# Study on Araneae in Agro-ecosystem of Amona, Goa

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By

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# DECLARATION BY STUDENT

I hereby declare that the data presented in this Dissertation report entitled, **"Study on Araneae in Agro-ecosystem of Amona, Goa"** is based on the results of investigations carried out by me in the Zoology at the School of Biological Sciences and Biotechnology, Goa University, under the Supervision of Dr. Preeti Antonetta Pereira and the same has not been submitted elsewhere for the award of a degree or diploma by me. Further, I understand that Goa University or its authorities will be not be responsible for the correctness of observations / experimental or other findings given the dissertation.

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This is to certify that dissertation report **"Study on Araneae in Agro-ecosystem of Amona, Goa"** is a bonafide work carried out by Ms. Anveeka Damodar Gauns under my supervision in partial fulfilment of the requirements for the award of the degree of Master's Degree in Zoology in the Zoology discipline at the School of Biological Sciences and Biotechnology, Goa University.

Dr. Preeti Antonetta Pereira

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# ABSTRACT

One of the most varied groupings of living things in India is the spider family. But they've been mostly disregarded. Recent studies have shown that spiders are essential ecological indicators and play a significant role in maintaining ecological balance. Seven months, from September 2023 to March 2024, were dedicated to the investigation of the diversity, abundance, distribution, guild, and web structure of spiders in the Agro-ecosystem of Amona, Goa. Spiders from agro-ecosystems were sampled using methods like visual search, hand picking, beating, and collecting leaf litter. Using the existing literature, the collected specimens were recognized up to the species or genus level. From this study area, 38 different species of spiders from 29 genera and 11 families were identified. Family Araneidae and Salticidae are discovered to be dominating in the present study. Eight functional categories were identified by guild structure studies of the spiders that were collected: orb-weaver, ambushers, ground runners, diurnal runners, foliage runners, aerial ambushers, space builder, and space web weaver. The distinct families have distinct web architectures and patterns. Four distinct web patterns—funnel web, orb web, signature web, and sheet/tangle web—were observed throughout the study period. Diversity indices like Shannon-Weiner, Simpson, Equitability and Margalef were used to calculate diversity, evenness and richness of the Agro-ecosystems. According to the study, the spider fauna of the agro-ecosystem is diverse and abundant.

**KEYWORDS:** Araneae, Agro-ecosystem, Amona, Diversity indices

# 1. INTRODUCTION

## 1.1 BACKGROUND

Spiders are among the most varied groups of creatures known to exist in the world (Sumesh, 2021). Spider fauna can be encountered almost everywhere, with the exception of a few regions, such as the Arctic and Antarctica. Worldwide, 135 families have been described, consisting of 4,377 genera and 52,038 species (World Spider Catalog, 2024). Out of these, 67 families and 552 genera comprising 2299 spider species have been documented from South East Asia (Siliwal & Molur, 2007). India is represented by 1984 species, spread across 501 genera and 62 families, (Caleb & Sankaran, 2021). Of these species, 71 are native to the Andaman and Nicobar Islands, 1002 are native to the Indian Mainland, and one species is native to Lakshadweep (Siliwal et al., 2005). In India, the families with the greatest number of genera and species are the Salticidae (108 genera and 326 species) followed by the Thomisidae (42 genera and 186 species), (Caleb & Sankaran, 2021) whilst Goa has 173 species, distributed throughout 128 genera and 23 families (Singh & Singh, 2022).

### 1.1.1 Classification of Spiders

Class Arachnida is a large and diverse group of Phylum Arthropoda, characterised by head and thorax usually fused together, forming a cephalothorax that is provided with four pairs of legs. In addition to Araneae, other members of the class Arachnida are Amblypygi (tailless whip scorpion), Ricinulei (ricinuleid), Pseudoscorpiones (false scorpion), Acari (acarid), Scorpiones (scorpion), Solifugae (sunspider), Opiliones (daddy longlegs), Palpigradi (palpigrade), Uropygi (whip scorpion). The order Araneae which are known as spiders are ideal for studying the interactions between organisms and their habitats because of their recognised sensitivity to structural and environmental changes (Wise, 1993).

### 1.1.2 External Morphology of Spiders

The external morphology of order Araneae is well illustrated by Sebastian and Peter (2009). A narrow pedicel connects the two separate cephalothorax and abdomen that together make up a spider's body. The sternum covers the cephalothorax ventrally and the carapace dorsally. The labium and the frontal border of the sternum articulate movably. There is a deep transverse groove that, with very few exceptions, forms a type of hinge between the labium and sternum. Between the lateral borders of the carapace and the sternum, the legs are articulated in the pleural membrane. There are six to eight simple eyes on the cephalic area. In general, there are two types of eyes: white or nocturnal eyes and black or diurnal eyes. In contrast to heterogeneous conditions, which involve the presence of both types, homogeneous conditions only exhibit one type. Usually, there are two rows of eyes—the anterior row and the posterior row. There are typically four eyeballs in each row. Often, the rows of eyes are curved. The eyes are referred to as anterior medians, posterior medians, anterior laterals, and posterior laterals depending on where they are located. If the curvature is oriented forward, the row is termed procurved, and if it is directed backward, the row is called recurved. The region of the skull that supports the eyes is called the ocular area. The term "ocular quadrangle" refers to the region bounded by the four median eyes. The clypeus is the region between the anterior border of the carapace and the anterior row of eyes. The thoracic groove, a dip in the middle of the thoracic area, is frequently seen.

Araneae family consist of six pairs of appendages on the cephalothorax. The chelicerae are the first pair. At the tip of each chelicera is a curved fang. The chelicera's inner surface may include a groove that can be used to enclose the resting fang in addition to being delicately denticulate. Additionally, this groove may have teeth on both sides; the inner margin is known as retromargin, while the outside margin is known as promargin. The second set of appendages are called pedipalps, and they are composed of six segments: coxa, trochanter, femur, patella, tibia, and tarsus. In females, the tarsus is

simple and may not have a single claw. Mature men have a modified tarsus of palp that functions as a complicated copulatory organ known as the palpal organ. When it comes to both generic and specific spider identification, the anatomy of the adult male palp is important. The four pairs of legs are numbered I, II, III, and IV, in that order. Every leg consists of seven segments. The legs are coated with several forms of hair, bristles, and spines. The tarsus has two or three claws at the end. The terms "ventral spines" and "dorsal spines" refer to the two types of spines found on the legs, respectively. The alimentary canal opens from a noticeable anal tubercle at the posterior end of the abdomen. The most remarkable characteristics of a spider are found underneath the anal tubercale: the spinnerets, which are used for producing the spider's snare or thread. The spinnerets have a shape similar to a finger and are typically six in number; however, they can be reduced to one pair or even two. Pairs of spinnerets called the first or anterior, second or middle and third or posterior pairs. The colulus is a tiny, somewhat useless appendage located in the space between the bases of the anterior spinnerets. It is often pointy and thin, although in other spider species, it can have a more flattened look. One or two pairs of book lungs and one or two pairs of spiracles are located on the ventral surface of the abdomen. The epigynum, sometimes called the epigastric furrow, is the female genital organ and is located just in front of the transvers fold. A sclerotized plate or a group of plates known as the lorum, covers the pedicel. Certain lycosid and pisaurid spiders may be distinguished from one another by the form of these plates (Patil, 2018).

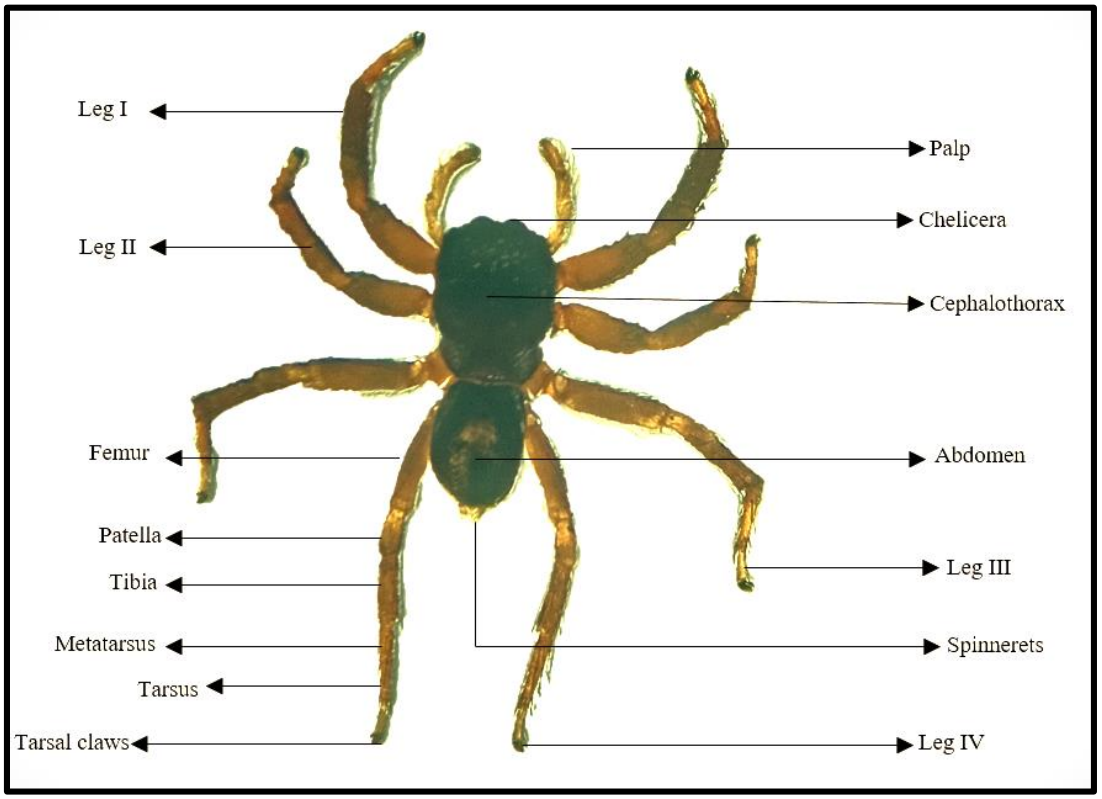


Figure 1.1: External Morphology of Spider

### 1.1.3 Spiders Guild Structure

The two main categories of spiders can be distinguished based on how they catch prey: (1) Web-building spiders, which create webs in unaltered environments to catch prey; they lie in or close to the web, wait for the prey to approach, and rely on vibrations in the web to sense the presence of prey; and (2) hunter spiders, which, in contrast to web-building, rely on speed and vision to pursue and catch prey. They can be either active hunters, searching for and pursuing their prey, or passive hunters, waiting to seize the prey as it gets close (Singh et al., 2023). Based on their hunting habits, spiders have been divided into various guilds in various ecosystems, made up of various spider groups (Cardoso et al., 2011). These spider guilds are given below:

a. **Orb web weavers**: The most prevalent group of spiders that create spiral, wheel-shaped webs that are frequently discovered in fields, gardens, and forests are the orb-weaver spiders. The majority of the members of the Araneidae and

Tetragnathidae families, for instance, have a rounded shape that is the source of their common name. The spiders secrete silk threads, which are used to make these orbs. The orb web's main job is to catch, halt, and hold onto prey so the spider can eventually catch it. Although these webs are nearly impervious to injury, the spiders constantly fix any harm that the prey causes. These silk threads are incredibly ductile and strong. But its topology determines how well the structure performs upon impact, and the way the various silk threads are arranged within the web also matters (Soler & Zaera, 2016).

b. **Hunters or stalkers**: Spider families that do not spin webs have alternative strategies to hunt and seize their prey, including aggressively stalking, sitting motionless (such as Oxyopidae and Salticidae members), or using camouflage (such as Philodromidae members). When hunting, members of the Salticidae family approach their prey cautiously before leaping upon it. One variety of these spiders even spits a substance that resembles glue in order to immobilise and ensnare its victims, *i.e.*, Scytodidae members.

c. **Ground runners**: These spiders spin silk, much like orb web weavers do, but they don't make any form of web, so they can't trap prey inside. Instead, they follow their prey as they hunt along the ground. They may hunt enormous, possibly dangerous animals, which they use their silk to restrain. These spiders attempt to entangle their victims in a wrap while hunting by secreting thick, sticky silk, which they often apply to their mouths and legs. The ground spiders can restrain proportionately huge prey while lowering their own risk of damage from their prey's attempts to fight back by immobilising potential prey in this way (Wolff et al., 2017).

d. **Foliage runners**: As suggested by their name, these spiders, which include members of the Clubionidae and Sparassidae families, spend the most of their time running on the leaves of plants.

e. **Space builders**: These spiders weave webs, but unlike orb webs, their structure is asymmetrical, trapping insects and making escape difficult. The spider delivers the deadly bite after swiftly covering its victim in silk. The prey might be preserved for subsequent use or consumed right away. Pholcidae family members are one example of this group.

f. **Ambushers**: Rather than creating webs to ensnare their victims, spiders in the Thomisidae family ambush or wait for unsuspecting insects to approach, grabbing them with their powerful, spiky, curled front legs, like the plant Venus flytrap.

### 1.1.4 Spiders in Agro-Ecosystem

Spiders play a significant role in ecosystems as predators; among all other invertebrates, they are considered the most abundant predators of insects in terrestrial ecosystems (Edwards et al., 1976). Mondal et al. (2020) reported that annually around 8 million metric tonnes of prey are consumed by spiders. They play an important role in the dynamics of specific habitats and are sensitive to climate change, habitat loss, and environmental turbulence (Chetia & Kalita, 2012) and as such can play an important role as ecological indicators. As spiders are obligate predators, they must consume other creatures in order to receive the energy necessary to survive. Insects are the most common food type for spiders, although they may also feed on other spiders and, in rare cases, vertebrates. It is estimated that one spider can eat as many as 2000 insects in one year (Walker, 2010). As generalist consumers, many spiders play an important role in each of the communities they are found in by regulating the density of organisms across multiple trophic levels. Spiders are among the most significant invertebrate predators in many ecosystems due to their abundance and diversity of food sources.

It is clear that spiders have important ecological roles in maintaining a healthy and stable community. Agricultural pests directly reduce crop yields by feeding on the plants, robbing their fruit/seed output that we harvest for food. By consuming a range of pests, such as aphids, grasshoppers, leafhoppers, beetles, and caterpillars, spiders indirectly help people (Maloney et al., 2003). India has a rich and diverse spider fauna, with over 1984 spider species documented so far (indianspiders.in). India's spider population is diverse, but research on them is still lacking, and many species are yet unknown (Majumder et al., 2020). The value of spiders in conservation is becoming more widely acknowledged, as evidenced by initiatives to catalogue their diversity and name certain species as flagship species for conservation.

When the density of a specific pest insect is low, spiders may easily survive. Because of this, spiders are able to establish themselves in their environments before pest populations have a chance to develop exponentially, which may help reduce pest populations through spider predation (Roince et al., 2013). Spiders are known to have non-consumptive impacts on pest communities, in addition to directly feeding on pest insects (Rendon et al., 2016). There are also significant considerations that need to be made when evaluating the ability of spiders to minimize pests. For instance, it has been demonstrated that spiders benefit from their cannibalistic tendency to eat both other helpful arthropods and other spiders (Michalko et al., 2020).

The current study intends to highlight the significance of spiders to the agro-ecosystem in Amona, Goa, as well as to describe the diversity of spiders in the area.

## 1.2 OBJECTIVES

i. To identify and document the Spider diversity in Agro-ecosystem.

ii. To evaluate the abundance and distribution of spiders in Agro-ecosystem.

iii. To study web structure of spider found in Agro- ecosystem.

# 2. LITERATURE REVIEW

Over the span of decades, many researchers have worked on the spiders in different arrays of field studies. Since the 18th century, naturalists have been interested in the distribution, quantity, and variety of spiders in many regions of the world (Sumesh, 2021). Many researchers carried out extensive studies on the variety of araneofauna in different countries. Namkung (2003) conducted research on Korean spiders. In the year 1987, Tikader explored the spiders of the Indo Pakistan sub-continent. Biswas (1987) described the spiders of Odisha. A phylogenetic and comparative system of classification for cribellate spiders was developed by Lehtinen in 1967. An overview of spiders from throughout the world has been given by Preston-mafham and Preston-mafham (1984). In 1993, Wise emphasized the significance of spiders in ecological webs. Gibson et al. (1992) examined how succession and grazing management affect spider assemblage changes.

Nyffeler and Sunderland (2003) carried out a spider study in agroecosystem in Europe and found that spiders contribute in controlling pest population. The spider diversity of tropical habitats was studied by Pinkus-Rendon et al. (2006) and revealed that habitat complexity and structure, influences the spider diversity and species composition. Habitats with structural complexity, like deciduous forests and coffee plantations, had greater spider diversity than those with lower complexity. Isaia et al. (2006) found that spider species diversity in vineyards is relatively high compared to other European agroecosystems. The study found that landscape heterogeneity, particularly woods, is a significant environmental factor influencing spider assemblages in vineyards. Refuge areas, such as woods, provide habitats for spider diversity in agroecosystems.

India is home to a rapidly increasing number of spider species from 1067 species (Tikader, 1987), 1442 species (Siliwal et al., 2005), 1520 species (Sebastian & Peter, 2009), 1686 species (Keswani et al., 2012) to 1852 species (Caleb & Sankaran, 2021). Presently, India is represented by 1984 species, spread across 501 genera and 62 families, (indianspiders.in). Biswas and Biswas (2004) made an important contribution to the variety of spider species by providing complete lists of newly discovered spider species from West Bengal and Manipur. The 34 species of spiders from 12 families and 27 genera were identified by Dhali et al. (2011) in Corbett National Park. According to Biswas and Biswas (2010), the state of Uttarakhand is home to 127 species of spiders divided into 49 genera and 17 families. 163 samples in all were gathered, and the results show that 63 species representing 38 genera under 10 families were present, with 2 species remaining unidentified. Of these ten families, the Araneidae family was found to have the most variety, followed by the Gnaphosidae, Thomisidae, Lycosidae, and Oxyopidae families.

Rithe (2012) conducted a study on the diversity of spiders in the relocated area of Melghat Tiger Reserve. The study recorded 254 species of spiders from Koha, Kund, and Bori meadows, representing 113 genera and 27 families. The study concluded that the relocation of three villages had a positive biological impact on habitat recovery. Diversity and distribution of spiders from Gibbon Wild Life Sanctuary, Assam was studied by Chetia and Kalita (2012). The spider fauna of Raigarh, Chhattisgarh's Indra Vihar Park was examined by Ekka and Kujur (2015). In 2015, Adarsh and Nameer studied the spider population at the Kerala Agricultural University campus in Thrissur, Kerala. The Mannavan shola forest in Kerala was the subject of an initial investigation on spider biodiversity by Sudhikumar et al. (2015). A total of 72 species from 20 families and 57 genera were gathered. In the Kerala area of the Western Ghats, Pradeep (2018) discovered 70 species of ground dwelling spiders from 48 genera and 20

families. In 2009, Hore examined the variety of spiders in the Terai Conservation Area, finding 186 species in all, spread among 77 genera and 27 families.

Tyagi et al. (2019) made the initial attempt at molecular taxonomy of Indian spiders. A total of 101 morphospecies from 72 genera in 21 families, including three holotypes and five endemic species, were found in this research. After creating and analyzing 489 barcodes, they were able to extract 85 unique barcodes representing 22 morphospecies, which they then added to the worldwide database. An updated list of yellow sac spiders (Cheiracanthiidae) found in Indian states and Union territories was published by Singh et al. (2020). The 38 species belonging to two genera were included in the checklist of these often-seen yellow sac spiders in India.

In 20$^{th}$ century, many researchers conducted a study on agroecosystems. Sudhikumar et al. (2005) investigated the spider population and seasonal variations and results showed slight differences in spider abundance and composition between the Rabi and Kharif seasons. In Gujarat and Tamil Nadu's rice fields, the spider fauna was studied by Kumar and Shiva Kumar (2006). Chapke (2012) conducted a study on spider fauna in agroecosystem of Washim district of Maharashtra and recorded 11 families, 30 genera, and 65 species, with Salticidae being the most prevalent, followed by Araneidae and Thomisidae. Solanki & Kumar (2015) recorded 67 species belonging to 43 genera of 17 families from five different crops in agro-ecosystem and founds that the Araneidae and Salticidae were the most abundant and dominant family. Lawania and Mathur (2017), studied a forest and agriculture fields of Eastern region of Rajasthan revealed spider diversity in the eastern region, revealing 51 species from 40 genera in 17 families. The spiders were grouped into seven feeding guilds, with Araneidae and Salticidae showing the most diversity. John and Tom (2018), studied in Kottayam, Kerala, involving 17 spider species from six families.

Lawania and Mathur (2015), conducted a study to identify six types of spider web patterns (irregular web, sheet webs, funnel web, orb web, single-line web, and dome-shaped horizontal webs) in Eastern Rajasthan and found that these webs resemble patterns reflected by flowers in UV light. The most common type is the orb web, and the study aims to understand spider web behavior and survival strategies to help conserve them and in the year 2017, they both studied a forest and agriculture fields of Eastern region of Rajasthan and revealed spider diversity in the eastern region. The spiders were grouped into seven feeding guilds, with Araneidae and Salticidae showing the most diversity. Spiders are abundant insectivorous predators in terrestrial ecosystems, influencing the population dynamics of other arthropods. They play a crucial role in insect pest control without harming agro-ecosystems. Spiders regulate insect pests by feeding on insects and other prey, reducing pesticide use and increasing productivity. Vairale (2017) recorded 143 spider species in Sangrampur Tahsil, District Buldhana, and found that spiders are beneficial bio-control agents of insect pests in agro-ecosystems. The Pandit Jawaharlal Nehru College of Agriculture and Research Institute in Karaikal studied spider biodiversity in an agroecosystem and 30 spider species were observed, with various biodiversity indices computed (Raghu & Kumar, 2021)

In Goa, Halarnkar and Pai (2018), examined spider diversity in two habitats, Akhada, St. Estevem, an island, and Tivrem-Orgao, as plantation area in Goa, India. A total of 1058 and 1339 spiders were observed at site 1 and site 2 respectively. Distribution and occurrence of spiders are influenced by environmental parameters, habitat type, vegetation structure, and anthropogenic activities. Singh & Singh (2022) updated the spider diversity checklist in Goa and identified 173 spider species from 128 genera, 23 families, and 32 species up to the generic level. The majority are Araneidae, followed by Salticidae, Thomisidae, Theriidae, and Tetragnathidae.

# 3. MATERIALS AND METHOD

## 3.1 STUDY AREA

The study was conducted during the period of September 2023 to March 2024 in the agriculture fields of Amona village which is located in the Bicholim taluka. It lies between latitudes 15°32'10.07"N and longitudes 73°58'41.70"E in the North district of Goa. Amona covers the 268 hectares' area. The area was chosen for its diverse agricultural cultivation. It is covered by greenery providing shelter to various animals. It is at the base of Mandovi river. Goan farmers mostly grows two crops per year *viz*, Rabi (10543 ha) and Kharif (25841 ha) crops of which total 36,384 ha area land under the crop (Anonymous, 2018-19).

The village is a hub of agricultural activities, with locals cultivating during Rabi and Kharif crops and yields various crops like cashew, egg plants, lady finger, watermelon, chilies in their fields. The area contains many mangroves, banana, mango, jungle berries, coconut trees and open long stretches of fields on all sides. Apart from birds many other organisms like wild pigs, monkeys, porcupine, monitor lizards, cobras, vipers, crocodiles are also observed here**.** Rice is planted throughout the monsoon season, while a range of vegetable crops, including as spinach, red amaranth, radish, and chillies, are grown after the monsoon. Being a part of agricultural landscapes and primary predators of crop-harming pests, spiders play an important role in preserving the well-being and efficiency of agricultural systems.

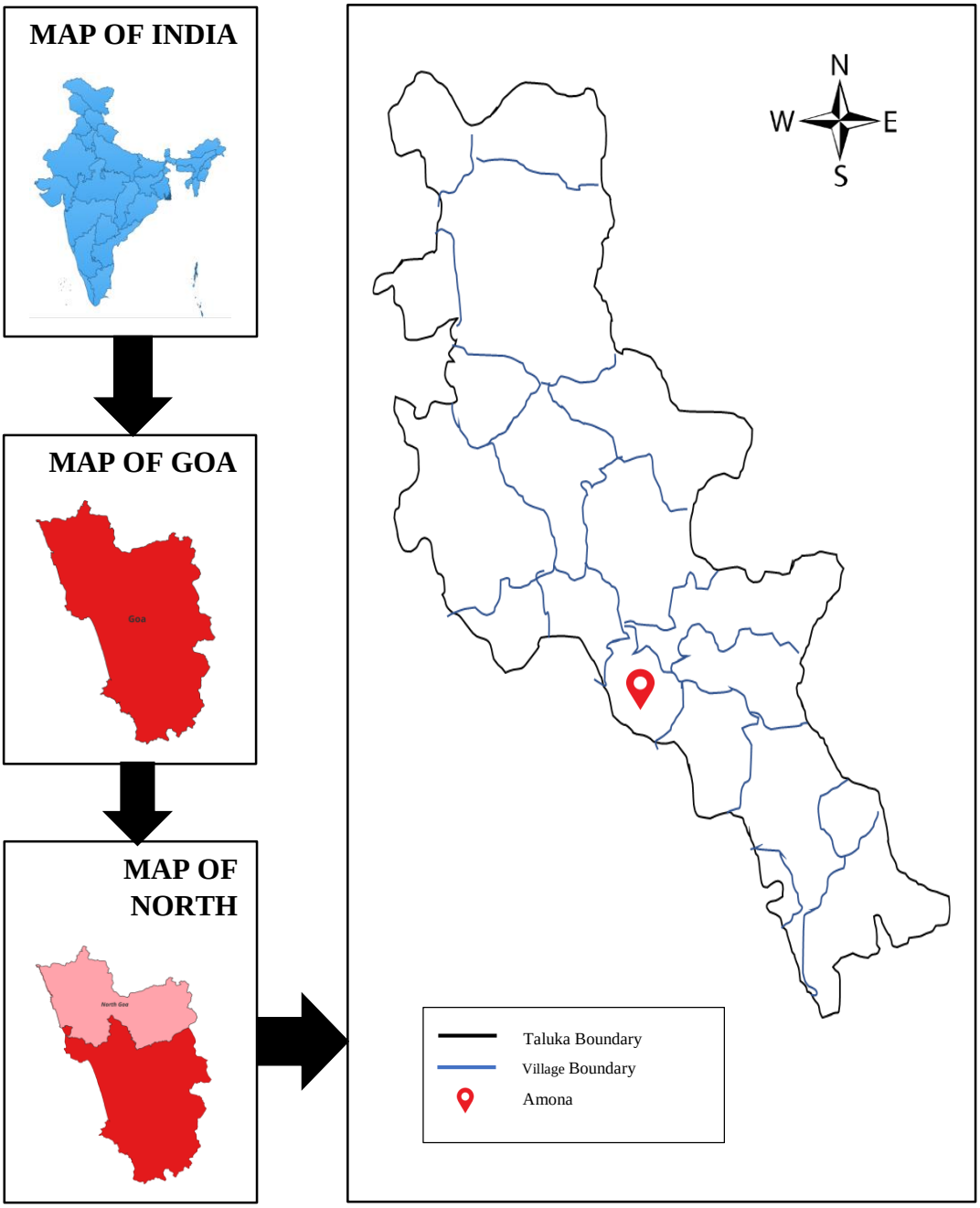


Figure 3.1: Map showing study area

## 3.2 METHODOLOGY

The methodology adopted for the present study is summarized below. Spider collection methods given by Sebastian et al. (2017) were used:

i. Visual Search Method:

The visual search method is one of the simplest and most widely used methods of gathering spider samples. This method, as its name implies, involves physically looking for spiders in their native environment. When sampling ground-dwelling or easily observed spiders, this technique tends to be helpful. Because the visual search approach is a non-destructive sample technique, neither the spiders nor their habitat will be harmed during the capture and release process. Researcher usually walks within the environment and visually scan the area to look for spiders in order to conduct a visual search. Because of their small size and frequently cryptic color, spiders can be challenging to notice, so this method requires patience and an excellent eye. It doesn't require specialized equipment and is reasonably inexpensive.

ii. Handpicking Method*:*

Best method to collect spiders is by hand. A soft paintbrush can be used to gently knock the specimen into a collecting vial. The specimens can also be carefully picked by hand. Turning over stones and logs exposes many spiders and hand collecting is the convenient method.

iii. Beating Method

The beating method is a sample technique where spiders and other arthropods are removed by beating vegetation or other surfaces with a stick or net. Spiders that reside in plants can be sampled very well with this method. In order to apply the beating method, researchers usually place a tray or beating sheet beneath a patch of plants or another surface and then beat the plants using a stick or net.

The displaced arthropods and spiders then land on the tray or beating sheet, where they are readily gathered. In a comparatively short amount of time, a wide area can be sampled using this method. However, collecting samples from highly mobile or burrow-dwelling spiders may not be a good use for this technique.

iv. Leaf litter sampling:

One way to gather spiders from the forest floor is to sample the leaf litter. The process of using this method includes gathering leaf litter, which is made up of fallen leaves, twigs, and other organic materials. This technique is very helpful for gathering ground-dwelling spiders that are hard to see with the naked eye. Due to their excellent camouflage, many spider species live their entire lives on the forest floor and are hard to identify with the human eye. Researchers can get a more accurate picture of the spider community in a certain habitat by gathering leaf litter. Usually, leaf litter sampling involves gathering multiple leaf litter samples from various study site locations. After that, the samples are brought to the lab for sorting and species identification.

## 3.3 PRESERVATION

To collect and preserve spider ethical permission bearing IAEC Approval Reference No. GUZ/IAEC/23-24/N30 has been taken. The specimens were preserved in 70% alcohol and were kept in small vial and were individually labelled.

## 3.4 STUDIES UNDER STEREOZOOM MICROSCOPE

The taxonomical study of spiders requires the observation of various morphological features like cephalothorax, eyes, sutures on cephalothorax, chelicerae, fangs, clypeus, maxilla, labium, sternum, legs along with their spinations, abdomen, spinnerets,

cribellum and the observations on genitalia are significant for family, generic and species level identification. The Model No. LEICA MZ125 and SZM-100 stereo zoom binocular microscope with high resolution USB digital camera was utilised for observations and identification.

## 3.5 IDENTIFICATION

The collected specimens of spiders were identified using standard literatures, field guide books, field guide experts used were Gajbe (2008), Mondal et al. (2020), Sebastian and Peter (2017), Tikader (1980), Tikader (1982a), Tikader (1982b), World Spider Catalog (2024). The taxonomy and nomenclature is followed as per World Spider Catalog (2024),

## 3.6 STUDY OF WEB STRUCTURE

The ability to produce silk sets spiders apart from other arachnids. Six silk glands, which are found underneath the abdomen's posterior region, create silk. diverse types of spiders have diverse web constructions to help them survive in their surroundings. In order to catch their prey and devour it in the morning, the majority of spiders weave their webs in the evening or at night. At the time of searching or collection of spiders the web patterns were also observed.

## 3.7 DATA ANALYSIS

A diversity index is a quantitative indicator of species variety in a particular community that is based on species richness (the total number of species present) and species abundance (the number of individuals per species). A region with a greater diversity index has a larger number of species. From the identified and recorded spiders'

numbers, Shannon-Weiner diversity index (H) was calculated using Shannon-Weiner equation and the dominance index that is Simpson index (C) was calculated.

**1) Shannon-Weiner Species Diversity Index (H)**

The Shannon-Weiner Species Diversity Index was calculated by multiplying the proportion by the natural log of the proportion for each species, taking the amount of each species and its percentage of the total number of individuals. Given that the value was negative, the following step included taking the negative of the negative of that total. The diversity of species increased with increasing numbers. The range of the index values is 0.0 to 5.0. Rarely do the results exceed 4.5, usually falling between 1.5 and 3.5. A number above 3.0 denotes a stable and balanced ecosystem; a value below 1.0 denotes pollution and habitat destruction.

$$\mathbf{H} = -\sum_{i=1}^{S} \frac{n_i}{N} \ln \frac{n_i}{N}$$

Where, H = Shannon-Weiner Diversity Index

$n_i$ = Number of individual of $i^{th}$ *species*

$N$ = Total number of individuals in the sample

**2) Shannon Equitability Index**

The Shannon diversity index divided by the maximum diversity gives the Shannon equitability index (EH), often known as the evenness index. The value of equitability is assumed to be between 0 and 1, where 1 represents total evenness or it means individuals are distributed equally.

$$\mathbf{E_H} = \frac{H}{ln(S)}$$

Where, $E_H$ = Shannon Equitability Index

$H$ = Shannon-Weiner Diversity Index

$S$ = Number of species or Species richness

**3) Simpson's Index of Dominance**

A measure of diversity called Simpson's Diversity Index considers both the total number of species and the relative abundance of each species. Variability rises with species richness and evenness. Simpson provided a possibility that any two people selected from an observably large group of different species living in the same location. The range of index value is between 0 and 1. A number 0 denotes infinite diversity and 1 denotes no or lower diversity.

$$\mathbf{D = \sum_{i=1}^{s} p_i^2}$$

Where, D = Simpson's Dominance Index

$p_i^2$ = Probability of *$i^{th}$ species* (i.e. $p_i = \frac{n_i}{N}$ )

- **Simpson's Index of Diversity is calculated as 1 – D.** In this index value is between 0 to 1 but here greater the value, the greater will be sample diversity.

**4) Margalef Diversity Index**

A community's richness can be evaluated by the Margalef index, which considers both the overall number of species and the number of species that are present. It varies according to the number of species and has no maximum or minimum.

$$\mathbf{d = \frac{(S-1)}{\ln S}}$$

Where, d = Margalef Diversity index

S = total number of species

N = total number of individual

(a)

(b)

(c)

(d)

Figure 3.2: Methods of Spider sampling used in study area

(a) Hand picking, (b) Leaf litter sampling, (c) Visual search, (d) Beating method

# 4. ANALYSIS AND CONCLUSION

## 4.1 RESULT

### 4.1.1 Spider diversity in Agro-ecosystem

In this present study conducted at Agro-ecosystem of Amona, a total of 38 species of spiders were documented (Table 4.1). This species value is close to 21% of the known Araneae species in Goa (Singh & Singh, 2022). These 38 species belong to 11 families and 29 genera which respectively comes to 47% and 22% of Araneae families known from Goa (Singh & Singh, 2022).

Table 4.1.1: Checklist of Spiders identified in Agro-ecosystem

| Serial No. | Species Name | Family | Guilds |
|---|---|---|---|
| 1 | *Araneus sp.* | Araneidae | Orb Weavers |
| 2 | *Argiope aemula* (Walckenaer, 1841) | Araneidae | Orb Weavers |
| 3 | *Argiope anasuja* Thorell, 1887 | Araneidae | Orb Weavers |
| 4 | *Argiope pulchella* Thorell, 1881 | Araneidae | Orb Weavers |
| 5 | *Argiope versicolor* (Doleschall, 1859) | Araneidae | Orb Weavers |
| 6 | *Cyrtophora sp.* | Araneidae | Orb Weavers |
| 7 | *Neoscona bengalensis* Tikader & Bal, 1981 | Araneidae | Orb Weavers |
| 8 | *Neoscona mukerjei* Tikader, 1980 | Araneidae | Orb Weavers |
| 9 | *Nephila kuhli (Doleschall, 1859)* | Araneidae | Orb Weavers |

| | | | |
|---|---|---|---|
| 10 | *Parawixia dehaani* (Doleschall, 1859) | Araneidae | Orb Weavers |
| 11 | *Hersilia savignyi* Lucas, 1836 | Hersilidae | Foliage runners |
| 12 | *Hippasa agelenoides* (Simon, 1884) | Lycosidae | Ground runner |
| 13 | *Lycosa mackenziei* Gravely, 1924 | Lycosidae | Ground runner |
| 14 | *Lycosa sp.* | Lycosidae | Ground runner |
| 15 | *Pardosa sp.* | Lycosidae | Ground runner |
| 16 | *Pardosa sumatrana* (Thorell, 1890) | Lycosidae | Ground runner |
| 17 | *Oxyopes birmanicus* Thorell, 1887 | Oxyopidae | Diurnal runner |
| 18 | *Oxyopes hindostanicus* Pocock, 1901 | Oxyopidae | Diurnal runner |
| 19 | *Oxyopes javanus* Thorell, 1887 | Oxyopidae | Diurnal runner |
| 20 | *Pholcus sp.* | Pholcidae | Space builders |
| 21 | *Dendrolycosa gitae* (Tikader, 1970) | Pisauridae | Ambushers |
| 22 | *Hygropoda sp.* | Pisauridae | Ambushers |
| 23 | *Bianor sp.* | Salticidae | Ambushers |
| 24 | *Carrhotus viduus* (C. L. Koch, 1846) | Salticidae | Ambushers |
| 25 | *Epocilla sp.* | Salticidae | Ambushers |
| 26 | *Hasarius adansoni* (Audouin, 1826) | Salticidae | Ambushers |
| 27 | *Hyllus semicupreus* (Simon, 1885) | Salticidae | Ambushers |
| 28 | *Icius alboterminus* (Caleb, 2014) | Salticidae | Ambushers |
| 29 | *Menemerus bivittatus* (Dufour, 1831) | Salticidae | Ambushers |
| 30 | *Menemerus sp.* | Salticidae | Ambushers |

| | | | |
|---|---|---|---|
| 31 | Plexippus paykulli (Audouin, 1826) | Salticidae | Ambushers |
| 32 | *Heteropoda venatoria* (Linnaeus, 1767) | Sparassidae | Foliage runners |
| 33 | *Olios sp.* | Sparassidae | Foliage runners |
| 34 | *Leucauge sp.* | Tetragnathidae | Orb weaver |
| 35 | *Tetragnatha sp.* | Tetragnathidae | Orb weaver |
| 36 | *Tylorida ventralis (Thorell, 1877)* | Tetragnathidae | Orb weaver |
| 37 | *Nesticodes rufipes* (Lucas, 1846) | Theridiidae | Space web weaver |
| 38 | *Thomisus sp.* | Thomisidae | Aerial ambushers |

Taxonomic characters of spider families collected from the Agro-ecosystem are described below. The descriptions of family given by Sumesh (2021) and the World Spider Catalog (2024) were followed:

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

Cephalothorax is often flat and varies; the cephalic area is often divided from the thoracic region by an oblique depression, with a conspicuous or non-existent fovea. There are two rows and eight eyeballs. Size and variety differ very little throughout species; medians form a trapezium or square-shaped quadrangle; laterals are typically closed and frequently protrude on angular tubercles. The sternum is heart-shaped or triangular, and it narrows behind, making Coxae IV almost continuous. Wide labium with a rebordered, enlarged distal margin. Maxillae are typically not longer than broad and are widest distally. Having three tarsal claws and auxiliary foot claws, trichobothria on all leg segments except the tarsi, and a fang furrow equipped with two rows of

powerful teeth covered in hair and spines, the chelicerates are robust, vertical, and non-divergent. Abdominal size and form vary; it is often globose, draping over the cephalothorax, and frequently has a unique pattern and humps on the dorsum covered with serrated setae. Six simple spinnerets with a colulus and aggregate silk gland spigots. The epigyne complex is made up of an epigynal plate with a transverse furrow that is either fully or partly sclerotized and frequently has a scapus. Female pedipalps have a single claw; males have a palpable complex. The bulbus rotates within the cymbium, the paracymbium is often connected to the proximal end of the cymbium, and it contains a sclerotized hook.

This family has several species that are frequently found in a variety of environments, and the majority of them build excellent orb webs to trap food. They tame their victim with the "spin-wrap-attack" technique. As sit-and-wait predators, spiders hang head down in their webs, and the web may be thought of as their home range. The overall form, quantity of radii, spirals, hub shape, and web decorations differ throughout genera and subfamilies. A few spiders use stability to adorn the web. Web design may be influenced by the spider's weight and size as well as the website.

Table 4.1.2: List of Genera and Species in family Araneidae

| | Genera | Species |
|---|---|---|
| World | 191 | 3132 |
| India | 34 | 192 |
| Goa | 20 | 41 |
| Amona | 6 | 10 |

## i. Genus *Araneus* Clerck, 1757

Description: The carapace of the *Araneus* genus is rather convex and devoid of hairy outgrowths. Colors range from cream to brown to black, and dorsally they typically have unique patterns. The eyes are arranged in two rows, with the central ocular quadrangle creating a trapezium and the lateral eyes almost continuous and typically positioned on conspicuous tubercles. The median eyes are typically longer than the wide ones. Typically, the abdomen has an oval or triangularly oval shape, is elevated at the anterior, and is broader than long. Male pedipalps have big, spiky patella and terminal apophysis.

Species recorded in present study are described below:

### *Araneus sp.*

Key Characters: The cephalothorax is slender in front, longer than it is broad, and covered with hairs and pubescence. The thoracic area has longitudinal grooves, chelicerates have long, robust legs covered with fur and spines (Figure 4.1.1 (a)).

Distribution: Assam, Bihar, Chhattisgarh, Goa, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, Uttarakhand

## ii. Genus *Argiope* Audouin, 1826

Description: The huge size and brightly coloured abdomens of members of the genus *Argiope* make them clearly identifiable. Males are relatively little, and females are larger than 9 mm. The cephalothorax is very flat and covered in a thick coating of pubescence. The two rows of eyes form a trapezium with the ocular quadrangle being longer than broad and wider posteriorly. The posterior row of eyes is significantly procurved, with anterior lateral eyes being smaller than posterior laterals, lateral eyes

closing, and the lateral eyes resting on prominent tubercles. Chelicerae has a tiny boss, is feeble, and is little. Strong and long legs, with a tibia and patella combined length that is less than the tarsus and metatarsus combined. Usually flat and varying in form, the abdomen is frequently scalloped around the edges and adorned with darker bands.

Species recorded in present study are described below:

### *Argiope aemula* (Walckenaer, 1841)

Key Characters: Chelicerae have a tiny boss and are feeble and small in size. Strong, lengthy legs covered with fur and spines. Labium has a golden colour and is longer than broad. The ventral section resembles a Christmas tree and has a grey border with yellow on each side (Figure 4.1.1 (b)).

Distribution: Andaman & Nicobar, Andhra Pradesh, Assam, Bihar, Chhattisgarh, Goa, Gujarat, Haryana, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Odisha, Punjab, Rajasthan, Tamil Nadu, Telangana, Uttar Pradesh, Uttarakhand, West Bengal

### *Argiope anasuja* Thorell, 1887

Key Characters: The cephalothorax has a thick covering of white pubescence with sporadic yellowish spots, and it is somewhat longer than broad. It is gray in colour. outer ring of darkness surrounding the posterior median eyes. Chelicerae are tiny and have a reddish-brown hue. The abdomen is quite large and pentagonal. The ventral side is dark brown in colour, while the dorsal side is chalk white with three pairs of segillae and brown transverse stripes (Figure 4.1.1 (c)).

Distribution: Andhra Pradesh, Assam, Bihar, Chhattisgarh, Goa, Gujarat, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Puducherry, Rajasthan, Tamil Nadu, Telangana, Tripura, Uttar Pradesh, Uttarakhand, West Bengal

### *Argiope pulchella* Thorell, 1881

Key Characters: Compared to lateral eyes, median eyes are nearer to one another. Labium has a golden colour and is both long and broad. Maxillae have a rounded appearance. The chelicerae have a simple boss and are tiny and feeble, with a brownish colour (Figure 4.1.1 (d)).

Distribution: Andaman & Nicobar, Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chhattisgarh, Delhi, Goa, Gujarat, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Lakshadweep, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Odisha, Punjab, Rajasthan, Sikkim, Tamil Nadu, Telangana, Tripura, Uttar Pradesh, Uttarakhand, West Bengal

### *Argiope versicolor* (Doleschall, 1859)

Key Characters: The female's silvery hair covers her cephalothorax. The abdomen is pentagonal, with two longitudinal yellow stripes on the ventral side and yellow, white, and black bands on the dorsal side. There are white dots within the black bars. Dark bands highlight the orange legs (Figure 4.1.1 (e)).

Distribution: Puducherry, Tamil Nadu, Tripura

Remarks: **This species is reported for the first time from Goa**

## iii. Genus *Cyrtophora* Simon, 1864

Description: With white markings, the color varies from cream to black. Cyrtophora's carapace is hairless and almost flat. The ocular quadrangle is often a little broader than the length, with the lateral eyes being continuous, sub equal in size, and not resting on protruding tubercles. Legs are sturdy and of a decent length. Typically, the abdomen has a high anterior end with conspicuous paired tubercles, and it is longer than broad.

Species recorded in present study are described below:

### *Cyrtophora sp.*

Key Characters: The cephalothorax is large and broad, with brown stripes and patches. Legs are black in colour, covered with hair. The dorsal side of the long, broad, black abdomen has conical tubercles (Figure 4.1.1 (f)).

Distribution: Bihar, Chhattisgarh, Gujarat, Jammu &, Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Tamil Nadu, Uttar Pradesh, Uttarakhand

## iv. Genus *Neoscona* Simon,1864

Description: The cephalothorax of the genus *Neoscona* has a longitudinal thoracic groove. The median ocular quadrangle forms a trapezium because it is somewhat longer than broad. The diameter of anterior median eyes is larger or almost equal to that of posterior median eyes. The smallest eyes are the posterior lateral eyes. The form of the abdomen can vary and might be ovoid, subovoid, triangular, or subtriangular. Simple and tongue-like is epigynum.

Species recorded in present study are described below:

### *Neoscona bengalensis* Tikader & Bal, 1981

Key Characters: Reddish-brown in colour, the cephalothorax is longer than white and covered with hair. The anterior median eyes are bigger than the black ones, and both rows of eyes are recurved. The sternum has a heart-shaped form, is brown in colour, and is covered in spines and hairs.

Distribution: Andhra Pradesh, Assam, Chhattisgarh, Goa, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Odisha, Punjab, Rajasthan, Tamil Nadu, Telangana, Uttarakhand, West Bengal

### *Neoscona mukerjei* Tikader, 1980

Key characters: The thoracic area has a deep longitudinal groove. Each lateral eye is located on a tubercle and is close together. Strong, yellowish, and with a modest boss, chelicerates are (Figure 4.1.2 (a)).

Distribution: Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chhattisgarh, Goa, Gujarat, Haryana, Jammu & Kashmir, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Odisha, Punjab, Rajasthan, Tamil Nadu, Telangana, Tripura, Uttar Pradesh, Uttarakhand, West Bengal

## v. Genus *Nephila* Leach, 1815

Description: The female *Nephila* is larger than the male. The female's tibia has a brush of bristles, and her first, second, and fourth pairs of legs are almost totally black. Cephalothorax is characterized by a convex cephalic region that is higher than the thoracic area and is typically accompanied by two posterior tubercles. The median ocular quadrangle is squares to somewhat wider in the posterior direction. Extremely lengthy and heavily spinulose legs. The total length of the tarsi and metatarsi is greater than the total length of the tibiae and patellae. The abdomen is long and oval in shape, with a black or blue posterior end and yellow speckles that blend into the yellow in the front.

Species recorded in present study are described below:

### *Nephila kuhli* (Doleschall, 1859)

Key Characters: There is a somewhat deep fovea in the thoracic area. Chelicerae have a reddish-brown colour, are robust and powerful, and have a district boss (Figure 4.1.2 (b)).

Distribution: Assam, Goa, Tamil Nadu, Uttarakhand, West Bengal

## vi. Genus *Parawixia* F. O. Pickard-Cambridge, 1904

Description: The *Parawixia* cephalothorax is thin in front, longer than broad, and covered with pubescence, hairs, and spines with granular bases. When seen from the front, the anterior row of eyeballs is procurved. The ocular quadrangle has anterior rows of procurved eyes and is somewhat broader in front. Typically, trapezoidal in form, the abdomen has acute tubercles at the front and end and noticeable shoulder hills. Simple, epigynum has a large scape that resembles a beak and is carried above a swelling base.

Species recorded in present study are described below:

### *Parawixia dehaani* (Doleschall, 1859)

Key Characters: Cephalothorax is longer than wide, narrowing in front, covered with white hairs, spines, pubescences with granular bases. Anterior rows of eye procurved in front and posterior row recurved from above. Sternum is heart shaped, pointed behind, reddish brown in colour (Figure 4.1.2 (c)).

Distribution: Andaman & Nicobar, Assam, Goa, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Odisha, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh, Uttarakhand, West Bengal

(a)

(b)

(c)

(d)

(e)

(f)

Figure 4.1.1: Family Araneidae (a) *Araneus sp.*, (b) *Argiope aemula* (Walckenaer, 1841), (c) *Argiope anasuja* Thorell, 1887, (d) *Argiope pulchella* Thorell, 1881, (e) *Argiope versicolor* (Doleschall, 1859), (f) *Cyrtophora sp.*

(a)

(b)

(c)

Figure 4.1.2: Family Araneidae (a) *Neoscona mukerjei* Tikader, 1980, (b) *Nephila kuhli* (Doleschall, 1859), (c) *Parawixia dehaani* (Doleschall, 1859)

## 2. Family: Hersilidae, Thorell, 1869 (Two tailed spider)

The flattened and ovoid cephalothorax has radiating striations and a small longitudinal fovea. It is heavily coated with plumose setae. On a huge tubercle are eight eyes arranged in two highly recurved rows. A greater anterior median than a posterior median. The anterior edge of the sternum is either straight or somewhat concave. Round-tipped, free labium; maxillae converge. Chelicerae are feeble, with a furrow with or without teeth, and a very tiny cheliceral fang. legs with trichobothria, a few spines, and three basic claws. In males with extremely lengthy legs, the patella-tibia joint has autopsy in the third leg. Flattened abdomen with a thick layer of plumose setae covering it, broader in back than in front. Longer than the abdomen, the posterior spinnerets are cylindrical, with extended and tapering apical segments, and have a colulus on the inner surface with a series of tubules that produce thin silk threads

These are energetic, fast-moving spiders that hunt. The remarkably large posterior lateral spinnerets of hersiliids, which are sometimes longer than the abdomen and occasionally nearly the whole body length—hence the term "two-tailed spiders"—are the most clearly identifiable characteristic of these spiders. They are able to lay quite close to the substratum without creating any shadows because to their flattened bodies. The spider detects when a little insect approaches because the insect activates those silk strands.

Table 4.1.3: List of Genera and Species in family Hersilidae

| | Genera | Species |
|---|---|---|
| World | 16 | 188 |
| India | 3 | 12 |
| Goa | 1 | 1 |
| Amona | 1 | 1 |

## i. Genus *Hersilia* Audouin, 1826

Description: With a pronounced high clypeus, the cephalothorax is flat, angular laterally, and somewhat wider than long. Legs I, II, and III have double segmented tarsi. The abdomen is round, almost round, and a little wider than long. The eyes' front and back rows are sharply recurved. The spinnerets on the posterior side are much longer than the abdomen. Separating the anterior pair of spinnerets is a distinct colulus.

Species recorded in present study are described below:

### *Hersilia savignyi* Lucas, 1836

Key Characters: Normally, Clypeus is quite tall and prominent. Maxillae are not straight. Segmented metatarsi II, III, and IV (Figure 4.1.3 (a)).

Distribution: Andaman & Nicobar, Andhra Pradesh, Bihar, Chhattisgarh, Delhi, Goa, Gujarat, Haryana, Jharkhand, Karnataka, Kerala, Lakshadweep, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Odisha, Puducherry, Punjab, Rajasthan, Tamil Nadu, Telangana, Tripura, Uttar Pradesh, Uttarakhand, West Bengal

(a)

Figure 4.1.3: Family Hersilidae (a) *Hersilia savignyi* Lucas, 1836

## 3. Family: Lycosidae, Sundevall, 1833 (Wolf spiders)

Longer than broad, thinner, and higher in the cephalic region, with an extended fovea and a densely setae-covered carapace; oval sternum  Eight eyes in three rows of four, two, and two; all dark in color and unequal in size; four small eyes in the anterior row, arranged in a straight or frequently slightly curved line; two large eyes in the second row, roughly the same width as the front row; and two eyes of intermediate size in the third row, on the anterio-lateral surface of the carapace, usually wider than the second row. Labium half the length of maxillae and as broad as long. Strong chelicerates with condyles and a toothed furrow. Trochanters are notched; legs are three clasped, typically with scopulae and spines. oval-shaped abdomen coated in thick layers of setae. Certain species have distinctive hairs covering their abdomens to help them carry their spiderlings on their mothers' bodies. The spines are made of typical kind without a colulus. Epigyne often exhibits a well-sclerotized median septum complex. Male palp with variable embolus and no tibial apophysis. The cocoons of the females are carried by the spinnerets. Often brown or gray in color, some have sandy hues with cryptically patterned abdomens, while some tiny species have colors ranging from brown to nearly black. These spiders are the most usual to come across in the wild since the majority of them are free-ranging, especially in unspoiled open spaces. Larger lycosids excavate underground tunnels.

Some of the smaller species don't create any webs at all, whereas others weave silken webs and retreats in the grass. Many tiny lycosid species' female members affix the egg sac to their spinnerets and transport them beneath their stomach. These egg sacs are frequently bigger than the female's abdomen and are frequently white or pale in color.

Table 4.1.4: List of Genera and Species in family Lycosidae

| | Genera | Species |
|---|---|---|

| | | |
|---|---|---|
| World | 133 | 2478 |
| India | 20 | 125 |
| Goa | 3 | 9 |
| Amona | 3 | 5 |

### i. Genus *Hippasa* Simon, 1885

Description: The apical component of the posterior spinneret is the same length as the basal piece, and the posterior spinnerets are longer than the anterior spinnerets. Carapace is longer than broad, with pale in the cephalic region, black streaks spreading toward the fovea, and sub marginal bands. The eyes' anterior rows are broader than their posterior rows. oval in shape and has dorsal patterns on it.

Species recorded in present study are described below:

#### *Hippasa agelenoides* Simon, 1884

Key Characters: Cephalothorax is elongated, elevated in the anterior region, and brownish. Legs are lengthy and covered with fur and spines. Longer and tapered in the back is the abdomen. The hairs on the abdomen are brownish-colored with tiny white patches (Figure 4.1.4 (a)).

Distribution: Assam, Andhra Pradesh, Arunachal Pradesh, Chhattisgarh, Goa, Gujarat, Jammu Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Meghalaya, Odisha, Punjab, Rajasthan, Tamil Nadu, Telangana, Uttar Pradesh, Uttarakhand, West Bengal

### ii. Genus *Lycosa* Latreille, 1804

Description: The carapace is nearly flat. In females, the ventral surface of the abdomen has a large black mark that is surrounded by a yellow, orange, or reddish patch that

contrasts starkly. The area around the black mark in male may appear paler. A thick field of setae covers the carapace's later edges. Compared to the posterior median eye row, the anterior eye row is shorter and more recurved.

Species recorded in present study are described below:

### *Lycosa mackenziei* Gravely, 1924

Key Characters: The cephalothorax is broad and extended. Dorsum at the base of the eyes, a little higher. Cephalothorax have thick, black fur and spines. Legs and pedipalps expanded (Figure 4.1.4 (b)).

Distribution: Arunachal Pradesh, Assam, Bihar, Gujarat, Haryana, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Meghalaya, Odisha, Punjab, Rajasthan, Telangana, Tripura, Uttar Pradesh, West Bengal

### *Lycosa sp.*

Key Characters: The cephalothorax has hairs and pubescence covering it, and it is longer than broad. Less space separates the front and posterior rows of eyes. Chelicerae have hairs all over them and are powerful.

Distribution: Assam, Chhattisgarh, Goa, Gujarat, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Rajasthan, Tamil Nadu, Telangana, Tripura, Uttar Pradesh, Uttarakhand, West Bengal

## iii. Genus *Pardosa* C. L. Koch, 1847

Description: The carapace is long and narrow, convex in the eye region, longer than wide, and covered in pubescence. Anterior procurved eye rows are often noticeably shorter than posterior median eye rows. Legs are either black or light, somewhat length,

and thin. The circular, mottled, greyish-brown abdomen has a white cardiac mark along its periphery, which is often followed by black chevrons going towards the back.

Species recorded in present study are described below:

### *Pardosa sp.*

Key Characters: Body is light brown to tansparent in colour. Carapace has lateral and median bands. They possess long legs with spines on foot than the rest species.

Distribution: Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chhattisgarh, Delhi, Goa, Gujarat, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Puducherry, Punjab, Rajasthan, Tamil Nadu, Tripura, Uttar Pradesh, Uttarakhand, West Bengal

### *Pardosa sumatrana* (Thorell, 1890)

Key Characters: The cephalothorax has two longitudinal black stripes that shorten in front and is longer than broad. The centre of the thoracic area contains the fovea. The oval, longer than broad abdomen is covered in pubescence and has patches of light and dark brown hair with black dots (Figure 4.1.4 (c)).

Distribution: Andaman & Nicobar, Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chhattisgarh, Goa, Gujarat, Haryana, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Punjab, Rajasthan, Tamil Nadu, Telangana, Tripura, Uttar Pradesh, Uttarakhand, West Bengal

(a)

(b)

(c)

Figure 4.1.4: Family Lycosidae (a) *Hippasa agelenoides* (Simon, 1884), (b) *Lycosa mackenziei* Gravely, 1924, (c) *Pardosa sumatrana* (Thorell, 1890)

## 4. Family: Oxyopidae, Thorell, 1869 (Lynx spiders)

With a broad clypeus and thin setae, the cephalothorax is wider than wide, elevated, and convex anteriorly before dipping posteriorly. It usually has noticeable markings and stripes. Clypeus is an extremely tall, vertical structure that typically has spots and stripes. A tiny region on the edge of the carapace is occupied by eight eyes arranged in two rows; the eyes form a hexagon with a strongly recurved anterior row and a slightly procurved posterior row. Compared to the anterior lateral eyes, the anterior middle eyes are significantly smaller. The labium is longer than broad, the maxillae are long and converge, and the scutiform sternum tapers between the coxae IV. Chelicerae have small teeth and are lengthy, tapering towards the distal end. Chelicerae have a short, armed margin that may be toothless or have one tooth on each side. Not as noticeable is the boss on the chelicerae's anterior lateral face. Long, three-clawed legs with noticeable spines; trochanters with shallow notches and no scopulae. belly tapering posteriorly and displaying bands or patches. The body might be brilliant green, dark brown, or yellowish brown in color. The epidermis is covered in tiny setae and occasionally has iridescent scales. Normal-type spines with a tiny middle pair and a present colulus. The structure of the epigyne complex differs between species, ranging from a semi-circular black rim encircling a shallow median depression to a deep pit in front with paired projections or a median depression with a projection resembling a scape. Male palpation exhibiting paracymbium and tibial apophysis.

Mostly spiders are frequently seen on green plants. The manner they hunt their prey has earned them the nickname "lynx spiders." hunters that hunt during the day or at night and have good vision to quickly identify their target. They hop from leaf to leaf as they travel about on plants. Legs are used to catch prey, and this is frequently accomplished by leaping several centimetres into the air to capture a flying insect or by making quick

hops to chase after prey that is flying over plants. The egg sac is either suspended in a tiny, asymmetrical web or attached to a twig or leaf. The female protects the eggs.

Table 4.1.5: List of Genera and Species in family Oxyopidae

| | Genera | Species |
|---|---|---|
| World | 9 | 446 |
| India | 4 | 91 |
| Goa | 4 | 8 |
| Amona | 1 | 3 |

## i. Genus *Oxyopes* Latreille, 1804

Description: Their colors range from dark brown to yellow-green. The sharply procurved posterior eyes row, spaced equally apart, is the defining feature of this species. The abdomen is long, thin, rounded, and broadest at the front before tapering all the way to the spinnerets. The cephalothorax is high and rounded, with the front half vertical. The face is nearly vertical. The ocular quadrangle has a longer width. Beginning at each of the anterior medians, a thin, black straight line descends the vertical face, through the centre of the chelicerate, and ends at the tip. Long and broad behind the base, the abdomen tapers to the spinnerets.

Species recorded in present study are described below:

### *Oxyopes birmanicus* Thorell, 1887

Key Characters: Clypeus has a dark brown patch on each side and is deep fawn at the outer angles. A little longer than the patella of legs I and the same breadth at the base as the femora I (Figure 4.1.5 (a)).

Distribution: Arunachal Pradesh, Assam, Goa, Gujarat, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Odisha, Punjab, Rajasthan, Tamil Nadu, Telangana, Tripura, Uttar Pradesh, West Bengal

## *Oxyopes hindostanicus* Pocock, 1901

Key Characters: The palpal morphology of males of the species is easily identifiable, as they have two different retrolateral patellar apophysis. From a lateral perspective, the distal apophysis is longer and resembles a beak, while the proximal projection is smaller, blunt, and finger-like. The morphology of the sclerotized epigynal plate, which has a large copulatory duct that is extensively sclerotized and a wide "V"-shaped depression at its anterior boundary, helps identify females (Figure 4.1.5 (b)).

Distribution: Assam, Chhattisgarh, Gujarat, Haryana, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Mizoram, Punjab, Rajasthan, Sikkim, Tamil Nadu, Telangana, Uttar Pradesh, Uttarakhand, West Bengal

**Remarks: This species is reported for the first time from Goa**

## *Oxyopes javanus* Thorell, 1887

Key Characters: Starting from each of the anterior medians and continuing down the vertical face is a thin black straight line. Broad, V-shaped, pale mark is called the dorsum. There are brownish spots on the lateral borders. Clypeus has two dark brown lines and is yellowish-brown in color (Figure 4.1.5 (c)).

Distribution: Andaman & Nicobar, Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Goa, Gujarat, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Odisha, Puducherry, Punjab, Rajasthan, Tamil Nadu, Telangana, Tripura, Uttar Pradesh, Uttarakhand, West Bengal

(a)

(b)

(c)

Figure 4.1.5: Family Oxyopidae (a) *Oxyopes birmanicus* Thorell, 1887, (b) *Oxyopes hindostanicus* Pocock, 1901, (c) *Oxyopes javanus* Thorell, 1887

## 5. Family: Pholcidae, Koch, 1850 (Cellar spiders)

The thoracic area has a deep median longitudinal fovea; the cephalic region is usually raised on the sides with deep striations; the clypeus is high and occasionally concave behind the eyes; the pedicel is dorsally curved like a "V" with two parallel or chitinous bands. The cephalothorax is short and wide, nearly circular. With the exception of the smallest or non-existent anterior medians and the huge rest that form two triads on each side, the carapace is filled with six or eight eyes. Labium united to sternum; sternum flat or slightly convex, extensively truncated posteriorly, broader than long. Chelicerae are weak, chelate, cylindrical, and have a tooth-like, translucent lamina or lobed cheliceral border. Extremely long, thin, frail, and slender legs with a flexible tarsus and a very short membranous onychium with three claws. big anal tubercle, triangular in form, well-developed epigastric area, and either globose or cylindrical to elongated abdomen. The front spinnerets are thick and cylindrical, with a little colulus separating them somewhat; the posterior spinnerets are conical, smaller, and compressed. Certain genera lack the tracheal spiracle. The female has a large, sclerotized region on the underside of her abdomen but no epigyne. The male tibia is huge and swollen, the tarsus is separated into two halves, and the palp complex is enormous with extremely little patella.

These spiders weave loose, tangled webs in a variety of patterns and are sedentary by nature. Some webs have lengthy, crisscrossing threads that make them irregular. Alternatively, the centre of the web may be made up of a huge, densely woven sheet with an uneven web of threads running through it above and below. The agglutinated clump of eggs is usually carried in the chelicerae of the females.

Table 4.1.6: List of Genera and Species in family Pholcidae

| | Genera | Species |
|---|---|---|

| | | |
|---|---|---|
| World | 97 | 1969 |
| India | 7 | 16 |
| Goa | 5 | 6 |
| Amona | 1 | 1 |

## i. Genus *Pholcus* Walckenaer, 1805

Description: In male, the ocular area often has stiff setae posteriorly. There is no thoracic furrow in carapace. Smaller than all other eyes and anterior median eyes is non-existent in certain species.

Species recorded in present study are described below:

### *Pholcus sp.*

Key Characters: Cephalothorax is circular and abdomen is cylindrical with brown to grey in colour. In addition to large on the margin the chelicerae are armed in male.

Distribution: Assam, Goa, Gujarat, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan, Tamil Nadu, Telangana, Uttar Pradesh, Uttarakhand.

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

Longer than wide, the cephalothorax is covered in plumose setae, and in certain species, the clypeus has blunt tubercles on its anterolateral border. It is also broad and truncated in front. often adorned with a wide, dark brown stripe that runs the entire length of the cephalothorax. Dark homogeneous eyeballs with at least one pair on shallow tubercles arranged in two or three rows. Sternum and labium are longer than the broad, flat sternal apex. Strong chelicerates have boss and scopulae, as well as teeth. There are three long, tapering, occasionally somewhat laterigrade legs with many trichobothria sporadically scattered in the tibia, metatarsi, and tarsi; the trochanters are severely notched, the inferior claw has two to three teeth, and onychium is occasionally present. The average abdomen is long, spherical, and broadest at the front. It narrows near the spinnerets and is coated with plumose setae. There is frequently folium, dots, or longitudinal bands. The size of the anterior and posterior spinnerets is identical. The vulva complex is made up of a base with an expanded lumen and a stalk that leads to the spermathecae. The complex epigyne is made up of two integument folds that generate two lateral elevations with a median region. The palp usually has tibial apophysis, the cymbium is anteriorly extended, the bulbus is oval, the longitudinal axis is often inclined, the median apophysis is present, and the embolus can be simple and short or long and curved.

They primarily don't spin webs and are energetic wanderers. Certain species can be found in grassy, dwarf shrub environments, while others can be found at the borders of ponds and streams, where they feed on fish. The chelicerae and palpi hold the egg sac in place when females carry it beneath the sternum. The female creates a silk framework, or "nursery web," in which the eggs are laid just before the young emerge. The young are known as "nursery web spiders" because they stay in the web after emerging from the egg sac until they start to disperse.

Table 4.1.7: List of Genera and Species in family Pisauridae

| | Genera | Species |
|---|---|---|
| World | 52 | 365 |
| India | 9 | 21 |
| Goa | 4 | 4 |
| Amona | 2 | 2 |

## i. Genus *Dendrolycosa* Doleschall, 1859

Description: The carapace is almost flat, brown, and may have a thoracic portion that is slightly raised. The central darker stripes appear to continue like a chevron on the abdomen, while the lateral borders are lighter. Of all the eyes, the anterior lateral eye is the smallest. The oval-shaped abdomen has a black folium with wavy edges.

Species recorded in present study are described below:

### *Dendrolycosa gitae* Tikader, 1970

Key Characters: A little more longer than wide is the median ocular region. The chelicerae have three teeth on the lower edge of their furrow (Figure 4.1.7 (a)).

Distribution: Andaman & Nicobar, Assam, Goa, Gujarat, Karnataka, Kerala, Maharashtra, Meghalaya, Odisha, Sikkim, Tamil Nadu, West Bengal

## ii. Genus *Hygropoda* Thorell, 1895

Description: The carapace is yellow or pale brown in color with two dark parallel stripes, two dark peripheral bands, and two bright white bands separating them. With two dark parallel stripes, two dark peripheral bands, and two bright white bands separating them, the carapace is yellow or pale brown in color. The fovea and posterior

median eyes are separated by the median band, which stretches as a thin line. The fovea is longitudinal and deep. Posterior eye row is significantly recurved, whereas anterior eye row is somewhat procurved. Long, thin legs with rigid spines are present. Tarsi are lengthy and supple. The distinctive pattern of the oval, elongated, and finely setae on abdomen is composed of a black median band that bifurcates anteriorly and a series of transverse lines.

Species recorded in present study are described below:

### *Hygropoda sp.*

Key Characters: Carapace with bands that is slightly wider than long. Clear vertical fovea. Longer than broad and tapering posteriorly, the abdomen is adorned with cryptic, dark-colored patterns that go from the front to the back.

Distribution: Goa, Maharashtra, Rajasthan, West Bengal

(a)

Figure 4.1.6: Family Pisauridae (a) *Dendrolycosa gitae* (Tikader, 1970)

## 7. Family: Salticidae, Blackwall, 1841 (Jumping spiders)

Active, hunting spiders that range in size from very small to medium may jump or leap a considerable distance. The most defining trait is the ocular clad, which is defined by eight eyes placed in three or four rows on the cephalothorax. The anterior median eye is the largest and most conspicuous of the four forward-facing eyes that make up the front row. Claw tufts adorn the two clawed legs. a distinctively shaped cephalothorax, with a large, rectangular ocular in the anterior cephalic area that is frequently covered in setae in eye-catching patterns and hues. All around the ocular clad are eyes. Its anterior end is widely truncated and consists of four eyes in the first row. Among these eyes that face forward, the anterior median eyes are the biggest and most noticeable. The two anterior lateral eyes, which are often placed in the front row or, in certain species, the second row, are only slightly larger than the anterior median eyes. The following row is made up of two posterior median eyes, which are typically smaller than anterior lateral eyes. The final row is made up of two posterior lateral eyes that are almost identical to the anterior lateral eyes and are situated in the posterior corners of the ocular membrane. Together, these eyeballs offer outstanding 360-degree vision. From a significant distance, jumping spiders may recognize their prey based on color recognition. In most cases, the thoracic area continues into the cephalic portion, but in certain cases, it is conspicuously divided. The sternum can vary in size and form. Specular deposits are commonly found in the labium, which is a triangular plate with a blunt front edge. Maxillae are large, slender plates that contain thick scopulae distally. Maxillary palps serve as copulatory organs and are relatively basic in females but very complex in males. They occasionally have femoral protuberances and frequently have tibial apophysis. Chelicerae have varying numbers and shapes of teeth on their outer and inner edges, together with a fang. In several genera, they are longer in males. It’s structure can occasionally be intricate and is extremely changeable.

Jumping spiders are nocturnal, able to move by strolling, sprinting, jumping, or leaping, and they employ all of these techniques to get their prey. They pursue, chase, and leap over their prey in order to hunt it. Insects make up the majority of prey; some also like other spiders or ants. A small number of salticids also aggressively imitate or even invade other spiders' webs in an attempt to grab prey. They often don't use webs to catch their prey. In the shape of a tube or sac that is attached to different substrates, salticids build a silken refuge. They utilize the retreat for sleeping throughout the night, mating, moulting, and egg laying. The majority of organisms exhibit blatant sexual dimorphism. Behavior during courtship differs depending on the species

Table 4.1.8: List of Genera and Species in family Salticidae

| | Genera | Species |
|---|---|---|
| World | 681 | 6670 |
| India | 108 | 326 |
| Goa | 30 | 45 |
| Amona | 8 | 9 |

## i. Genus *Bianor* G.W. Peckham & E. G. Peckham, 1886

Description: From a dorsal view, the carapace appears to be rectangular, but its posterior is thinner and slopes downward. The ovoid abdomen has a black stripe and is coated in iridescent setae. The first pair of legs are strong and have stiff spines on the ventral surfaces of the tibia and metatarsus.

Species recorded in present study are described below:

### *Bianor sp.*

Key Characters: Spiders of a small to medium size. Cephalothorax is reticulate and elevated. Three rows of eyes, with the front row being smaller than the posterior row.

Chelicerae have two medium-sized teeth and are robust. Oval sternum, extended abdomen that is longer than wide, and dark in colour (Figure 4.1.7 (a)).

Distribution: Bihar, Goa, Punjab, Telangana, Uttarakhand, West Bengal

### ii. Genus *Carrhotus* Thorell, 1891

Description: Vary in size from modest to big. Typically, males are black with reddish, brownish, or white setae covering them. In general, females are yellowish brown. Cephalothorax has a greater length than breadth. The ocular quadrangle, which protrudes upward, has fine setae. The round, hirsute abdomen is longer than itis wide. The length of each leg is almost the same

Species recorded in present study are described below:

#### *Carrhotus viduus* (C. L. Koch, 1846)

Key Characters: The male is black and has two strong white stripes which run the length of his head on either side. There are two more stripes that span the length of the abdomen but do not connect there. Its eyes have a rim of bright orange (Figure 4.1.7 (b)).

Distribution: Andhra Pradesh, Assam, Goa, Gujarat, Karnataka, Kerala, Lakshadweep, Madhya Pradesh, Maharashtra, Nagaland, Puducherry, Punjab, Rajasthan, Tamil Nadu, Telangana, Tripura, Uttar Pradesh, West Bengal

### iii. Genus *Epocilla* Thorell, 1887

Description: While females are transparent and have a golden color, males are deeper in color and slenderer. There is a noticeable elevation directly below the eye region, contributing to the high cephalothorax. Abdomen has a row of bands or chevron patterns. The metatarsus and first tarsi have strong spines

Species recorded in present study are described below:

### *Epocilla sp.*

Key Characters: The carapace is reddish-brown in colour, coated in whitish hairs, and has large white spots along its lateral border. The posterior eyes are encircled by black patches. Sternum is oval in shape (Figure 4.1.7 (c)).

Distribution: Assam, Karnataka, Maharashtra, Manipur, Odisha, Tripura

**Remarks: This species is reported for the first time from Goa**

## iv. Genus *Hasarius* Simon, 1871

Description: The color of the males is blackish, while the females are greyish. On the femoral to midlength of the tibial surface of the pedipalp, males exhibit white setae. Males have a larger, lighter stripe down the abdomen posteriorly, coupled with two large white spots

Species recorded in present study are described below:

### *Hasarius adansoni* (Audouin, 1826)

Key Characters: The cephalothorax is flat, dark brown, and U-shaped. The region holding the eyes in the upper anterior cephalothorax is elevated. Legs have dense hair and are sturdy. There are whitish hairs in the joints. The abdomen is tiny and has a pronounced taper toward the back. There is a single, thick white band in the abdomen's anterior region (Figure 4.1.7 (d)).

Distribution: Assam, Bihar, Goa, Gujarat, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Puducherry, Rajasthan, Tamil Nadu, Telangana, Uttar Pradesh, Uttarakhand, West Bengal

### v. Genus *Hyllus* C. L. Koch, 1846

Description: The females are yellowish, brownish, or gray, while the males are bright and metallic in appearance. Slightly rounded, the cephalothorax has long, stiff, slightly curved setae just below the anterior lateral eyes. The abdomen is wide in the front and narrows in the back. For the most part, their species exhibit an abdominal pattern. The first two pairs of legs have stiff spines on the tibia and metatarsus.

Species recorded in present study are described below:

#### *Hyllus semicupreus* (Simon, 1885)

Key Characters: spherical head with big round eyes and a noticeable ocular quadrangle. broad in the base, blunt at the tip of the abdomen. Strong, robust legs with hairs and spines. thick covering hairs covering legs (Figure 4.1.7 (e)).

Distribution: Andhra Pradesh, Arunachal Pradesh, Assam, Goa, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Meghalaya, Odisha, Puducherry, Punjab, Rajasthan, Tamil Nadu, Telangana, Tripura, Uttar Pradesh, Uttarakhand, West Bengal

### vi. Genus *Icius* Simon, 1876

Description: These salticids have an elongated body and are quite tiny. The cephalothorax is flat and dark brown to black. The cephalothorax is mostly covered by the ocular quadrangle.

Species recorded in present study are described below:

#### *Icius alboterminus* (Caleb, 2014)

Key Characters: Blackish carapace with hairs running down the cephalothorax's; pale brownish scales covering the anterior abdomen; deeper reddish-black hairs covering the lower half; white dots on the dorsum (Figure 4.1.7 (f)).

Distribution: Tamil Nadu, Uttarakhand

Remarks: This species is reported for the first time from Goa

## vii. Genus *Menemerus* Simon, 1868

Description: These are medium-sized salticids with a brown or gray color. The lateral borders of the flat cephalothorax have a white setae stripe. The legs are broad and short. The belly is round and wide.

Species recorded in present study are described below:

### *Menemerus bivittatus* (Dufour, 1831)

Key Characters: The dull black, U-shaped cephalothorax has a wide, light brown area behind it and a white, hairy band around its edges. The oval-shaped, long, black-coloured abdomen has a blunt anterior end and a pointed posterior end (Figure 4.1.8 (a)).

Distribution: Andhra Pradesh, Assam, Goa, Gujarat, Haryana, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Puducherry, Rajasthan, Tamil Nadu, Tripura, Uttar Pradesh, Uttarakhand, West Bengal

### *Menemerus sp.*

Key Characters: The cephalothorax has a dark brown colour and a few brown and white hairs scattered over its surface. Long, black bristles cover the eyes. Light brown chelicerates with a few white hairs (Figure 4.1.8 (b)).

Distribution: Bihar, Goa, Karnataka, Maharashtra, Uttarakhand, West Bengal

## viii. Genus *Plexippus* C. L. Koch, 1846

Description: Less than 10 mm in length, the genus Plexippus constitutes the medium-sized jumping spider group. This genus's members have a high, somewhat convex cephalothorax, with rounded thoracic regions and almost parallel cephalic sides. The cephalothorax's height is less than half of its length. The posterior truncation of the convex carapace is followed by a very gentle curve that ends slightly below the front eyes, where it momentarily diverges. It is dark brown in color, with a black eye field and a wide, white median band that connects two similarly wide, complete sub marginal bands at the rear edge, extending from the posterior eyes. A thin border strip of black is present. The shoulders are hunched forward on the elongated oval abdomen. It is nearly as long as the carapace and has a wide white median stripe that extends to the spinnerets. It is dark brown in hue. The abdomen's sides are white. Two distinctive circular white spots next to the white median band and two more close to the spinnerets are seen at approximately one-third of the distance from the spinnerets.

Species recorded in present study are described below:

### *Plexippus paykulli* (Audouin, 1826)

Key Characters: The cephalothorax is broad, lengthy, and has a light brown hue. The abdomen is oval in shape, lighter brown in colour, and has a prominent white area around the centre. It is longer than broad (Figure 4.1.8 (c)).

Distribution: Andaman & Nicobar, Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chhattisgarh, Goa, Gujarat, Haryana, Jammu & Kashmir, Karnataka, Kerala, Lakshadweep, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Odisha, Puducherry, Punjab, Rajasthan, Sikkim, Tamil Nadu, Telangana, Tripura, Uttar Pradesh, Uttarakhand, West Bengal

(a)

(b)

(c)

(d)

(e)

(f)

Figure 4.1.7: Family Salticidae (a) *Bianor sp.*, (b) *Carrhotus viduus* (C. L. Koch, 1846), (c) *Epocilla sp.*, (d) *Hasarius adansoni* (Audouin, 1826), (e) *Hyllus semicupreus* (Simon, 1885), (f) *Icius alboterminus* (Caleb, 2014)

(a)

(b)

(c)

Figure 4.1.8: Family Salticidae (a) *Menemerus bivittatus* (Dufour, 1831), (b) *Menemerus sp.*, (c) *Plexippus paykulli* (Audouin, 1826)

## 8. Family: Sparassidae, Bertkau, 1872 (Crab spiders)

Largely oval cephalothorax that is longer than broad and thinner around the eye area. It has a thick coating of fine setae covering it, and it has a fovea. The color range of the cephalothorax is cream to dark brown, grey, green, or white, with black stripes and mottling frequently present. Eight eyes in two rows; anterior eyes vary in size depending on the species, medians are usually the largest, and the posterior row is uniformly spaced. sternum with a sharp apex that is nearly round and longer than broad. Maxillae have thick serula and scopula, and the free labium is small and rebordered distally, never more than half the length of the maxillae. Chelicerae have two rows of teeth on the boss and fang furrow. Long laterigrade legs held at a right angle to the body; legs I and II bigger than legs III and IV; well-developed leg scopulae; tarsal claws with tufts; slightly notched trochanters; soft trilobate membrane at the apical ends of metatarsi. They run sideways because of their laterigrade legs. Female gives a clawed palpation. Round to oval-shaped abdomen covered in a thick coating of fine setae; frequently marked with a black, central heart. Strong tibial apoptosis in a male palp.

When the spiders are resting on dry grass, their normal body and leg colors are grey, brown, and black, frequently with just enough mottling to offer helpful camouflage. Being nocturnal, the females conceal their egg sac throughout the day. Certain species' females clasp their egg sac with their pedipalps to transport it beneath their bodies. They simply make silk retreats; they don't spin webs.

Table 4.1.9: List of Genera and Species in family Sparassidae

| | Genera | Species |
|---|---|---|
| World | 97 | 1473 |
| India | 1 | 90 |
| Goa | 5 | 9 |

| | | |
|---|---|---|
| Amona | 2 | 2 |

## i. Genus *Heteropoda* Latreille, 1804

Description: The genus *Heteropoda* comprises of hunting spiders that typically have robust mandibles and legs with ungual tufts and two claws on the tarsi. In the genus Heteropoda, the maxillae are not crested, the vulva is composed of two lobes and is not marked with circular pits, the cephalothorax is square and typically elevated behind, the eyes of the posterior line are recurved, the lateral eyes are larger and prominent, and the anterior eyes are straight or procurved with their laterals larger than the medians.

Species recorded in present study are described below:

### *Heteropoda venatoria* (Linnaeus, 1767)

Key Characters: The cephalothorax is hairy, golden brown in colour, and longer than broad. There are two rows of eight eyes: a procurved anterior row and a recurved posterior row. Long legs with spines are present. The abdomen has an oval form and is extended (Figure 4.1.9 (a)).

Distribution: Andaman & Nicobar, Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Goa, Gujarat, Jammu & Kashmir, Karnataka, Kerala, Lakshadweep, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Odisha, Puducherry, Rajasthan, Tamil Nadu, Telangana, Tripura, Uttar Pradesh, Uttarakhand, West Bengal

## ii. Genus *Olios* Walckenaer, 1837

Description: *Olios,* or pale-brown to grey-brown spiders, are distinguished from other spider species by bright patterns on the underside of the abdomen. *Olios* has a particularly high, convex carapace. The anterior row of eyes is somewhat recurved, the

anterior medians are bigger than the laterals, and the anterior row is straight. Usually, the second leg is longer than the first.

Species recorded in present study are described below:

### *Olios sp.*

Key Characters: Light brown, longer than broad cephalothorax. The oval-shaped abdomen has white markings on it. Legs are the colour of midnight black. There are two rows of eight eyes: a procurved anterior row and a recurved posterior row. Long, pointy legs with two claws.

Distribution: Andhra Pradesh, Assam, Bihar, Delhi, Goa, Gujarat, Haryana, Jammu & Kashmir, Karnataka, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Odisha, Rajasthan, Telangana, Uttar Pradesh, Uttarakhand

(a)

Figure 4.1.9: Family Sparassidae (a) *Heteropoda venatoria*, (Linnaeus, 1767)

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

Longer than broad, cephalothorax is often fawn to dull brown or gray with silvery patterns, and the folium is frequently grey and silvery. Two rows of eight eyes, with lateral eyes spaced apart or adjacent. Maxillae are parallel, labium is rebordered, and the sternum is longer than broad and pointed posteriorly. Varying in length and development, chelicerae are robust, have a row of big teeth, and have powerful projecting spurs. Some species feature noticeable tufts or setae on the femora and tibia of the legs, or the posterior femora with a double fringe of trichobothria on the prolateral side of the basal half, or rows of straight trichobothria on the tibia of all legs. These species have long, slender legs with three claws, either with or without spines. Variable in shape, the abdomen is long and cylindrical or spherical to ovoid, and in certain species it extends caudally past the spinnerets. The epigastric furrow is almost straight. Size of the front and posterior spinnerets is the same. Tracheal spirals in certain species are located halfway between spinnerets and epigyne. complex epigyne with unsclerotized genital plate, moveable and distinct male paracymbium, spherical tegulum with coiled conductor and embolus at distal tip, absence of median apophysis, and presence of embolus tegulum membrane. It is orb weavers, who live in a range of environments.

Table 4.1.10: List of Genera and Species in family Tetragnathidae

| | Genera | Species |
|---|---|---|
| World | 45 | 987 |
| India | 11 | 55 |
| Goa | 7 | 18 |
| Amona | 3 | 3 |

## i. Genus *Leucauge* White, 1841

Description: *Leucauge* species have an amazing silvery abdomen decorated with gold, green, and red patterns. There aren't many size differences between male and female. Silvery skin tones are widespread. Eye size sub equal, posterior row straight or slightly procurved; carapace large posteriorly, substantially constricted at sides anteriorly. The anterior surface of the chelicerae is slightly enlarged and robust. Femora IV has a double fringe of hairs, or trichobothria, while legs I and II are long and thin. Silvery in color, the abdomen is twice as long as it is broad, and it has one or more pairs of tubercles anteriorly.

Species recorded in present study are described below:

### *Leucauge sp.*

Key Characters: Cephalothorax elongated with a raised cephalic area and hairs covering it. Chelicerae are robust, and huge with dark brown in colour. The elongated abdomen has one blunt anterior and two anterior patches, and it is silver white in colour with black and white lines with yellow patch. Legs are long, thin, and covered in spines and hair (Figure 4.1.10 (a)).

Distribution: Assam, Bihar, Chhattisgarh, Delhi, Goa, Gujarat, Haryana, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Odisha, Punjab, Rajasthan, Sikkim, Tamil Nadu, Uttar Pradesh, Uttarakhand, West Bengal.

## ii. Genus *Tetragnatha* Latreille, 1804

Description: The body is far longer than it is wide, with a long and thin shape. The oval carapace is flattened above, broadest in the centre, and prominently has a thoracic

groove. Small, black pigment rings around the eyes; lateral eyes on either side are often clearly demarcated,

Species recorded in present study are described below:

### *Tetragnatha sp.*

Key Characters: The abdomen is longer than its cephalothorax. Labium has a yellowish-brown tip and is broader than long. The ocular quadrangle is somewhat broader in back than it is in front. It has long, thin, brownish legs with first pair is longer than the others (Figure 4.1.10 (b)).

Distribution: Assam, Bihar, Chhattisgarh, Goa, Gujarat, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, Uttarakhand, West Bengal

## iii. Genus *Tylorida* Simon, 1894

Description: The carapace is yellowish brown in color with gray patterns; it is occasionally pitted, somewhat low, broadest in the middle, and softly narrows in the front and rear. The size of the eyes is sub equal, with the lateral eyes meeting on either side and the posterior row being about straight. They feature a single row of straight trichobothria on legs I–IV, and their first leg is very lengthy. The shape of the abdomen is basically a right-angled triangle, and it is high.

Species recorded in present study are described below:

### *Tylorida ventralis* (Thorell, 1877)

Key Characters: The cephalothorax is narrower and longer, with less hairs. Legs have spines at the joints and are slender and small. The oval-shaped, greyish-coloured

abdomen has spots of silver. There are many pairs of pits on the dorsum of the abdomen. Hair covers the carapace. Heart-shaped sternum covered with hair (Figure 4.1.10 (c)).

Distribution: Andaman & Nicobar, Assam, Goa, Gujarat, Karnataka, Kerala, Lakshadweep, Maharashtra, Meghalaya, Rajasthan, Sikkim, Tamil Nadu, Uttar Pradesh, Uttarakhand, West Bengal

(a)

(b)

(c)

Figure 4.1.10: Family Tetragnathidae (a) *Leucauge sp.*, (b) *Tetragnatha sp.*, (c) *Tylorida ventralis (Thorell, 1877)*

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

Cephalothorax can vary in morphology from high to flat, with a somewhat high clypeus. Certain species exhibit alterations in the frontal area of the cephalothorax. Eight eyes in two rows, almost parallel, with the anterior medians black and the remaining eyes pale, usually surrounded by a brownish ring. Scutiform to triangular sternum posteriorly attenuated; typical mild convergence of the maxillae. Chelicerae can be modest in number or occasionally quite lengthy without cheliceral teeth. The tibia, metatarsi, and femur of a three-clawed animal are all rather long and curved, with the tarsi typically tapering towards the tip. The tarsal comb, a collection of bristles on tarsi IV that is unique to large theridiids, is used to extend the throw of sticky silk threads across the prey. In smaller species and males, the comb may be missing or diminished. Each tibia has two rows of trichobothria, which the female palpates with a claw. There are several species with a dorsal stridulating plate near the pedicel, cryptic with darker patterns on a brownish gray background in color, and either absent or present colulus. The shape of the abdomen ranges from oval to round and high to elongate, reaching beyond spinnerets. Epigyne complex containing one or two pairs of spermatheca. Male palp without apophysis, with the paracymbium creating a hook on the cymbium's distal edge.

The lifestyles of these spiders are varied. The majority of organisms construct three-dimensional space webs of various shapes. Some webs, made of crisscrossed viscid strands, allow the spider to capture flying insects. During escape actions, prey adhered to the threads becomes increasingly entangled since the strands break readily. Certain species build unique hideouts either within or outside the frame, and they conceal their webs with plant or dirt fragments. Some species hide in a silken refuge that is constructed in an angle or corner with the web spread out below and buried in debris or darkness. certain of them don't even create webs; instead, you might see them strolling

through leaf litter, lying on the ground, or, in the case of certain cryptic species, simply relaxing on bare branches.

Table 4.1.11: List of Genera and Species in family Theridiidae

| | Genera | Species |
|---|---|---|
| World | 129 | 2569 |
| India | 34 | 93 |
| Goa | 11 | 14 |
| Amona | 1 | 1 |

## i. Genus *Nesticodes* Archer, 1950

Description: These are medium in size having brownish cephalothorax and shiny white or grey abdomen which are globular in shape.

Species recorded in present study are described below:

### *Nesticodes rufipes* (Lucas, 1846)

Key Characters: Reddish in colour, the cephalothorax is round at the back and tapering at the front. Cephalothorax is hairless, and the fovea is clearly visible. Legs are slender and have a reddish-brown hue. The abdomen is round and has a reddish hue. Small people have little, straight hairs (Figure 4.1.11 (a)).

Distribution: Arunachal Pradesh, Assam, Gujarat, Haryana, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Meghalaya, Puducherry, West Bengal

**Remarks: This species is reported for the first time from Goa**

## 11. Family: Thomisidae, Sundevall, 1833 (Crab spiders)

The cephalothorax can be semi-circular, oval, or elongated, and it often has simple erect setae. However, some species include eye tubercles or robust, rounded protuberances. Eight eyes in two rows, dark and uniform, frequently with a white outline; the posterior row is typically recurved; the lateral eyes are typically elevated on tubercles, which may or may not be linked; the medians are typically bigger than the others. Heart-shaped sternum, labium, and maxillae are often longer than broad. Chelicerae are free, the boss is typically present, the cheliceral teeth are missing, the promargin occasionally has cusps or tiny denticles, the retromargin is vague and unarmed, and the scopulae are poorly developed. With two pairs of clawed laterigrade legs, I and II are longer than III and IV, the front tarsi lack scopulae, and the claw tuft is typically missing. The first two pairs of ventral spines are paired and have larger, stronger spines than the third and fourth pairs. These spiders hunt by stealth and ambush rather than by weaving webs; instead, they utilize their muscular, spiny legs to seize their victim. The form of the abdomen can vary more than that of the cephalothorax, ranging from spherical to ovoid or elongated, extending caudally past the spinnerets and often covered in sporadic, simple setae. To complement the color of the surface, the body might be white, green, or brown. Colulus present; anterior spinnerets small, conical, and closely spaced. Typically, the epigyne complex has a bordered atrium and hood. Male palpation exhibiting disc-like tegulum and ventral and retrolateral apophysis on tibia. Usually, the members have an odd look similar to a crab.

The spiders' typical homes are leaves or flowers, where they may better blend in with their surroundings by roughening their surfaces. In general, they don't make webs. Their popular name comes from their sideways or crab-like walk, which makes them most active during the day. Despite having feeble chelicerae, they may attack large insects

because of their incredibly strong venom. There are no cheliceral teeth, and the prey is swallowed dry rather than crushed.

Table 4.1.12: List of Genera and Species in family Thomisidae

| | Genera | Species |
|---|---|---|
| World | 171 | 2174 |
| India | 42 | 186 |
| Goa | 17 | 22 |
| Amona | 1 | 1 |

## i. Genus *Thomisus* Walckenaer, 1805

Description: This genus's members are sexually dimorphic, with the male being darker than the female.

Without setae, the cephalothorax is nearly as long as it is wide. The head has enormous, horn-like protuberances that protrude laterally between the lateral eyes. The eyes are tiny, underdeveloped, and of sub equal size. Largest are the anterior lateral eyes. The male abdomen is more sclerotized than the female's, while the female has a more prominent broader abdomen.

Species recorded in present study are described below:

### *Thomisus sp.*

Key Characters: The shape of the cephalothorax is oval; the anterior median and anterior lateral eyes are smaller. Sternum is hair-covered and has a yellowish-gold colour. White as chalk is the colour of the abdomen. Dorsum has a faint pattern in dark brown (Figure 4.1.11 (b)).

Distribution: Andhra Pradesh, Assam, Bihar, Chhattisgarh, Goa, Gujarat, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Puducherry, Rajasthan, Tamil Nadu, Telangana, Uttar Pradesh, Uttarakhand

(a) (b)

Figure 4.1.11: Family Theridiidae (a) *Nesticodes rufipes* (Lucas, 1846), Family Thomisidae (b) *Thomisus sp.*

## 4.1.2 Diversity indices and abundance of Spiders

A total of 38 species belonging to 29 genera representing 11 families were collected during the entire field survey (Table 4.1). Amongst the families the Salticidae was the most abundant (30%) followed by Araneidae (25%), Lycosidae (10%), Oxyopidae (9%), Tetragnathidae (7%), Hersilidae (6%), Pisauridae and Pholcidae (4%), Sparassidae and Theridiidae (2%) and Thomisidae (1%) (Table 4.2; Figure 4.1).

Table 4.1.13: Representation of recorded spider families from Agro-ecosystem

| FAMILY | NUMBER OF INDIVIDUAL SPECIES |
|---|---|
| Araneidae | 64 |
| Hersilidae | 16 |
| Lycosidae | 27 |
| Oxyopidae | 22 |
| Pholcidae | 10 |
| Pisauridae | 11 |
| Salticidae | 78 |
| Sparassidae | 6 |
| Tetragnathidae | 17 |
| Theridiidae | 6 |
| Thomisidae | 2 |

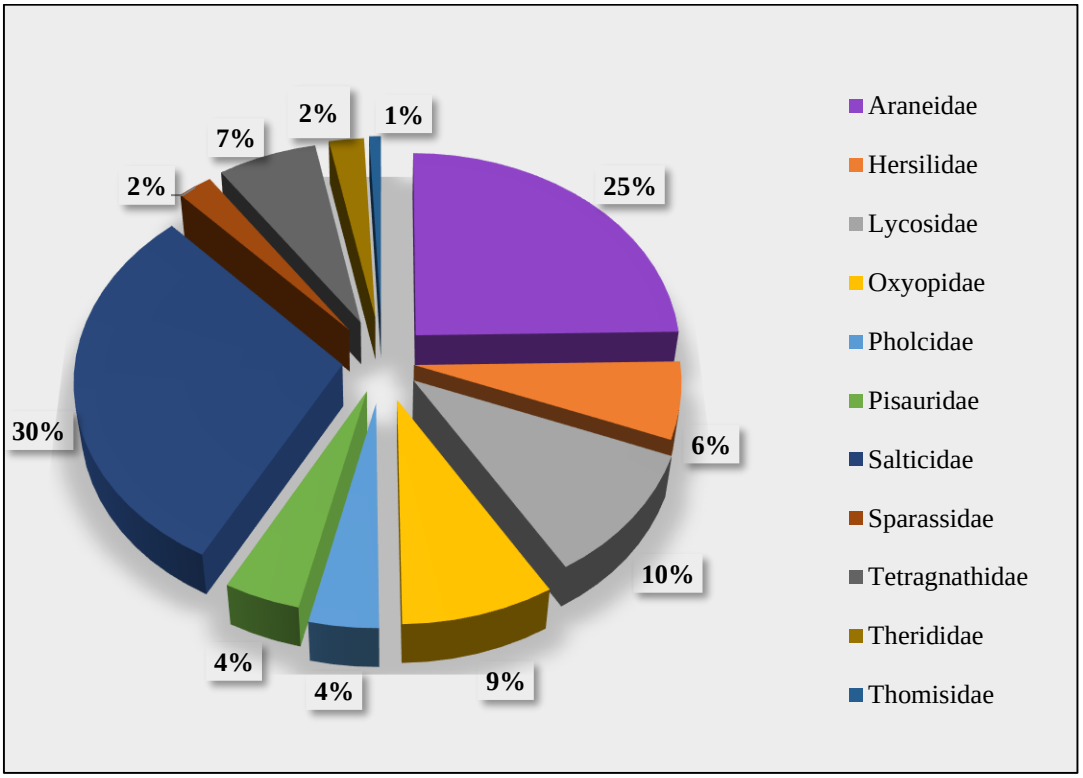


Figure 4.1.12: Family composition of spider abundance (% occurrence of individual captured per family) from Agro-ecosystem

During a study period a total of 259 individual of spiders were recorded in Agro-ecosystem, belonging to 11 families, 29 genus and 38 species. Among various families observed, 78 individual species were recorded from Salticidae, 64 individual species from Araneidae, 27 individual species were recorded from Lycosidae, 22 individual species from Oxyopidae, 17 individual species were recorded from Tetragnathidae, 16 individuals from Hersilidae, 11 individuals from Pisauridae, 10 individuals from Pholcidae, 6 individuals from Sparassidae and Theridiidae one individual species Thomisidae.

Table 4.1.14: Representation of family wise distribution of species and genera from Agro-ecosystem

| FAMILY | GENUS | SPECIES |
|---|---|---|
| Araneidae | 6 | 10 |
| Hersilidae | 1 | 1 |
| Lycosidae | 3 | 5 |
| Oxyopidae | 1 | 3 |
| Pholcidae | 1 | 1 |
| Pisauridae | 2 | 2 |
| Salticidae | 8 | 9 |
| Sparassidae | 2 | 2 |
| Tetragnathidae | 3 | 3 |
| Theridiidae | 1 | 1 |
| Thomisidae | 1 | 1 |

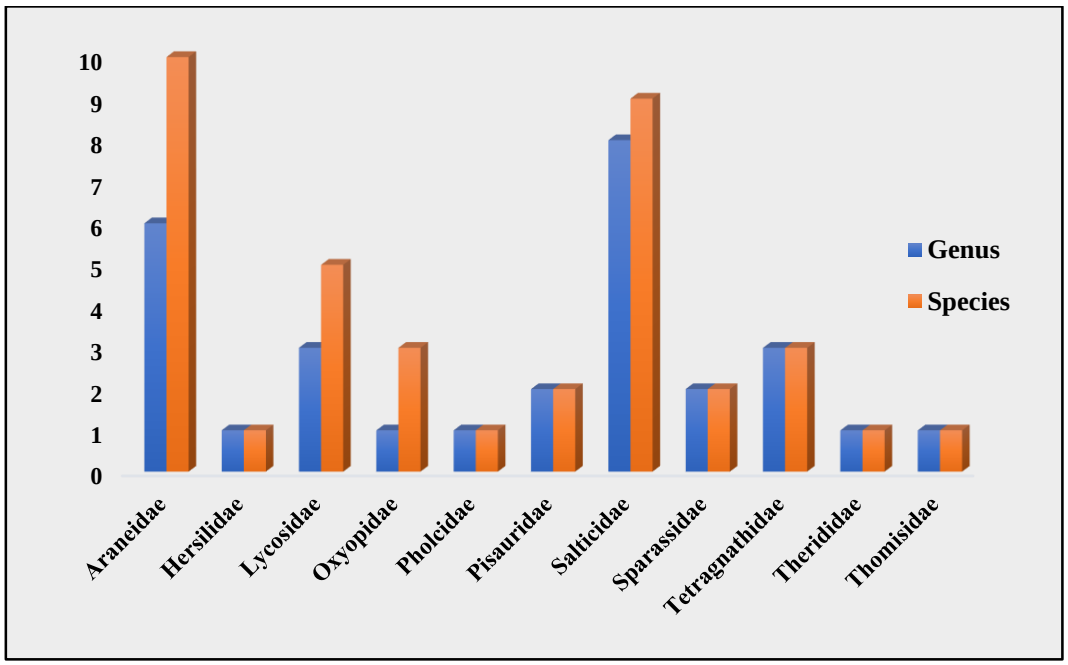


Figure 4.1.13: Family wise distribution of species and genus from Agro-ecosystem

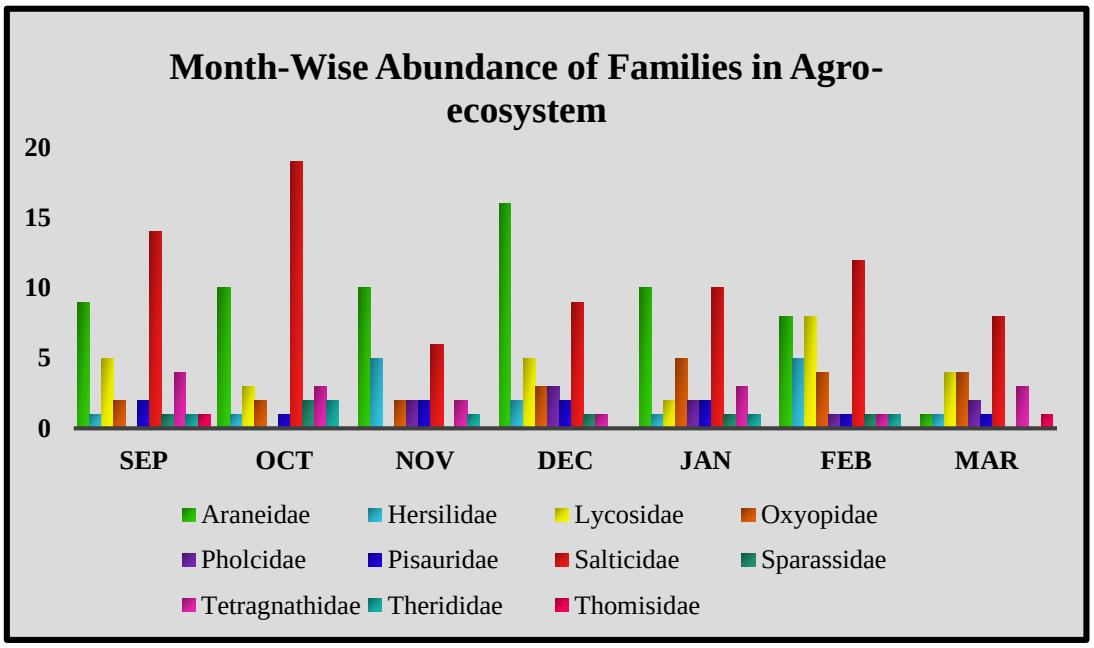


Figure 4.1.14: Graph showing month-wise abundance of families in Agro-ecosystem

Table 4.1.15: Diversity indices using family wise recorded data

| | Individuals | Simpson_1-D | Shannon_H | Margalef | Equitability_J |
|---|---|---|---|---|---|
| Araneidae | 64 | 0.8286 | 1.817 | 1.443 | 0.934 |
| Hersilidae | 16 | 0.7734 | 1.68 | 2.164 | 0.8634 |
| Lycosidae | 27 | 0.8038 | 1.705 | 1.517 | 0.9515 |
| Oxyopidae | 22 | 0.8388 | 1.882 | 1.941 | 0.9673 |
| Pholcidae | 10 | 0.78 | 1.557 | 1.737 | 0.9675 |
| Pisauridae | 11 | 0.843 | 1.894 | 2.502 | 0.9732 |
| Salticidae | 78 | 0.8386 | 1.884 | 1.377 | 0.968 |
| Sparassidae | 6 | 0.7778 | 1.561 | 2.232 | 0.9697 |
| Tetragnathidae | 17 | 0.8304 | 1.844 | 2.118 | 0.9476 |
| Theridiidae | 6 | 0.7778 | 1.561 | 2.232 | 0.9697 |
| Thomisidae | 2 | 0.5 | 0.6931 | 1.443 | 1 |

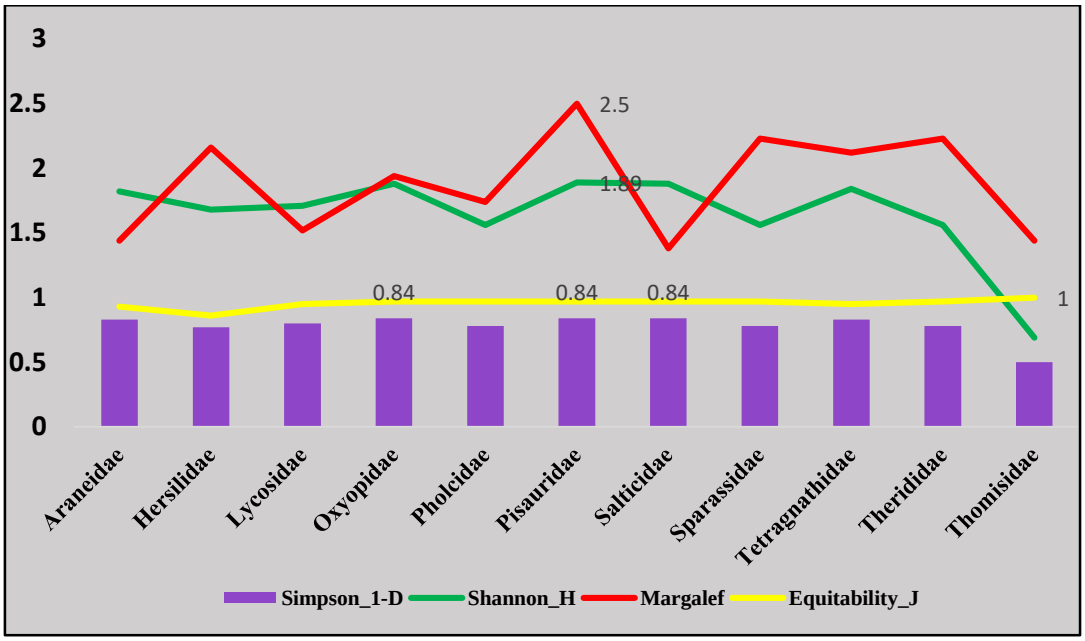


Figure 4.1.15: Graph showing diversity indices

## 4.1.3 GUILD COMPOSITION AND STRUCTURE

The spiders of Agro-ecosystems can be divided into eight different guilds based on their foraging behaviours in the field. The dominant guild was of the Orb weavers (34%). Spiders of the families Araneidae and Tetragnathidae, fall under this category. Spiders of the category Ambushers (29%) formed the next dominant guild in the ecosystem consist of Pisauridae and Salticidae family spiders. Ground runners (13%), family Lycosidae, Diurnal runners (8%) and Foliage runners (8%), of family Oxyopidae and Hersilidae and Sparassidae respectively. Space builder and Space web weaver (3%), consist of family Pholcidae and Theridiidae respectively. Aerial ambushers (2%) of family Thomisidae.

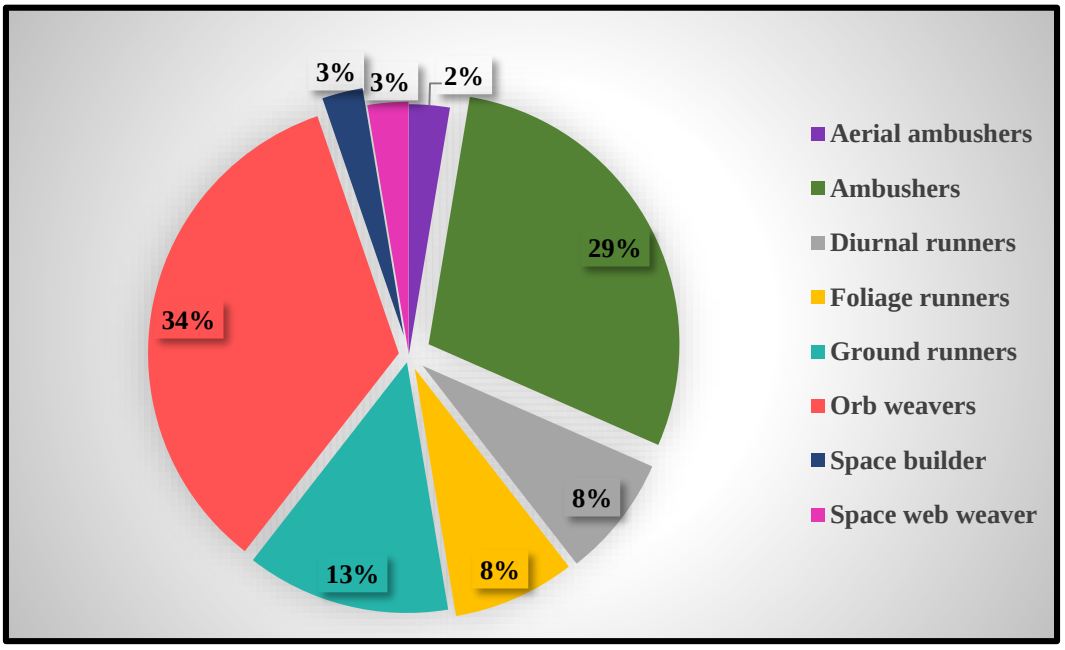


Figure 4.1.16: The guilds of spiders (%) collected from Agro-ecosystem

## 4.1.4 WEB ARCHITECTURE

**Funnel web:**

A certain type of spider web known as a funnel web is constructed by spiders in the Lycosidae family, sometimes referred to as funnel weavers. The funnel and the horizontal sheet make up the two primary parts of a funnel-shaped spider web's construction. The funnel is made like a vertical tube, with a bigger opening at the bottom and a little one at the top. Usually, the flat sheet of the web is built against a vertical surface, such as rocks, at a small inclination or horizontally on the ground. The web's silk strands are usually woven together in a radial design, with spokes extending from the funnel's opening. The funnel-shaped web's construction is intended to effectively catch prey. The horizontal sheet offers a greater surface area for capturing insects, while the funnel enables the spider to quickly identify and seize anything that enters the web. Usually, the spider waits for food to fall into its web by sitting near the narrow end of the funnel. The funnel web's small opening enables the spider to swiftly identify and seize any prey that reaches the web (Figure 4.18).

Figure 4.1.17: Funnel web

**Orb webs:**

The Araneidae and Tetragnathidae family of spiders, known as orb-weavers, create this particular style of web. Orb webs have an outward-extending spiral of sticky silk from their center, and they are shaped like circles or slightly ovals. An orb web's structure is very well-organized and made up of several unique parts. Radial threads, frame threads, and spiral threads are the three primary parts of an orb web. The radial threads serve as the web's support system and spread outward from its center toward the edges. The frame threads, which wrap around the outside edge of the web to support the structure, are stronger and thicker than the radial threads. The radial thread is encircled by spiral threads that are sticky enough to stick to prey. These webs include extra structure that increases their efficiency in catching prey. Examples of this structure are the stabilimentum, which is typically seen in zigzag lines, and the hub, which is a thicker part in the center of the web where the spider waits for food (Figure 4.19).

Figure 4.1.18: Orb web

**Signature webs:**

One kind of orb web is the X-shaped web. Some orb weaving spider species, especially those belonging to the genus *Argiope*, are responsible for creating it. The core portion of the spider's web is spun with a unique silk pattern called the stabilimentum. Although the purpose is unclear, it is believed to increase the web's visibility to birds and other animals, which lowers the possibility of the web being unintentionally destroyed. Usually, the web is made up of radial threads that are extended between plants or anchor points like branches. The spider then weaves spiral threads around the radial threads in a certain manner, leaving a hole in the middle of the web. This space frequently resembles a 'X,' with its arms creating a zigzag design (Figure 4.20).

Figure 4.1.19: Signature web

**Sheet web/ Tangle web:**

A sheet web has two major lines that go down the center and is flat. It is sometimes referred to as a triangle web. Any insect that falls on a sheet web is shaken by the spider, which makes them fight and get tangled in the threads. Principal portion of the web of a sheet that is more or less tightly woven, consisting of threads that extend in all directions within a single plane. A sheet web's structure typically consists of a horizontal silk sheet held up by a number of threads that cling to surrounding objects like rocks or plants. The family Linyphiidae, Pholcidae, Theridiidae exhibits a sheet-type web construction (Figure 4.21

Figure 4.1.20: Sheet/Tangle web

# 4.2 DISCUSSION

The objective of the current study was to document the diversity and abundance of spiders in the Agro-ecosystem, Amona, Goa. As the spiders in this region are unexplored, a thorough investigation of the distribution and ecology of the Agroecosystem's spiders was conducted.

## Diversity of Spiders

The only way to comprehend the endless species diversity of life is through taxonomy (Ghavami et al., 2007). In the present study 259 individual representing 38 species, 29 genus and 11 families were recorded at agro-ecosystem of Amona. Working from several agricultural fields inside the Jambughoda wildlife sanctuary, Solanki and Kumar (2015) found that the families Araneidae, Salticidae, and Lycosidae had the highest species diversity in these areas. Warghat et al. (2010) conducted research in several agricultural fields that are adjacent to the foothills of the Satpura Mountain ranges in the Amravati district. They identified the major families as Araneidae, Thomisidae, and Salticidae. In the present study Salticidae and Araneidae family are found to be dominant.

Scientific reports on spider diversity in Agro-ecosystem of Goa are limited, as per literature only one study has been conducted so far. In 2018, Halarnkar and Pai reported 15 families, 37 genera and 59 species of which 7 families, 18 genera and 30 species were reported in plantation of Tivrem-Orgao, Marcela, Goa.

Among the spiders documented, five species viz., *Argiope versicolor, Oxyopes hindostanicus, Epocilla sp., Icius alboterminus, Nesticode rufipes* were recorded for the first time from the Goa.

Family wise number of species indicate that the maximum *i.e.,* 10 number of species are reported from family Araneidae. Then second highest number of species *i.e.,* 9 species are reported from Salticidae family. Third highest number of species *i.e.*,5 are reported from Lycosidae. Oxyopidae and Tetragnathidae family reported 3 species each whereas Pisauridae and Sparassidae reported 2 species. Families such as Hersilidae, Theridiidae and Thomisidae are represented by single number of species from the Agro-ecosystem of Amona, Goa.

## Diversity Indices

Diversity indices including the Shannon Weiner Index, Simpson Index of Dominance and Diversity, Equitability, and Margalef species richness were computed using PAST (Paleontological Statistics software package for education and data analysis) version 4.03 software in order to assess the value of alpha diversity for agro-ecosystem.

The study's use the Shannon-Wiener diversity index reveals significant variations in the richness and distribution of spiders. This index makes the assumption that people are chosen at random from a "indefinitely large" population (Peilou, 1975). It was seen that the family Salticidae had the highest number of individual (78), while the family Thomisidae had the lowest (2). The Shannon Index is a measure of species diversity, taking into account both species richness and evenness. High biodiversity gives ecosystems the flexibility to adapt and survive in a continually changing world. Therefore, addressing decreased biodiversity is crucial to ensure the continued existence of these ecosystems (Zaw et al., 2020). Study results showed that the family Pisauridae had the highest Shannon Weiner Index value (1.894), indicating a high level of diversity and evenness among the species present. The family Thomisidae had the lowest Shannon Index value (0.693), indicating a lower level of diversity and evenness. In the present study Salticidae and Pisauridae family are found to be dominant. Higher species

diversity, according to Hill (1973), is an indicator of a healthier and more complex community because a larger range of species allows for more interactions, which leads to greater system stability, which indicates good environmental conditions.

Equitability measures the evenness of species abundance, with a value closer to 1 indicating more evenness. Results showed that the family Thomisidae had the highest equitability value (1.00), indicating that the species present were relatively evenly distributed in terms of abundance. The family Hersilidae had the lowest equitability value (0.8634), indicating that species abundance was less even, which could be due to high competition among species for resources or may be due to habitat fragmentation that restricts the movement of species and leads to uneven distribution. The Margalef Index is a measure of species richness, taking into account the number of species present and the total number of individuals observed. The results showed that family Pisauridae had the highest Margalef Index value (2.502), indicating a high level of species richness relative to the number of individuals observed, which indicates a healthy ecosystem, as the presence of many different species suggests a well-functioning food web.

## Guild Structure

Vegetation factors and the structure of the habitat have a considerable impact on the distribution and presence of spiders (Souza & Martins, 2004). When comparing descriptions of various communities, the organisms inside guilds can be useful in describing a portion of the organization of those communities. According to Uetz et al. (1999), family level determination might be used to create spider guilds. A worldwide pattern of spider guild composition and functional diversity was identified by Cardosa et al. (2011). The eight guilds that they have discussed are: sheet, space, orb web weavers, specialists, ambush, ground, and other hunters. In the present study, we have observed eight different types of guilds namely Aerial ambushers, Ambushers, Diurnal

runners, Foliage runners, Ground runners, Orb weavers, Space builder, Space web weaver (Figure 4.5).

Based on available literature on the guild structure and composition of spiders in various crop fields, including peanut, alfalfa, soybean, rice, corn, cotton, sugar, and sorghum fields in the United States, the guild concept has been employed to compare spider communities within agro ecosystem (Uetz et al., 1999).

## Spider Webs Architecture

One of the most fascinating aspects of the study is the analysis of the spider web's structure and patterns. Spiders are widely renowned for their ability to weave many kinds of webs. They make webs for a variety of uses, including as creating egg sacs (cocoons), lining their nests, inflating, mating silk, creating draglines, and creating webs to trap animals (Yadav, 2019). In the present study site, four types of webs namely Funnel web, Orb web, Signature web and Sheet/Tangle web were recorded. Rich vegetation, including many flowering trees, herbs, and shrubs, enabled the spiders to create a variety of web kinds, designs, and sizes (Solanki & Kumar 2015a). According to Suthar et al. (2018), members of the Araneidae family have been seen creating tent webs and orb-webs using plants like shrubs with more spacious branches that can support the formation of orb-webs, such as Neoscona, Parawixia, Argiope, and Cyrtophora. Ground spiders found in the Lycosidae family build funnel webs on the ground, in leaf litter, or inside of leaves. The families Lycosidae, Theridiidae, and Pholcidae create sheet webs on bushy or lower plants, such as grass and moist regions. Studying web structure becomes increasingly significant from an economic perspective since it shows the great diversity of the research regions' flora and wildlife. The ecological diversity and complexity of spiders are strongly correlated with the

environment's structural complexity. The region may include many smaller but varied environmental niches due to the intricate interplay of different climatic parameters like as temperature, rainfall, and the presence of a local water supply (Wankhade et al., 2012).

As they eat a variety of insect pests, such as flies, beetles, aphids, and other bugs, spiders are useful in reducing insect pests because they are strong indicators of a healthy environment and preserve ecological balance. They serve as bio-indicators to track biodiversity, and their existence signals alterations to a specific ecosystem (Hore & Uniyal, 2008).

We may conclude with certainty from all of the above-mentioned data that the agro-ecosystem's spider fauna is rather abundant. Thus, we may conclude that research on variety and ecology always provides insight into a region's health and richness and aids in the preservation of a particular ecosystem.

## 4.3 CONCLUSION

The study analysed the diversity, abundance and distribution of spider species in the Agro-ecosystem of Amona, Goa over the period of seven months. This region has a high diversity of spiders, which suggests that the agroecosystem is a healthy ecosystem. There are 38 species of spiders in the study region, representing 29 genera and 11 families. The families Araneidae, Salticidae, Lycosidae, Oxyopidae, Tertragnathidae, Pisauridae, Sparassidae, Hersilidae, Pholcidae, Theridiidae, and Thomisidae have the majority of spider species among the eleven families. The results showed that spider abundance varied significantly across months, with October month having the highest abundance and March having the lowest. The family Salticidae was the most abundant family throughout the study period.

One of the main outcomes of this study is the distributional record of five new spider species namely *Argiope versicolor* (Araneidae), *Oxyopes hindostanicus* (Oxyopidae), *Epocilla sp.* (Salticidae), *Icius alboterminus* (Salticidae), *Nesticode rufipes* (Theridiidae).

To evaluate the value of alpha diversity for each habitat, diversity indices such as Shannon Index, Simpson Index, Equitability, and Margalef Index were calculated. All the value indicates an infinite and equally distributed diversity and also stable and balanced ecosystems.

Overall, the study provides valuable insights into the impact of Agro-ecosystem on spider abundance and diversity. The findings can be useful in understanding the ecology of spider communities and can aid in the conservation of spider biodiversity in Agro-ecosystem.

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