species, 8 species are dragonflies under 2 families Libellulidae and Gomphidae. *Rhyothemis variegata* was the most abundant species with 43 individuals, second dominant species was *Rhodothemis rufa* with 31 species. *Archibasis oscillans* dominate with 43 individuals in damselflies and *Ceriagrion cerinorubellum* represented by the lowest number of individuals (3) in damselflies.

ONGICHIRA		
Sl.No.	**Species**	**Total number of individuals**
1	*Brachythemis contaminata*	195
2	*Ictinogomphus rapax*	10
3	*Brachydiplax chalybea*	3
TOTAL		**208**

Table 1. List of species found from Ongichira pond

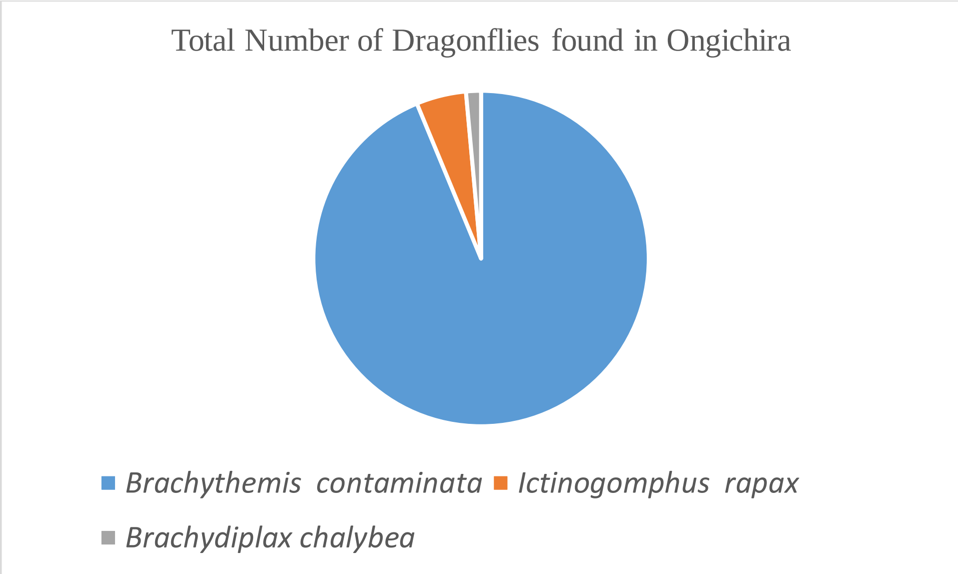

Figure 1. Total Number of Dragonflies found in Ongichira pond

MANNATHIKULAM		
Sl.No.	**Species**	**Total number of individuals**
1	*Ictinogomphus rapax*	34
2	*Rhodothemis rufa*	28
3	*Brachythemis contaminata*	12
4	*Rhyothemis variegata*	8
5	*Neurothemis tullia*	7
6	*Brachydiplax chalybea*	4
TOTAL		**93**

Table 2. List of species found from Mannathikulam pond

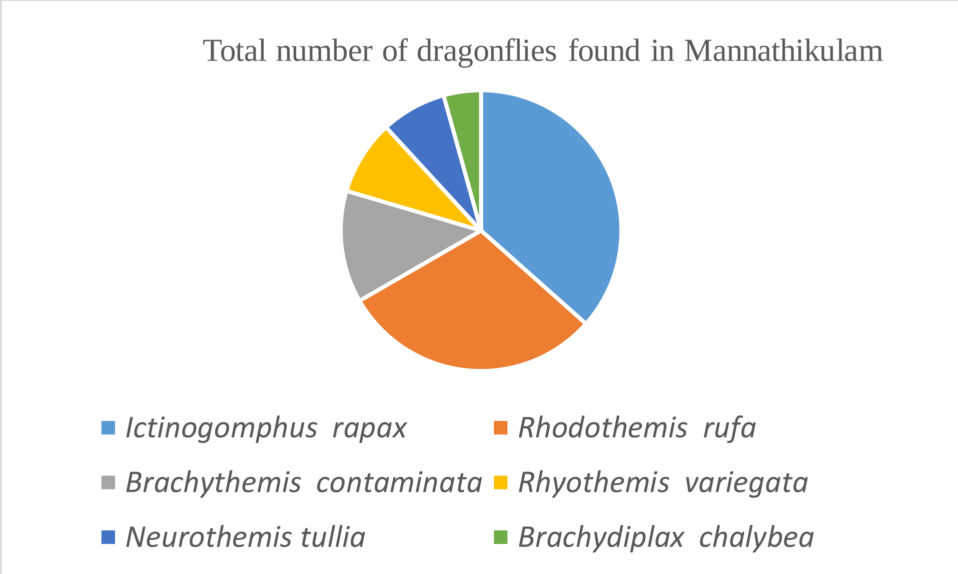

Figure 2. Total Number of dragonflies found in Mannathikulam

ANDANIKULAM		
Sl. No.	**Species**	**Total number of individuals**
Dragonflies		
1	*Rhyothemis variegata*	117
2	*Rhodothemis rufa*	64
3	*Brachythemis contaminata*	33
4	*Neurothemis tullia*	11
5	*Aethriamanata brevipennis*	10
6	*Orthetrum sabina*	10
7	*Ictinogomphus rapax*	8
8	*Brachydiplax chalybea*	7
9	*Diplacodes trivialis*	7
10	*Orthetrum chrysis*	2
Damselflies		
1	*Archibasis oscillans*	51
2	*Pseudagrion malabaricum*	21
3	*Ceriagrion cerinorubellum*	14
4	*Ceriagrion coromandelianum*	8
5	*Pseudagrion microcephalum*	3
TOTAL		**366**

Table 3. List of species found from Andanikulam pond.

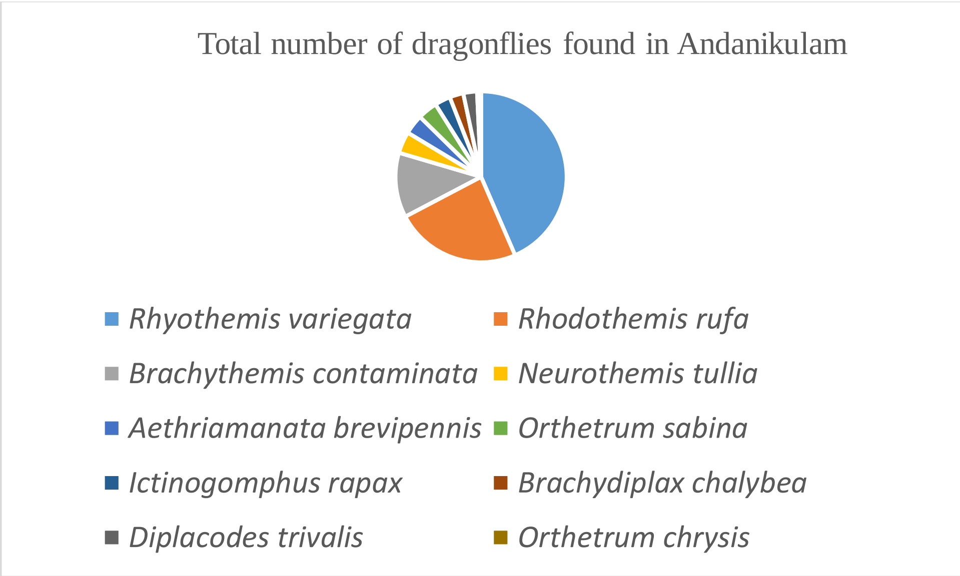

Figure 3. Total Number of dragonflies found in Andanikulam

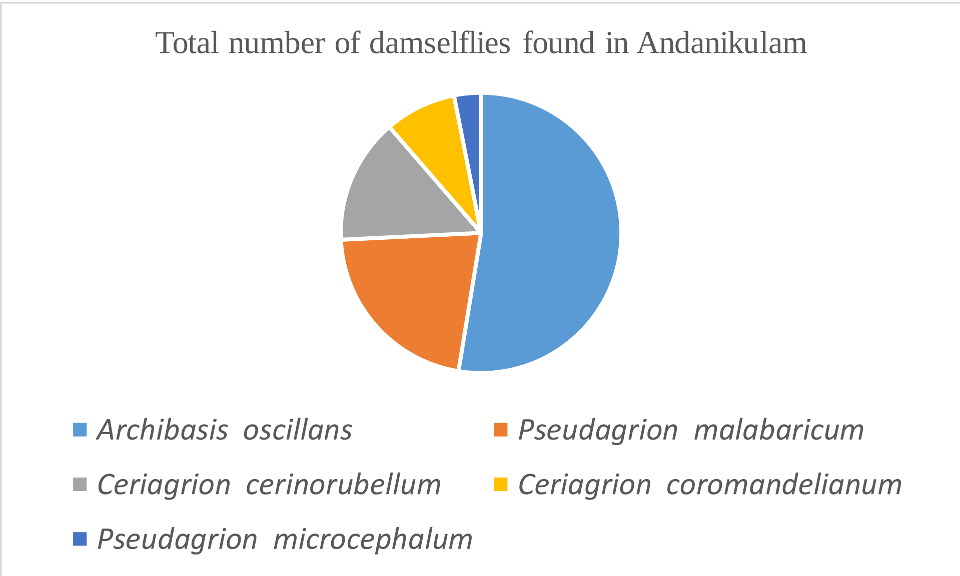

Figure 4. Total number of damselflies found in Andanikulam

KALLANKULAM		
Sl. No.	**Species**	**Total number of individuals**
	Dragonflies	
1	*Rhyothemis variegata*	43
2	*Rhodothemis rufa*	31
3	*Brachydiplax chalybea*	29
4	*Neurothemis tullia*	28
5	*Ictinogomphus rapax*	9
6	*Neurothemis fulvia*	8
7	*Orthetrum sabina*	4
8	*Aethriamanta brevipennis*	3
	Damselflies	
1	*Archibasis oscillans*	40
2	*Pseudagrion malabaricum*	5
3	*Ceriagrion cerinorubellum*	2
TOTAL		**202**

Table 4. List of species found from Kallankulam pond.

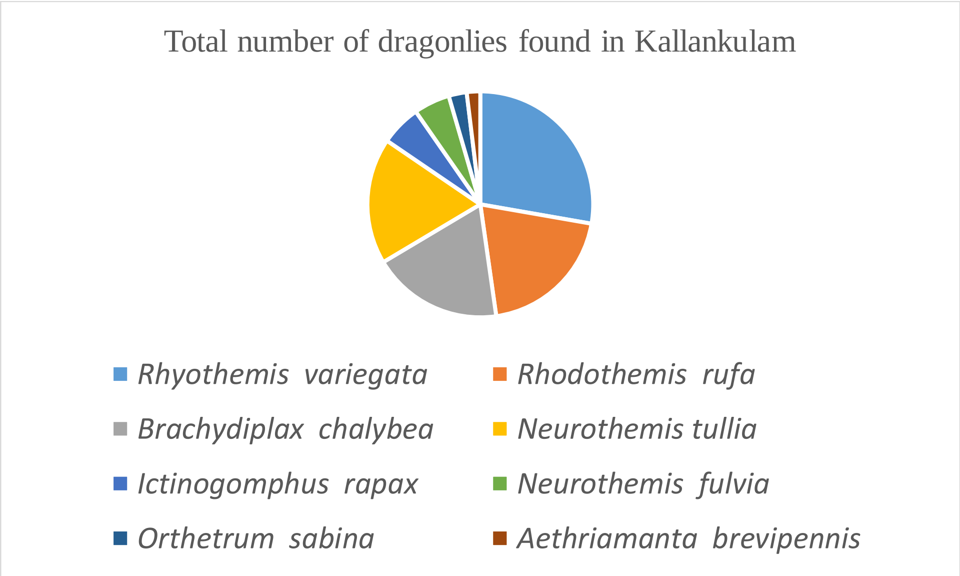

Figure 5. Total number of dragonflies found in Kallankulam

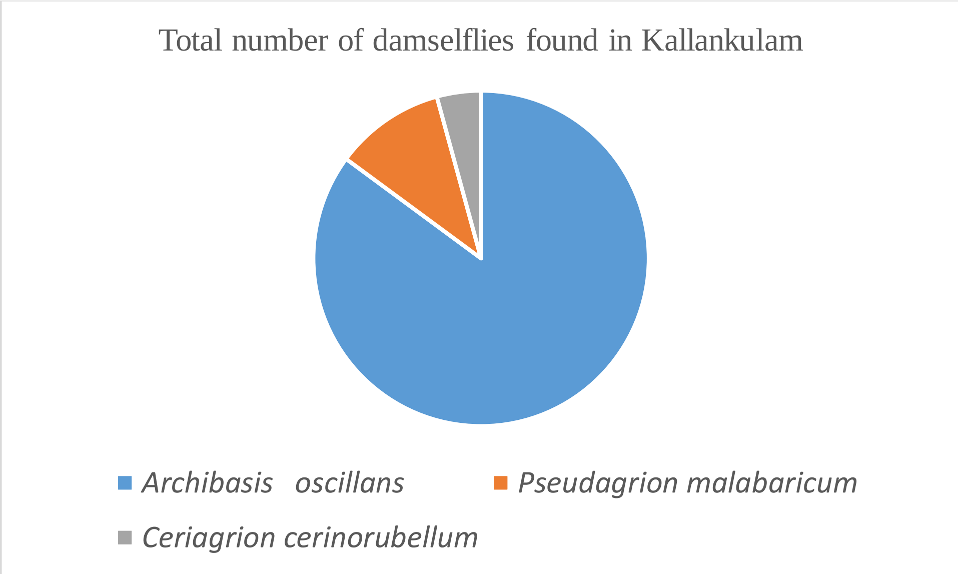

Figure 6. Total number of damselflies found in Kallankualm

MONTH WISE ODONATA DIVERSITY DISTRIBUTION

SEPTEMBER: 8 species of Odonata under 7 genera were collected in the month of September, among which, 7 species are dragonflies which belong to 2 families; Libellulidae and Gomphidae and 1 species comes under family Coenagrionidae. The most abundant species found in this month was *Rhyothemis variegata* (19).

OCTOBER: 8 species of Odonata under 8 genera were collected in month of October. Out of which 6 species are dragonflies which belongs to 2 families; Libellulidae and Gomphidae and 2 species are of damselfly which comes under family Coenagrionidae. *Rhyothemis variegata* (30) was the most abundant species found in month of October. *Archibasis oscillans* and *Pseudagrion malabaricum* are the two damselflies found in this month.

NOVEMBER: 7 species of Odonata under 7 genera were collected in month of November. Out of which 6 species are dragonflies and 1 species of damselfly which belongs to family Coenagrionidae. *Brachythemis contaminata* (34) is the most abundant species present in month of November. *Pseudagrion malabaricum* was the only damselfly found in the month of November with 5 number of individuals.

DECEMBER: 11 species of Odonata under 10 genera were collected in month of December. Among which 8 species are dragonflies and 3 species of damselflies which belongs to family Coenagrionidae. *Brachythemis contaminata* and *Rhyothemis variegata* are the two most abundant species found in this month. *Pseudagrion microcephalum* was the only damselfly found in this month.

JANUARY: 10 species of Odonata under 10 genera were collected in the month of January. Out of which 8 species are dragonflies and 2 species of damselflies which belongs to the family Coenagrionidae. *Brachythemis contaminata* is the most abundant species found with a 35 number of individuals in this month.

Aethriamanta brevipennis and *Diplacodes trivialis* were the dragonflies belonging to the family Libellulidae, which were only found in the month of December and January.

FEBRUARY: 8 Species of Odonata under 7 genera were collected in the month of February. Among which 5 species are dragonflies which belongs to 2 families; Libellulidae and Gomphidae and 3 species of damselflies which belongs to the family Coenagrionidae. The most abundant species is *Brachythemis contaminata* with 32 number of individuals.

MARCH: 9 species of Odonata under 7 genera were collected in the month of March. Among which 6 species are dragonflies which belongs to 2 families; Libellulidae and Gomphidae and 3 species of damselflies belongs to the family Coenagrionidae. The most abundant species is *Rhyothemis variegata* with 30 number of individuals. *Orthetrum chrysis* was the dragonfly species found only in the month of March with least abundance.

Ceriagrion cerinorubellum and *Ceriagrion coromandelianum* were the two damselfly species found only in the month of February and March.

APRIL: 6 species of Odonata under 6 genera were collected in the month of April. Among them, 5 species are dragonflies and 1 species of damselfly which belongs to the family Coenagrionidae. The most abundant species is *Brachythemis conataminata* with 31 number of individuals.

MAY: 6 species of Odonata under 6 genera were collected in the month of May. Among them, 1 species of damselfly which belongs to the family Coenagrionidae and 5 species of dragonflies. The most bountiful species is *Brachythemis conataminata* with 31 number of individuals. There was comparatively less number of individuals of both dragonflies and damselflies in month of May.

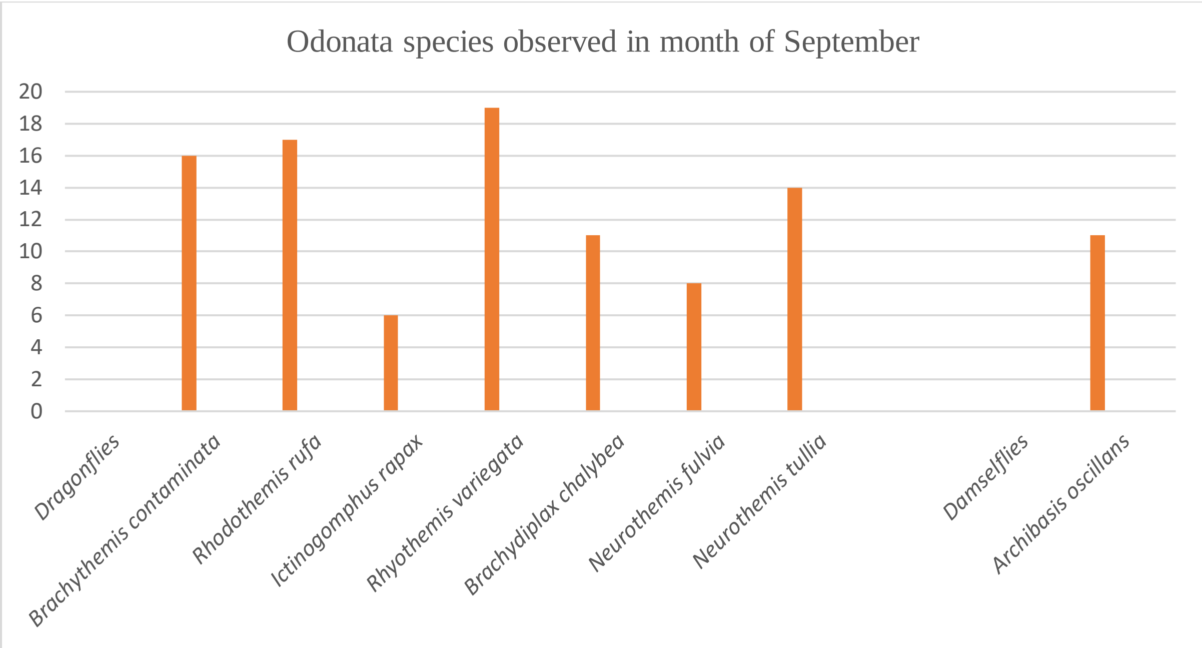

Figure 7. Total number of Odonata species observed in month of September

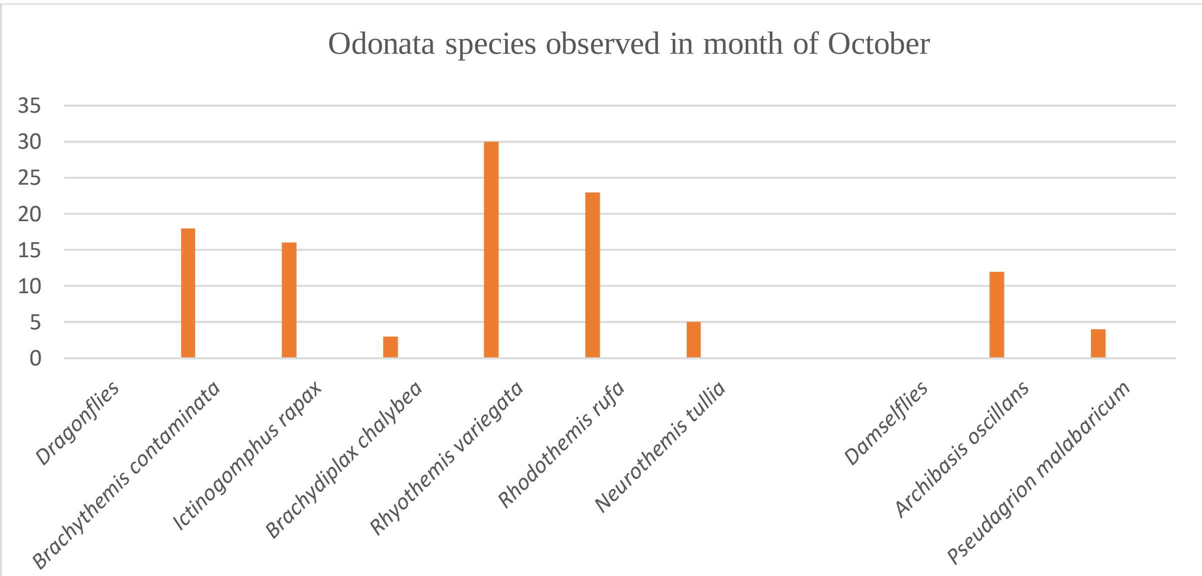

Figure 8. Total number of Odonata species observed in month of October

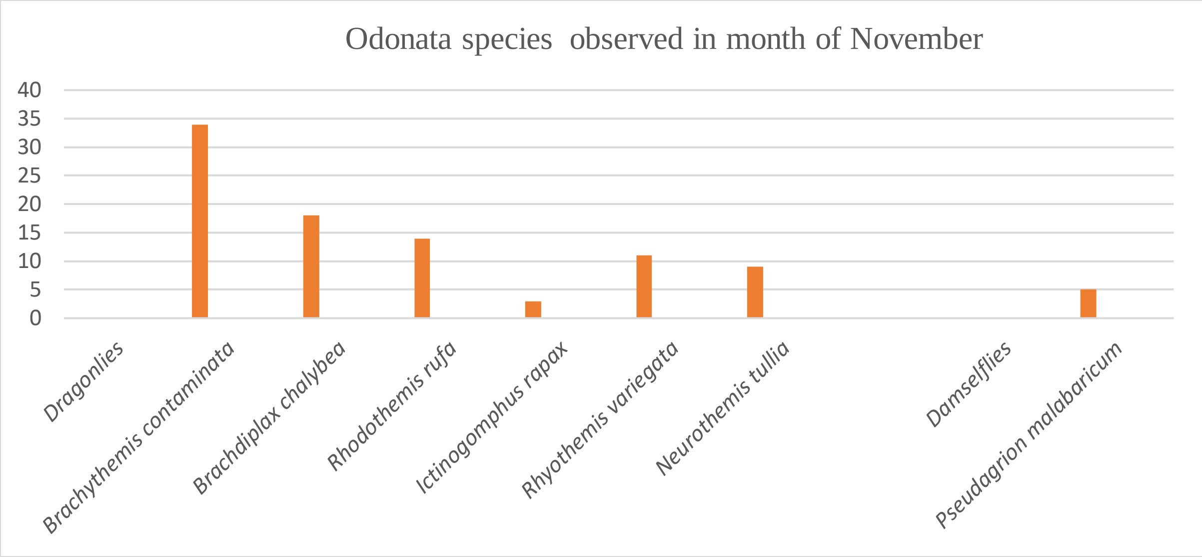

Figure 9. Total number of Odonata species observed in month of November

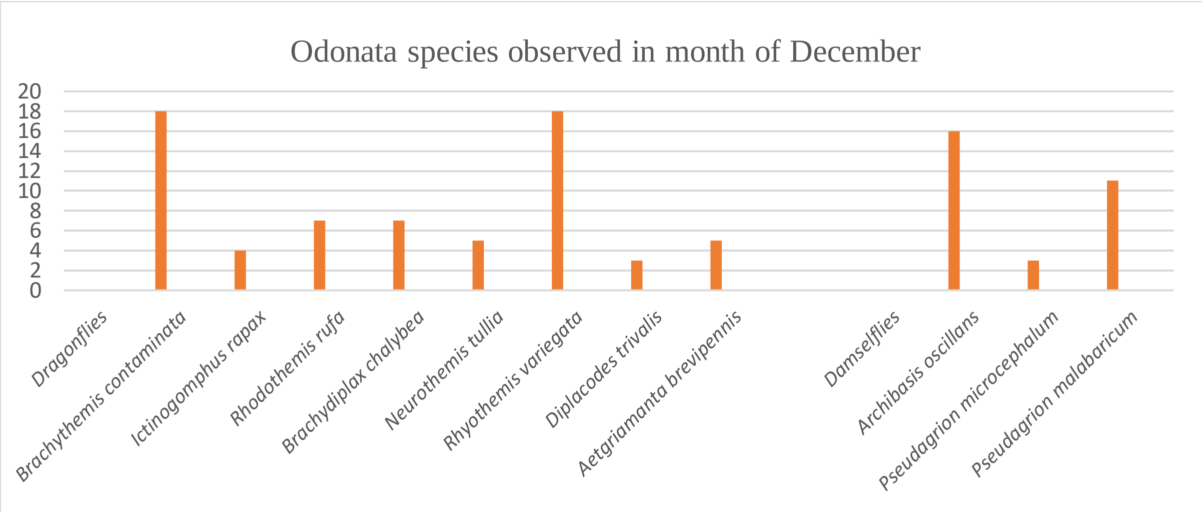

Figure 10. Total number of Odonata species observed in month of December

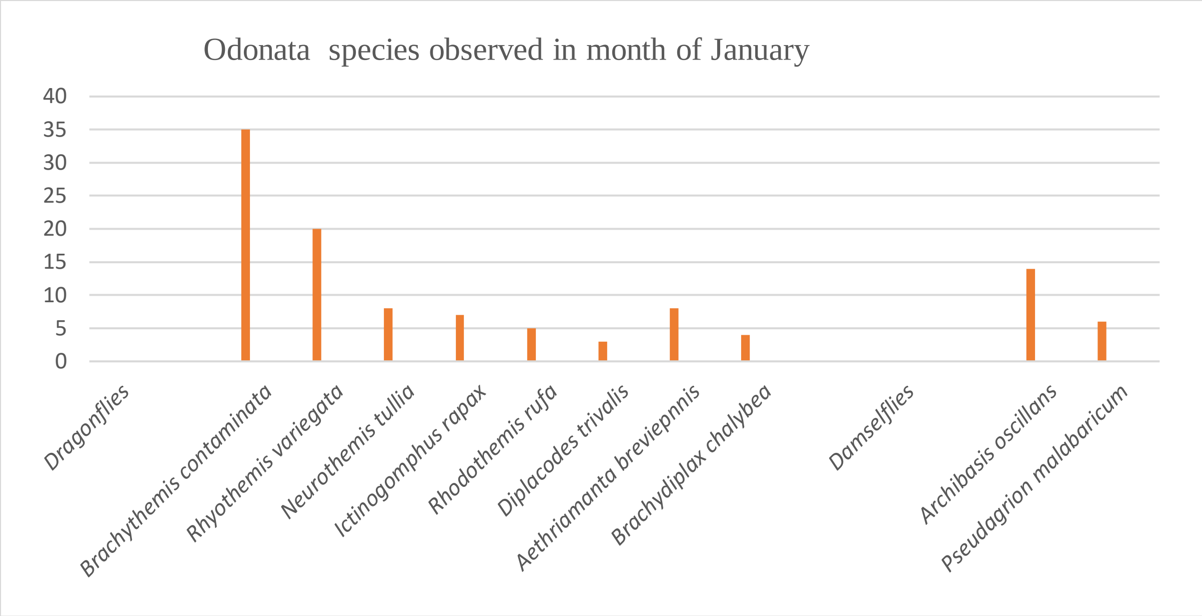

Figure 11. Total number of Odonata species observed in month of January

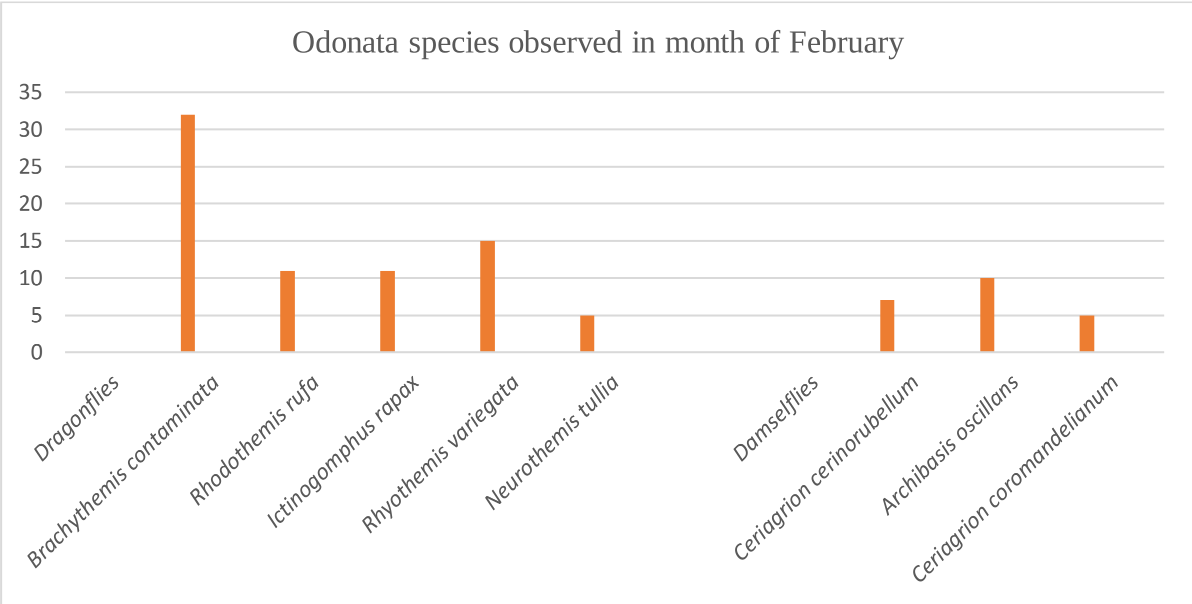

Figure 12. Total number of Odonata species observed in month of February

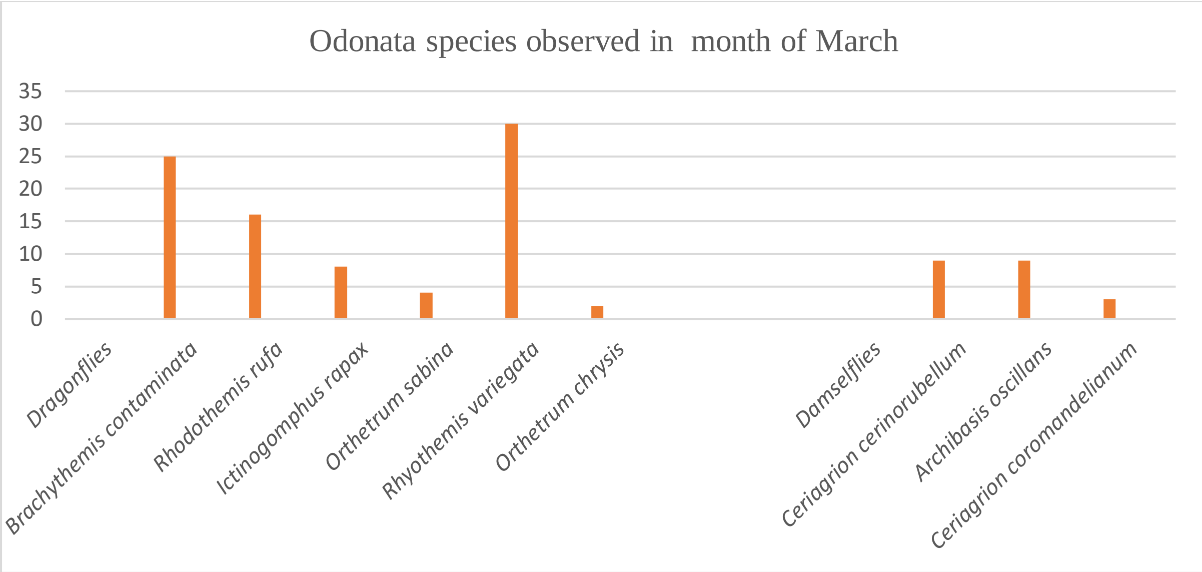

Figure 13. Total number of Odonata species found in month of March

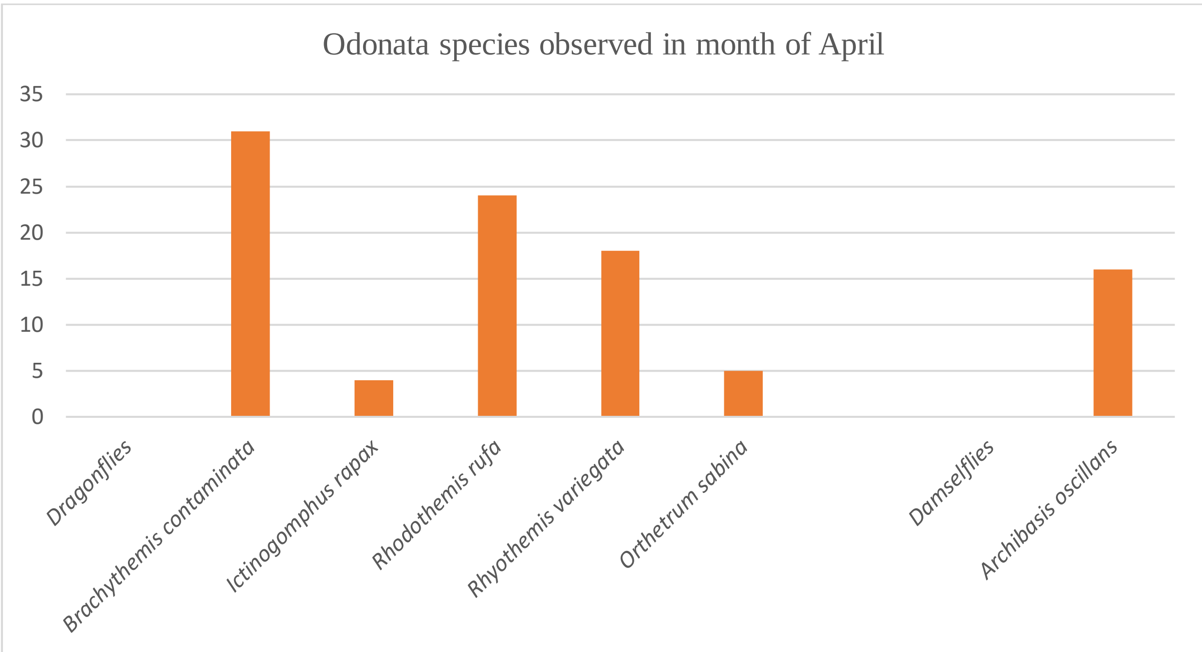

Figure 14. Total number of Odonata species found in month of April

RELATIVE ABUNDANCE OF ODONATA SPECIES

Sl. No.	Species	Relative abundance %	Total No. of individuals
Dragonflies			
1	*Brachythemis contaminata*	33.1034	240
2	*Ictinogomphus rapax*	8.41379	61
3	*Rhyothemis variegata*	23.1724	168
4	*Rhodothemis rufa*	17.1034	124
5	*Neurothemis tullia*	6.34483	46
6	*Brachydiplax chalybea*	5.93103	43
7	*Orthetrum sabina*	1.93103	14
8	*Aethriamanta brevipennis*	1.7931	13
9	*Orthetrum chrysis*	0.27586	2
10	*Diplacodes trivialis*	0.82759	6
11	*Neurothemis fulvia*	1.10345	8
Damselflies			
1	*Archibasis oscillans*	63.1944	91
2	*Ceriagrion cerinorubellum*	11.1111	16
3	*Ceriagrion coromandelianum*	5.55556	8
4	*Pseudagrion microcephalum*	2.08333	3
5	*Pseudagrion malabaricum*	18.0556	26

Table 5. Relative abundance of Odonata species

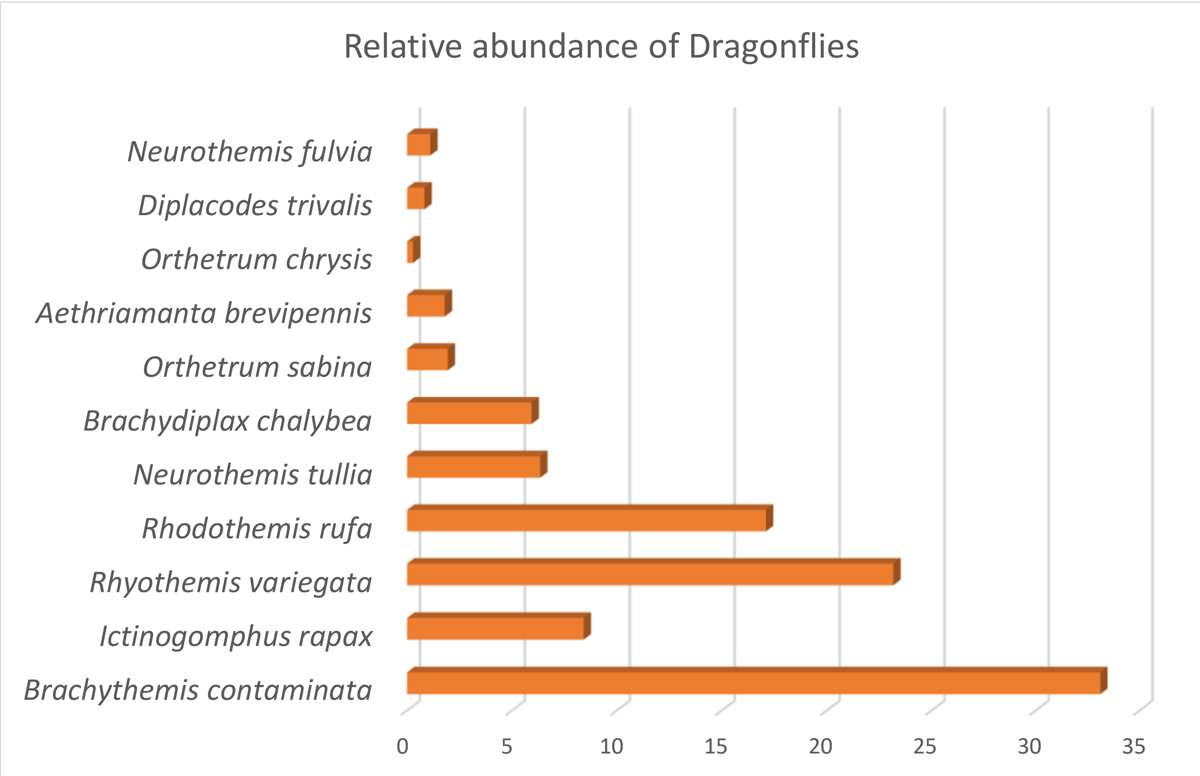

Figure 15. Relative abundance of Dragonflies

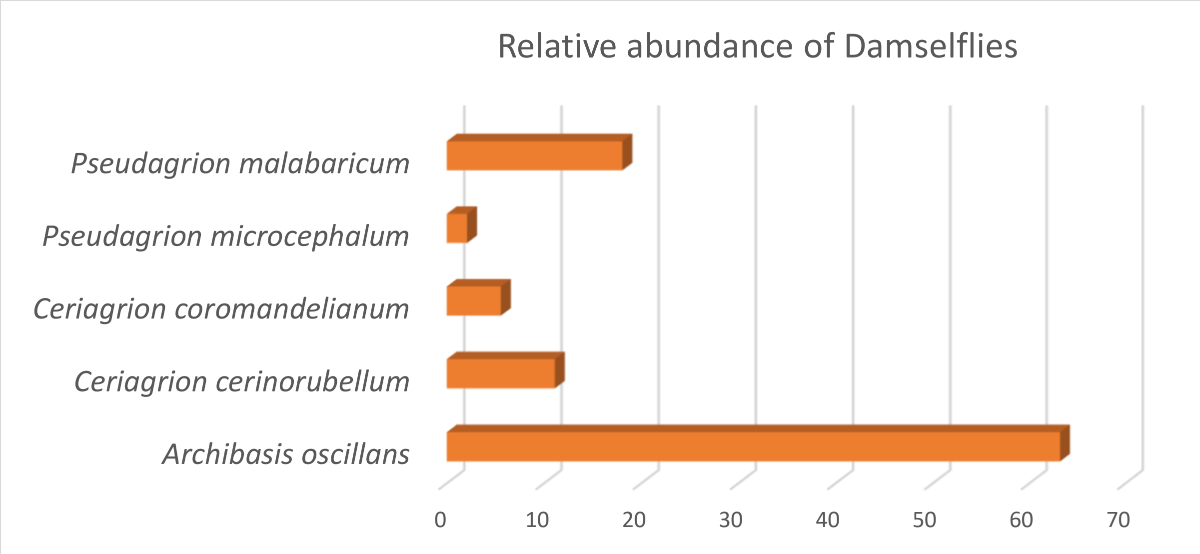

Figure 16. Relative abundance of Damselflies

Diversity indices of dragonflies collected from four selected ponds in and around Irinjalakuda									
Diversity indices	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**
Taxa	7	6	6	8	8	5	6	5	5
Individuals	91	95	89	67	90	74	85	82	52
Simpson (1-D)	0.8496	0.7819	0.7704	0.8295	0.78	0.7331	0.7507	0.726	0.6094
Shannon (H)	1.915	1.613	1.614	1.925	1.782	1.462	1.526	1.403	1.237
Evenness	0.97	0.8363	0.8374	0.857	0.7425	0.8628	0.7664	0.8131	0.6892

Table 6. Diversity indices of dragonflies collected from four selected ponds in and around Irinjalakuda

Diversity indices of damselflies collected from four selected ponds of Irinjalakuda									
Diversity indices	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**
Taxa	1	2	1	3	2	3	3	1	1
Individuals	11	16	5	30	20	22	21	16	3
Simpson (1-D)	0	0.4	0	0.5908	0.4421	0.671	0.6429	0	0
Shannon (H)	0	0.5936	0	0.9667	0.6359	1.105	1.052	0	0
Evenness	1	0.9052	1	0.8764	0.9443	1.006	0.9543	1	1

Table 7. Diversity indices of damselflies collected from four ponds in and around Irinjalakuda

TAXONOMIC ACCOUNT

ANISOPTERA (DRAGONFLY)

1) ***Brachythemis contaminata*** (Fabricius,1793) (Plate B, Figure 1 & 2)

   Family: Libellulidae

   Common Name: Ditch Jewel

   Frequency of observation: Common

   Comments: It is a dragonfly of polluted waters

   Diagnosis:

   A) *Brachythemis contaminata* male

   Face olivaceous; eyes olivaceous brown above and bluish grey below; thorax olivaceous brown to reddish brown above with 2 reddish brown lateral strips; legs dark brown; wings transparent with venation; abdomen bright red.

   B) *Brachythemis contaminata* female

   Face yellowish white; eyes pale brown above and bluish grey below; Thorax pale greenish-yellow with a narrow brown mid dorsal stripe; legs similar to male; wings transparent and bright orange wing patches of males absent; abdomen pale olivaceous brown with a black mid dorsal stripe.

2) ***Ictinogomphus rapax*** (Rambur,1842) (Plate B, Figure 3 & 4)

   Family: Gomphidae

   Common Name: Common Club-tail

   Frequency of observation: Common

   Comment: Commonly found in ponds and mating takes place over water.

   Diagnosis:

   A) *Ictinogomphus rapax* male

   Eyes bluish grey; thorax black marked with yellow; legs black; wings transparent; abdomen black, marked with yellow, with total 8 segments and a black wing-like projection present in segment 8.

   B) *Ictinogomphus rapax* female

Female very similar to male, yellow markings in female broader and abdomen bulky, laterally compressed and short.

3) ***Rhyothemis variegata*** (Linnaeus, 1763) (Plate B, Figure 5 & 6)

Family: Libellulidae

Common Name: Common Picture Wing

Frequency of observation: Very common

Comments: Weak flier and frequently perches on aquatic weed

Diagnosis: It is a medium-sized dragonfly with butterfly like yellow and brown wing

A) *Rhyothemis variegata* male

Frons iridescent green; eyes dark reddish brown above; thorax iridescent green; legs black in colour; forewing transparent and golden yellow, center of wing and wing tip marked with deep coffee brown spots and hindwing has similar spots, trailing edge of hindwing has a characteristic ‘W’ shaped coffee brown mark; abdomen black.

B) *Rhyothemis variegata* female

A dark brown opaque area extends to centre of forewing and tips of forewing transparent; hindwings have brown opaque area which is more extensive and reaches upto wingtip; abdomen black.

4) ***Rhodothemis rufa*** (Rambur, 1842) (Plate C, Figure 1)

Family: Libellulidae

Common Name: Rufous marsh glider

Frequency of observation: Rare

Comments: They are seen near water bodies like open ponds.

Diagnosis: Male: It is a medium sized red coloured dragonfly with red eyes; thorax reddish brown with dorsal citron-yellow stripe or without marking; legs also dark reddish brown; abdomen brilliant scarlet red.

5) ***Neurothemis tullia*** (Drury, 1773) (Plate D, Figure 1)

Family: Libellulidae

Common Name: Pied Paddy Skimmer

Frequency of observation: Very common

Comment: Weak flier and a conspicuous species found in ponds.

Diagnosis: Male: Face black; eyes blackish brown above and violaceous below; thorax black with mid-dorsal cream stripe; legs black; wing's basal half opaque blue-black and bordered by a milky white patch towards tip and wing tips transparent; abdomen black with a broad mid dorsal creamy white stripe on upper side.

6) ***Brachydiplax chalybea*** (Brauer, 1868) (Plate C, Figure 5)

Family: Libellulidae

Common Name: Rufous backed marsh hawk

Frequency of observation: Common

Comments: This species can be easily distinguished from other species in this genus by its larger size, characteristics colour of thorax and basis of wings.

Diagnosis: Male: Size about 33-35 mm long. It is powder blue with light brown sides and dark tip to abdomen. Wings hyaline, with tinted burnt-brown base, fading to amber.

7) ***Orthetrum Sabina*** (Drury, 1773) (Plate C, Figure 2)

Family: Libellulidae

Common Name: Green Marsh Hawk

Frequency of observation: Rare

Comments: It flies so quickly.

Diagnosis: Male: Face yellowish green; eyes green mottled with black; thorax greenish yellow with black tiger like stripes; legs black; wings transparent; abdomen with 1-3 segments and green with broad black rings and distinctly swollen at base.

8) ***Aethriamanta brevipennis*** (Rambur, 1842) (Plate C, Figure 6)

Family: Libellulidae

Common Name: Scarlet Marsh Hawk

Frequency of observation: Rare

Comment: In morning they are active.

Diagnosis: It is a small dragonfly with black thorax and scarlet yellow abdomen.

Male: Face covered with short, stiff black hairs; eyes dark reddish brown; thorax dark chocolate brown above which pales to golden olivaceous brown on sides; legs black; wings transparent and tinted with deep golden amber at base; abdomen bright red contrasting with blackish thorax.

9) ***Orthetrum chrysis*** (Selys, 1891) (Plate C, Figure 3 & 4)

Family: Libellulidae

Common Name: Brown backed red marsh hawk

Frequency of observation: Very rare

Comments: It perches near the side area of ponds.

Diagnosis: The dragonfly is medium sized red and brown in colour; eyes coffee brown above and bluish grey below; thorax rusty brown; wings transparent and its base amber tinted; abdomen bright red in colour.

10) ***Diplacodes trivalis*** (Rambur, 1842) (Plate D, Figure 3)

Family: Libellulidae

Common Name: Ground skimmer

Frequency of observation: Rare

Comment: Flies very rarely.

Diagnosis: It is a blue dragonfly with black markings; eyes reddish brown above and pale bluish below; abdomen greenish yellow with black stripes.

11) ***Neurothemis fulvia*** (Drury, 1773) (Plate D, Figure 2)

Family: Libellulidae

Common Name: Fulvous Forest Skimmer

Frequency of observation: Rare

Comment: It is seen in large number during September.

Diagnosis: Medium sized rusty coloured dragonfly with transparent wing tips. Male: Face reddish brown; eyes dark reddish brown above and golden brown below; Thorax reddish brown; legs dark reddish brown; wings opaque dark reddish brown with an irregular triangular transparent area at tip of the wing.

ZYGOPTERA (DAMSELFLY)

1) ***Archibasis oscillans*** (Selys,1877) (Plate E, Figure 1)

Family: Coenagrionidae

Common Name: Long-banded bluetail

Frequency of observation: Common

Comment: Mostly flying near the water level.

Diagnosis: Slender and long damselfly; eyes light blue with blue capped; thorax black with azure blue anti-humeral stripes followed by blue on lateral sides; abdomen black on dorsal and greenish yellow on ventral half of lateral sides upto segment 7, remaining segments azure blue with apical black rings.

2) ***Ceriagrion cerinorubellum*** (Brauer, 1865) (Plate E, Figure 2)

Family: Coenagrionidae

Common Name: Orange tailed marsh dart

Frequency of observation: Very rare

Comment: Active at morning.

Diagnosis: Bluish green and orange coloured, medium-sized damselfly; thorax pale green; legs greenish yellow; abdomen with black basal and terminally reddish orange.

3) ***Ceriagrion coromandelianum*** (Fabricius, 1798) (Plate E, Figure 3)

Family: Coenagrionidae

Common Name: Coromandel marsh darsh

Frequency of observation: Very rare

Comments: Seen in shrub land.

Diagnosis: It is yellow and medium-sized damselfly; eyes light green with yellow posterior margin; legs yellow; abdomen yellow.

4) Pseudagrion malabaricum (Fraser, 1924) (Plate F, Figure 1)

Family: Coenagrionidae

Common Name: Jungle Grass Dart

Frequency of observation: Rare

Comment: It breeds on ponds.

Diagnosis: It is medium-sized damselfly; eyes blue; thorax azure blue with broad black dorsal, medial and humeral stripes; abdominal segments 1 and 2 blue with black marks on dorsum.

5) ***Pseudagrion microcephalum*** (Rambur, 1842) (Plate F, Figure 2)

Family: Coenagrionidae

Common Name: Blue grass dartlet

Frequency of observation: Rare

Comment: Strongly migratory species.

Diagnosis: It is blue and medium-sized damselfly; eyes dorsally brown cap and ventrally dark azure blue fading to sky blue beneath; thorax azure blue with broad black medial stripe and black narrow stripe on each side; legs and abdomen azure blue.

DISCUSSION

The current study was done to observe the Odonata diversity of four selected ponds in and around Irinjalakuda. A total of 869 individuals belonging to 16 species of Odonates were observed during the study period which lasts for 9 months. Among them, 11 species are dragonflies and 5 species are damselflies. Identified odonates belongs to 3 families; namely Libellulidae, Gomphidae (Dragonflies) and Coenagrionidae (Damselflies).

The study area includes four selected ponds, Ongichira (3 Dragonflies), Mannathikulam (6 Dragonflies), Andanikulam (10 Dragonflies & 5 Damselflies) and Kallankulam (8 Dragonflies & 3 Damselflies). Andanikualm has the highest Odonata diversity with 15 species. Andanikulam has both the highest diversity of dragonflies and damselflies species.

Among four selected ponds, 2 ponds; Andanikulam and Kallankulam has more vegetational habitat and occupies invasive plant species, *Eichhornia crassipes* only for a few months and it was cleared later. Other two ponds, Ongichira and Mannathikulam has very low vegetation and only dragonflies are found there and not even a single species of damselflies are found there. This may be because of anthropogenic activities such as vegetation clearing possibly affect the Odonata diversity by decreasing diversity and abundance (Mafuwe and Moyo, 2020).

Brachythemis contaminata is the most abundant species found in Ongichira. It is a dragonfly seen in polluted water (Subramanian, 2005) and hence its abundance indicates the poor water quality of ponds (Chandran *et al*., 2020). *Ictinogomphus rapax* is the most abundant species in Mannathikulam. Andanikulam has the highest diversity of odonates in which some of dragonflies such as *Aethriamanta brevipennis*, *Orthetrum chrysis* and *Diplacodes trivalis* was only found in this pond compared to other three ponds. Some of the damselflies such as *Pseudagrion microcephalum* and *Ceriagrion coromandelianum* found only in this pond. . *Rhyothemis variegata* was the most abundant species found both in Andanikulam and Kallankulam. Kallankulam ranks the second highest diversity of odonata when compared to other 3 ponds. *Neurothemis fulvia* is only found in this pond and it was found in large numbers in the month of September as usually they are seen in large numbers between May-September (Subramanian, 2005).

Among dragonflies the genus *Neurothemis* (Brauer) has its two species, *Neurothemis tullia* and *Neurothemis fulvia* found in these four ponds. The genus *Pseudagrion* (Selys) has its two species, *Pseudagrion microcephalum* and *Pseudagrion malabaricum* and the genus *Ceriagrion* (Selys) has its two species, *Ceriagrion cerinorubellum* and *Ceriagrion coromandelianum* found in the study area.

In case of dragonflies, the highest relative abundance is for *Brachythemis contaminata* (33.103), followed by *Rhyothemis variegata* (23.172), *Rhodothemis rufa* (17.103) and the least abundance is for *Orthetrum chrysis* (0.2759).

In case of dragonflies, the highest Simpson diversity index ranks in month of September (0.8496) and the least Simpson diversity index is in the month of May (0.6094) and in case of damselflies the highest Simpson diversity index is 0.671 in month of February and the least Simpson index is in the following months of September, November, April and May.

Regarding the dragonflies, the highest Shannon diversity is in month of December (1.928) and the least Shannon diversity is in month of May (1.237). In case of damselflies, the highest Shannon diversity in the month of February (1.105) and the least Shannon diversity in the following months of September, November, April and May.

The Evenness is found highest in month of September (0.97) in case of dragonflies and in month of February (1.006) in case of damselflies.

Towards the end of study period, summer months, especially during month of May, the number of individuals of odonata species were very few in number. this may be due to the scarcity of water present in the ponds.

CONCLUSION

- A total of 16 species including 869 individuals of Odonata under 3 families were observed from the study area. Libellulidae was the most dominant family with 16 species. The second dominant family was Coenagrionidae with 5 species.
- The study area includes four selected ponds in and around Irinjalakuda, Thrissur district; Ongichira, Mannathikulam, Kallankulam, Andanikulam.
- Three families of odonata species found in study area which are Libellulidae, Gomphidae (Dragonflies) and Coenagrionidae (Damselflies).
- Andanikulam has the highest diversity of Odonata species with 15 species.
- *Brachythemis contaminata* is the most abundant species found in Ongichira and it is the indicator species of polluted water.
- *Ictinogomphus rapax* is the most abundant species found in Mannathikulam.
- *Rhyothemis variegata* is the most abundant species found in both Andanikulam and Kallankulam.
- *Archibasis oscillans* was the most abundant species in damselflies which belongs to family Libellulidae.
- In these four selected ponds, species like *Brachythemis contaminata* (240), *Rhyothemis variegata* (168) and *Rhodothemis rufa* (124) were the most abundant species recorded in dragonflies and *Archibasis oscillans* is the most abundant one in damselflies.
- In case of dragonflies, the highest relative abundance is for *Brachythemis contaminata* (33.103), next is for *Rhyothemis variegata* (23.172), followed by *Rhodothemis rufa* (17.103) and the least abundance is for *Orthetrum chrysis*(0.2759).

- In case of dragonflies, the highest Simpson diversity index ranks in month of September(0.8496) and the least Simpson diversity index in the month of May(0.6094)
- Regarding the damselflies, the highest Simpson diversity index is (0.671) in month of February and the least Simpson index is in following months of September, November, April and May.
- In case of dragonflies, the highest Shannon diversity in month of December (1.928) and the last Shannon diversity is in month of May (1.237).
- Regarding the damselflies, the highest Shannon diversity is in month of February (1.105) and the least damselfly Shannon diversity in the following months of September, November, April, May.
- The Eveness is found higestv in month of September (0.97) in case of dragonflies and in month of February (1.006) in case of damselflies.

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APPENDIX

Table A1: Data on Odonates observed on various ponds in the month of September

Month: September						
Sl. No.	**Species**	**No. of individuals**				
	Dragonflies	**OC**	**MK**	**AK**	**KK**	**Total**
1	*Brachythemis contaminata*	16				16
2	*Rhodothemis rufa*		4	5	8	17
3	*Ictinogomphus rapax*		6			6
4	*Rhyothemis variegata*			19		19
5	*Brachydiplax chalybea*			4	7	11
6	*Neurothemis fulvia*				8	8
7	*Neurothemis tullia*				14	14
	Total	**16**	**10**	**28**	**37**	**91**
	Damselflies					
1	*Archibasis oscillans*			3	8	11
	Total			**3**	**8**	**11**

Table A2: Data on Odonates observed on various ponds in the month of October

Month: October						
Sl. No.	**Species**	**No. of individuals**				
	Dragonflies	**OC**	**MK**	**AK**	**KK**	**Total**
1	*Brachythemis contaminata*	17	1			18
2	*Ictinogomphus rapax*	6	4	3	3	16
3	*Brachydiplax chalybea*		1		2	3
4	*Rhyothemis variegata*		3	24	3	30
5	*Rhodothemis rufa*		4	13	6	23
6	*Neurothemis tullia*			2	3	5
	Total	**23**	**13**	**42**	**17**	**95**
	Damselflies					
1	*Archibasis oscillans*			6	6	12
2	*Psedagrion malabaricum*			4		4
	Total			**10**	**6**	**16**

Table A3: Data on Odonates observed on various ponds in month of November

Month: November						
Sl. No.	**Species**	**No. of individuals**				
	Dragonflies	**OC**	**MK**	**AK**	**KK**	**Total**
1	*Brachythemis contaminata*	28		6		34
2	*Brachydiplax chalybea*	3		1	14	18
3	*Rhodothemis rufa*		4	5	5	14
4	*Ictinogomphus rapax*		3			3
5	*Rhyothemis variegata*			11		11
6	*Neurothemis tullia*				9	9
	Total	**31**	**7**	**23**	**28**	**89**
	Damselflies					
1	*Pseudagrion malabaricum*			5		5
	Total			**5**		**5**

Table A4: Data on Odonates observed on various ponds in the month of December

Month: December						
Sl. No.	**Species**	**No. of individuals**				
	Dragonflies	**OC**	**MK**	**AK**	**KK**	**Total**
1	*Brachythemis contaminata*	14		4		18
2	*Ictinogomphus rapax*	4				4
3	*Rhodothemis rufa*		4	3		7
4	*Brachydiplax chalybea*		3	2	2	7
5	*Neurothemis tullia*		4		1	5
6	*Rhyothemis variegata*			5	13	18
7	*Diplacodes trivalis*			3		3
8	*Aethriamanta brevipennis*			5		5
	Total	**18**	**11**	**22**	**16**	**67**
	Damselflies					
1	*Archibasis oscillans*			11	5	16
2	*Pseudagrion microcephalum*			3		3
3	*Pseudagrion malabaricum*			8	3	11
	Total			**22**	**8**	**30**

Table A5: Data on Odonates observed on various ponds in the month of January.

Month: January						
Sl. No.	**Species**	**No. of individuals**				
	Dragonflies	**OC**	**MK**	**AK**	**KK**	**Total**
1	*Brachythemis contaminata*	28	3	4		35
2	*Rhyothemis variegata*		3	9	8	20
3	*Neurothemis tullia*		3	4	1	8
4	*Ictinogomphus rapax*		3		4	7
5	*Rhodothemis rufa*			2	3	5
6	*Diplacodes trivalis*			3		3
7	*Aethriamanta brevipennis*			5	3	8
8	*Brachydiplax chalybea*				4	4
	Total	**28**	**12**	**27**	**23**	**90**
	Damselflies					
1	*Archibasis oscillans*			7	7	14
2	*Pseudagrion malabaricum*			4	2	6
	Total			**11**	**9**	**20**

Table A6: Data on Odonates observed on various ponds in the month of February

Month: February						
Sl. No.	**Species**	**No. of individuals**				
	Dragonflies	**OC**	**MK**	**AK**	**KK**	**Total**
1	*Brachythemis contaminata*	23	2	7		32
2	*Rhodothemis rufa*		5	6		11
3	*Ictinogomphus rapax*		6	5		11
4	*Rhyothemis variegata*			10	5	15
5	*Neurothemis tullia*			5		5
	Total	**23**	**13**	**33**	**5**	**74**
	Damselflies					
1	*Ceriagrion cerinorubellum*			5	2	7
2	*Archibasis oscillans*			3	7	10
3	*Ceriagrion coromandelianum*			5		5
	Total			**13**	**9**	**22**

Table A7: Data on Odonates observed on various ponds in the month of March

Month: March						
Sl. No.	**Species**	**No. of individuals**				
	Dragonflies	**OC**	**MK**	**AK**	**KK**	**Total**
1	*Brachytemis contaminata*	18	1	6		25
2	*Rhodothemis rufa*		4	8	4	16
3	*Ictinogomphus rapax*		6		2	8
4	*Orthetrum sabina*			4		4
5	*Rhyothemis variegata*		2	21	7	30
6	*Orthetrum chrysis*			2		2
	Total	**18**	**13**	**41**	**13**	**85**
	Damselflies					
1	*Ceriagrion cerinorubellum*			9		9
2	*Archibasis oscillans*			9		9
3	*Ceriagrion coromandelianum*			3		3
	Total			**21**		**21**

Table A8: Data of Odonates observed on various ponds in the month of April

Month: April						
Sl. No.	**Species**	**No. of individuals**				
	Dragonflies	**OC**	**MK**	**AK**	**KK**	**Total**
1	*Brachythemis contaminata*	28		3		31
2	*Ictinogomphus rapax*		4			4
3	*Rhodothemis rufa*		3	16	5	24
4	*Rhyothemis variegata*			11	7	18
5	*Orthetrum sabina*			5		5
	Total	**28**	**7**	**35**	**12**	**82**
	Damselflies					
1	*Archibasis oscillans*			11	5	16
	Total			**11**	**5**	**16**

Table A9: Data of Odonates observed on various ponds in the month of May

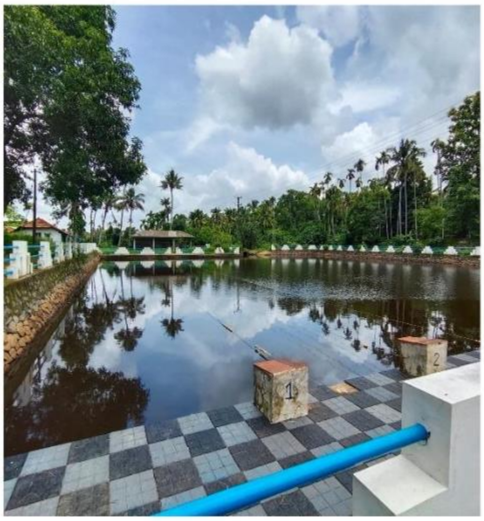
Month: May						
Sl. No.	**Species**	**No. of individuals**				
	Dragonflies	**OC**	**MK**	**AK**	**KK**	**Total**
1	*Brachythemis contaminata*	23	5	3		31
2	*Ictinogomphus rapax*		2			2
3	*Rhodothemis rufa*			7		7
4	*Rhyothemis variegata*			7		7
5	*Orthetrum sabina*			1	4	5
	Total	**23**	**7**	**18**	**4**	**52**
	Damselflies					
1	*Archibasis oscillans*			1	2	3
	Total			**1**	**2**	**3**

STUDY AREA (4 PONDS)

PLATE A

Pond 1. Kallankulam

Pond 2. Andanikulam



Pond 3. Ongichira

Pond 4. Mannathikulam

Photographs of 4 selected ponds in and around Irinjalakuda were clicked on date 25/06/2023.

PLATE B

1. *Brachythemis contaminata* (M)

2. *Brachythemis contaminata* (F)

3. *Ictinogomphus rapax* (M)

4. *Ictinogomphus rapax* (F)

5. *Rhyothemis variegata* (M)

6. *Rhyothemis variegata* (F)

PLATE C

1. *Rhodothemis rufa*

2. *Orthetrum sabina* (M)

3. *Orthetrum chrysis* (M)

4. *Orthetrum chrysis* (F)

5. *Brachydiplax chalybea*

6. *Aethriamanata brevipennis*

PLATE D

1. *Neurothemis tullia*

2. *Neurothemis fulvia*

3. *Diplacodes trivialis*

PLATE E

1. *Archibasis oscillans*

2. *Ceriagrion cerinorubellum*

3. *Ceriagrion coromandelianum*

PLATE F

1. *Pseudagrion malabaricum*

2. *Pseudagrion microcephalum*

STUDY ON THE IMMATURE LARVAL STAGES OF *ASPIDIMORPHA FURCATA* (THUNBERG)

DISSERTATION SUBMITTED

IN PARTIAL FULFILMENT OF THE REQUIREMENTS

FOR THE AWARD OF THE DEGREE OF

MASTER OF SCIENCE IN ZOOLOGY
UNIVERSITY OF CALICUT

By

SANDRA WILSON

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DEPARTMENT OF ZOOLOGY

CHRIST COLLEGE (AUTONOMOUS)

IRINJALAKUDA, THRISSUR, KERALA -680125

JULY 2023

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JULY 2023

Examiners: 1.

2.

<u>DECLARATION</u>

I, Sandra Wilson , do hereby declare that the dissertation entitled " **STUDY ON THE IMMATURE LARVAL STAGES OF *ASPIDIMORPHA FURCATA* (THUNBERG) "** is an authentic record of original work carried out by me under the guidance of Dr. Sr. Dilla Jose, Assistant Professor, Christ College Irinjalakuda and that no part of the thesis has been presented for the award of any other degree or diploma in any university.

Place:Irinjalakuda SANDRA WILSON

Date:

CHRIST COLLEGE, IRINJALAKUDA

DEPARTMENT OF ZOOLOGY

CERTIFICATE

This is to certify that the project work entitled **" STUDY ON THE IMMATURE LARVAL STAGES OF, ASPIDIMORPHA FURCATA (THUNBERG) "** is an authentic record of research work carried out by Ms. **SANDRA WILSON (Reg. No. CCAVMZL016)** as part of the M.sc project work during the year 2022-2023 and the result of this work has not been presented for the award of any other degree/diploma in any university.

Place: Irinjalakuda | Dr.Sudhikumar A.V

Date: | Head, Department Of Zoology

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CERTIFICATE

This is to certify that the contents of this dissertation work entitled" STUDY ON THE IMMATURE LARVAL STAGES OF , *ASPIDIMORPHA FURCATA* (THUNBERG) " is the original research work done by SANDRA WILSON under my supervision and guidance at the DEPARTMENT OF ZOOLOGY, CHRIST COLLEGE, IRINJALAKUDA (AUTONOMOUS) ,Thrissur.

I further certify that no part of the work has been presented before for the award of any other degree/ diploma.

Place : Irinjalakuda | Dr. Sr. Dilla Jose

Date : | Supervisor & guide

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I am indebted to all the teaching and non-teaching staff of the department and to my friends for their timely help and encouragement.

Finally, I recall with sincere gratitude to my parents, friends and all those who have helped me in one or other way in my endeavour and above all , Almighty God.

CONTENTS

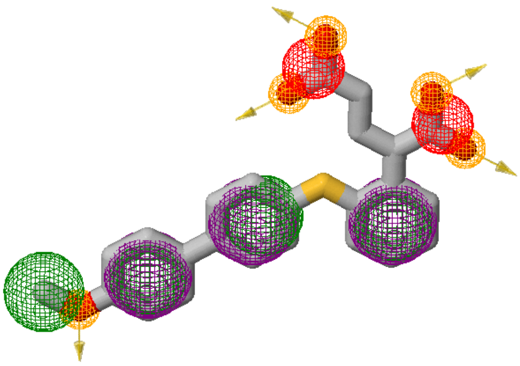
A PHARMACOPHORE MODELLING APPROACH FOR THE DISCOVERY OF NEW MMP-9 INHIBITORS

Dissertation submitted to

UNIVERSITY OF CALICUT

in partial fulfilment of the requirement for the award of

MASTER OF SCIENCE IN ZOOLOGY



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KERALA – 680125

2023

Examiners

1.

2.

DECLARATION

I, Jesna Maria do hereby declare that this dissertation entitled **“A PHARMACOPHORE MODELLING APPROACH FOR THE DISCOVERY OF NEW MMP-9 INHIBITORS”** is a genuine record of dissertation done by me under the guidance of **Dr. Leyon Varghese**, Asst. Professor, Department of Zoology, Christ College (Autonomous), Irinjalakuda, and the results of this study have not previously formed the basis of the award of any degree in any university.

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CERTIFICATE

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CERTIFICATE

This is to certify that, the dissertation entitled **“A PHARMACOPHORE MODELLING APPROACH FOR THE DISCOVERY OF NEW MMP-9 INHIBITORS”** is an authentic work carried out by **JESNA MARIA (Reg. No. CCAVMZL010)**, Department of Zoology, Christ College, Irinjalakuda, and is in partial fulfilment of the requirements for the degree of **Master of Science in Zoology** of the **University of Calicut** and the results of this work has not formed the basis for the award of any degree or diploma.

Dr. Sudhikumar A.V.

Head, Dept. of Zoology

Christ College, Irinjalakuda

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JESNA MARIA

CONTENTS