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COMMUNICATION

Spider diversity (Arachnida: Araneae) at Saurashtra University Campus, Rajkot, Gujarat during the monsoon

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Abstract: The present work deals with the diversity of spiders during the monsoon within the Saurashtra University Campus, Rajkot, Gujarat. A total of 38 species of spiders belonging to 32 genera and 14 families were recorded. Araneidae (25.81%) was found to be the most dominant family, with nine species from five genera. Guild structure analysis revealed seven feeding guilds, among all 31% most dominant feeding guilds represented by orb-web builders and stalkers, followed by ground runners (13%), irregular webs (10%), ambushers (7%), foliage hunters (6%), and space-web builders (2%). Ecological indices reveal high species richness (Margalef's d = 8.97) and diversity (Shannon Index H' = 3.526, Fisher alpha diversity α = 41.73). It concludes that the abundance of spider species at this study site was high and the evenness index was also high (e >0, e = 0.8944). These findings suggest the absence of stress elements in the study area.

Keywords: Climate, evenness, feeding guilds, habitat, H' index, predatory status, Rajkot, species distribution, western India.

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General ethics: The author declares that this work is carried out within an appropriate ethical framework and voucher specimens were deposited at museum of Department of Biosciences, Saurashtra University, Rajkot, Gujarat and specimens were registered under SUBZ1 – SUBZ60.

Author details: Following the completion of his master's degree at Saurashtra University, Rajkot, Jyotil K. Dave is presently pursuing a PhD scholar at the Tropical Ecology and Evolution (TrEE) lab, Indian Institute of Science Education and Research Bhopal (IISER Bhopal). His master's work focused on the ecology and taxonomy of spiders. Additionally, he studied the ecological aspects in the polymorphism of *Cellana karachiensis* (Gastropoda). He focused his B. Sc. thesis on the foraging habits of the Jungle Babbler *Turdodies straita*. In the International Science Symposium, he received first place for his poster and second place for his oral presentation. He was a volunteer for WII's CAMPA Dugong Conservation Program and Wildlife Crime Control Bureau (WCCB, Western region). Varsha Trivedi is a retired professor in Zoology, Department of Biosciences, Saurashtra University, worked since 1998- 2021. Research Interest: Work carried out in avian biology related to functional anatomy and eco-morphology in Columbiformes birds in PhD; other fields with research team animal taxonomy & ecology - spider, moth, butterfly, birds, amphibians and reptilians; Behavioral and habitat ecology; Wildlife & Conservation Biology. Mentored Dissertation Thesis -70 MSc., 06 MPhil. and 03 PhD.

Author contributions: JD undertook field data collection, field photography and preservation and handling of spiders, organized and assimilated the data, table and graphic preparation and drafted the manuscript. VT has done Spider Identifications, field and microscopic generic photography, final manuscript preparation, analysis, read, approval and communication.

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INTRODUCTION

Spiders are ubiquitous predatory organisms in the animal kingdom (Riechert & Lockley 1984). They are abundant predators in many terrestrial ecosystems, with populations estimated to approach one million individuals per hectare in the wild (Bristowe 1971). They are primarily entomophagous, while few are involved in arachnophagy (Wise 1993). Many spider families contain species capable of capturing vertebrate prey, which are termed ''habitual vertebrate-eaters'' and ''occasional vertebrate-eaters''; some larger spider species occasionally feed on small mice, birds and lizards (Nyffeler & Gibbons 2022). Spiders play a significant ecological role as exclusive predators and regulate insect populations (Wise 1993). Being ectothermic organisms, the food, feeding behaviors, metabolic rate and activity levels of spiders vary with temperature (Barghusen et al. 1997).

Currently, 51,733 species of spiders, belonging to 4,355 genera and 136 families, are reported worldwide (World Spider Catalog 2023). Their diversity in India is represented by 1,968 species in 498 genera and 62 families (Caleb & Sankaran 2023) and in Gujarat with 533 species under 190 genera and 41 families (Singh et al. 2023).

The present work intends to study the diversity and predatory functional group of spider species, during the monsoon and add information to the database of spider species on the Saurashtra University Campus, Rajkot.

Study area

Saurashtra University Campus (SUC) is situated in Rajkot City (22.291˚N, 70.743˚E, 140 m), in central Gujarat, State in western India (Figure 1). Biogeographically, the area falls within the biotic province 4B — Gujarat Rajputana — of the 4 - semi-arid zone (Rodgers & Panwar 1988). The climate of Rajkot is tropical semi-arid with three distinct seasons each year: monsoon, winter and summer. The annual rainfall is erratic in its occurrence, duration, and intensity. The annual rainfall was high (1,187.5 mm) during 2021; the average temperature varies between 21.73 ˚C and 34.62 ˚C, and the average annual humidity ranges from 59.0–93.8 % (morning) and 16.5–83.9 % (evening). The area spans 1.456 km^2 (360 acres) with hilly terrain (Figure 1B).

The SUC has centrally congregated concrete buildings, many parking sites where human activities are more common, habitat structures, and vegetation layers including many small to large water catchment areas, large ponds, check dam, a landscape with flat and hilly rocky terrain covering herbs and grassland patches, a large sports complex, wasteland on the periphery, vegetative implant areas like Dhanvantri Aaushadhi Udayan, forest lands, and a large botanical garden with a newly developed Miyawaki dense garden, which comprises a floristic diversity of 71 species in 62 genera belonging to 32 families (Lagariya & Kaneria 2021).

METHODS

The present work was conducted from August to October 2021 at SUC, Rajkot, comprising 31 visits conducted randomly in morning and evening sessions. On average, two hours were spent during each visit using techniques such as beating vegetation, aerial handpicking from buildings, vegetation and the ground surface handpicking technique during active visual searching.

Preservation and identification

The captured spiders were stored in plastic bottles with small holes for aeration. In the laboratory, only voucher specimens were transferred to 70% alcohol for later identification and kept in specimen tubes with labeling and the remaining live specimens after microscopic examination were freed into the wild. Detailed species identification was carried out under a stereo-zoom dissecting binocular microscope (Stemi 305 Zeiss ISH500) up to the generic and species levels. Microscopic photographs of the spider were captured using a Canon Power Shot A2300 HD Digital Camera and a Tucsen Camera (ISH500) mounted on the stereomicroscope.

Taxonomic identification was performed using the following references: Tikader (1971, 1982), Tikader & Biswas (1981), Tikader & Malhotra (1980), Sethi & Tikader (1988), Majumder & Tikader (1991), Beatty et al. (2008), Gajbe (1999, 2008), Chen & Chen (2002), Shukla & Broome (2007), Han & Zhu (2010), Kim & Lee (2014), Pravalikha & Srinivasulu (2015), Hänggi & Sandrine (2016), Caleb et al. (2017), Caleb & Acharya (2020), Prajapati & Kamboj (2020), Sankaran et al. (2021), Caleb & Wijesinghe (2022) and other relevant literature from the World Spider Catalog (WSC 2023).

Voucher specimens were deposited at the museum of the Department of Biosciences, Saurashtra University, Rajkot, Gujarat, with registration numbers from SUBZ1 to SUBZ62. Shannon diversity – (H'), evenness – (e^H/S), Margalef's species richness (d) and Fisher

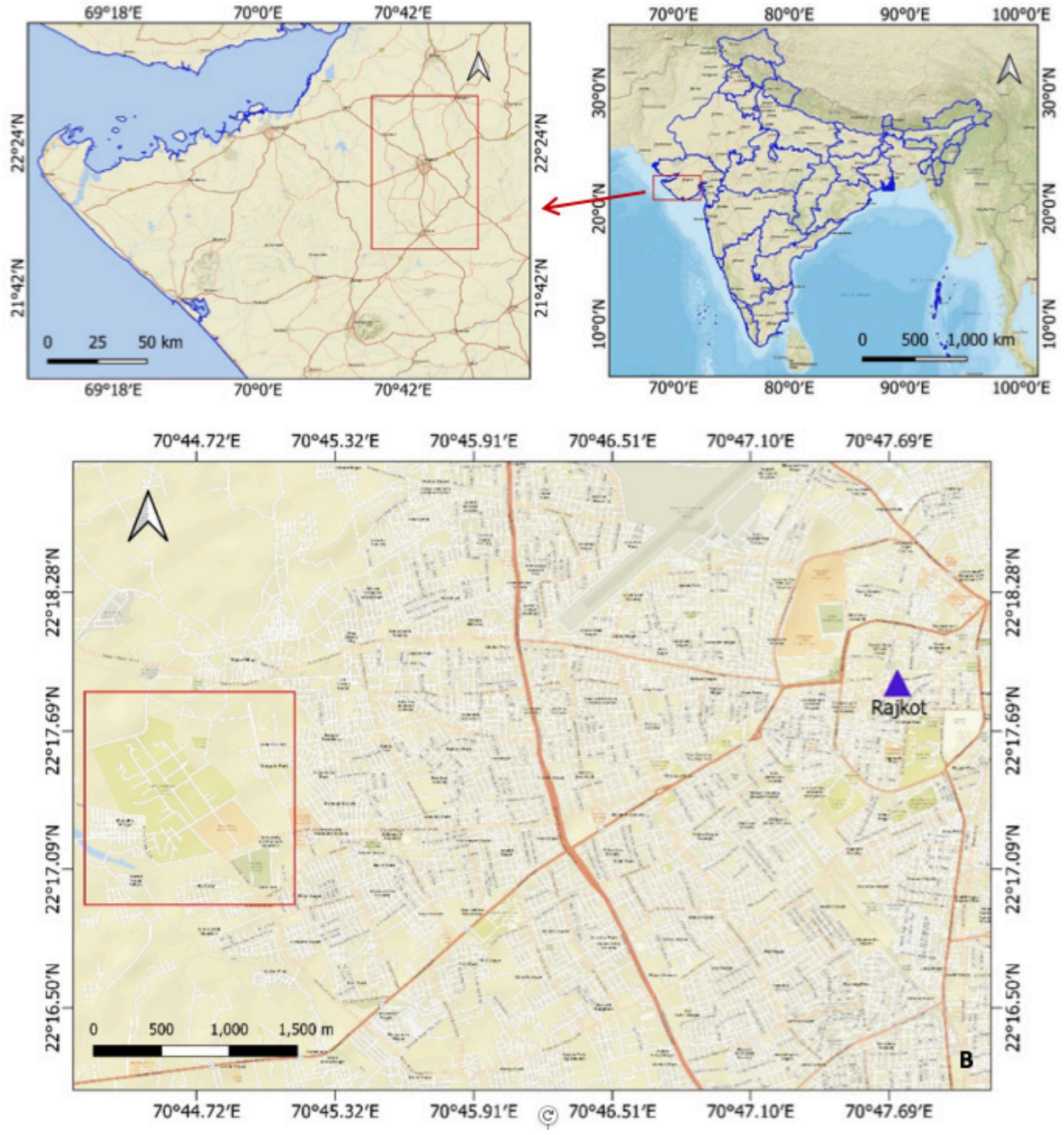

Figure 1. Map showing study areas: A—Location of Rajkot (red square) in Gujarat state of Western India | B —Location of Saurashtra University Campus (red square) in Rajkot. (Mapping by QGIS 3.28.3). Prepared by Varsha Trivedi.

alpha diversity (α) were computed using PAST software (Hammer et al. 2001) and their interpretations followed Magurran (2004).

RESULTS AND DISCUSSION

Out of the 62 spider specimens collected, a total of 38 species classified under 32 genera and 14 families were recorded during the monsoon at Saurashtra University Campus (Table 1). This represents 22.58% of the total 62 families reported from India (Caleb & Sankaran 2023). The family Araneidae exhibited the

Table 1. Checklist of spiders of Saurashtra University Campus areas.

Common name / Feeding guild	Registration no.	Scientific name	No. of specimens, sex & stage
True-orb weavers /Orb-web builders	**Family: Araneidae Clerck, 1757**		**16**
	SUBIOZ1	1. *Argiope anasuja* Thorell,1887	1♀
	SUBIOZ2	2. *Argiope* sp. 1	1♀J
	SUBIOZ3	3. *Argiope* sp. 2	1Y
	SUBIOZ4	4. *Eriovixia excelsa* (Simon, 1889)	3♀
	SUBIOZ7	5. *Eriovixia* sp.	1♂J, 1VY
	SUBIOZ54	6. *Guizygiella* sp.	1Y
	SUBIOZ9	7. *Neoscona theisi* (Walckenaer, 1841)	1♀
	SUBIOZ10	8. *Neoscona* sp.	2♀J, 1Y,1VY
	SUBIOZ14	9. *Poltys* sp.	2♀J
Sac spider/Foliage hunters	**Family: Clubionidae Simon, 1878**		**1**
	SUBIOZ16	10. *Clubiona* sp.	1♀J
Ground sac spiders/ Ground runners	**Family: Corinnidae Karsch, 1880**		**1**
	SUBIOZ17	11. *Castianeria* sp.	1♀J
Ground spider/ Ground runners	**Family: Gnaphosidae Banks, 1892**		**1**
	SUBIOZ18	12. *Eilica tikaderi* Platnick, 1976	1♂
Two tailed spiders/ Foliage hunters	**Family: Hersiliidae Thorell, 1869**		**2**
	SUBIOZ19	13. *Hersilia savignyi* Lucas,1836	1♀, 1♀SA
Wolf spiders/Ground runners	**Family: Lycosidae Sundevall, 1833**		**6**
	SUBIOZ21	14. *Evippa shivajii* Tikader & Malhotra, 1980	1♀
	SUBIOZ22	15. *Hippasa* sp.	1♀J
	SUBIOZ23	16. *Wadicosa fidelis* (O. Pickard-Cambridge, 1872)	1♀, 1♂
	SUBIOZ25	17. *Wadicosa* sp.	2♂J
Lynx spiders/ stalkers	**Family: Oxyopidae Thorell, 1869**		**5**
	SUBIOZ27	18. *Oxyopes bharatae* Gajbe, 1999	2♀
	SUBIOZ29	19. *Oxyopes hindostanicus* Pocock, 1901	3♀
Daddy long-leg spiders/irregular webs	**Family: Pholcidae C. L. Koch, 1850**		**6**
	SUBIOZ32	20. *Artema atlanta* Walckenaer, 1837	1♀
	SUBIOZ33	21. *Crossopriza lyoni* (Blackwall, 1867)	3♀
	SUBIOZ36	22. *Pholcus phalangioides* (Fuesslin, 1775)	1♀, 1♂
Nursery web Spiders/ambushers	**Family: Pisauridae Simon, 1890**		**1**
	SUBIOZ38	23. *Perenethis* sp.	1 Y
Jumping spiders/ Stalkers	**Family: Salticidae Blackwall, 1841**		**14**
	SUBIOZ40	24. *Hasarius* sp.	1♀J, 1♂J
	SUBIOZ42	25. *Hyllus semicupreus* (Simon, 1885)	1♀, 1♂
	SUBIOZ44	26. *Langona* sp.	1♂
Jumping spiders/ Stalkers	SUBIOZ45	27. *Menemerus* sp.	1♀J, 1♂J, 1Y
	SUBIOZ39	28. *Mogrus* sp.	1♀
	SUBIOZ51	29. *Phintelloides undulatus* (Caleb & Karthikeyani, 2015)	1♂
	SUBIOZ48	30. *Plexippus paykulli* (Audouin, 1826)	1♀, 2♂
	SUBIOZ52	31. *Thyene imperialis* (Rossi, 1846)	1♀
Huntsman spiders/ Foliage hunters	**Family: Sparassidae Bertkau, 1872**		**1**
	SUBIOZ53	32. *Olios obesulus* (Pocock, 1901)	1♀

Common name / Feeding guild	Registration no.	Scientific name	No. of specimens, sex & stage
Comb-footed/ Space web builders	**Family: Theridiidae Sundevall, 1833**		**2**
	SUBIOZ55	33. *Latrodectus geometricus* C. L. Koch, 1841	1♀,1♂
Crab spiders/ Ambushers	**Family: Thomisidae Sundevall, 1833**		**3**
	SUBIOZ57	34. *Monaeses* sp.	1♂
	SUBIOZ58	35. *Thomisus* sp.	1♀J
	SUBIOZ59	36. *Tmarus kotigeharus* Tikader, 1963	1♀
Feather legged lace weaver/ Orb-web builders	**Family: Uloboridae Thorell, 1869**		**3**
	SUBIOZ60	37. *Miagrammopes* sp.	1♀SA
	SUBIOZ61	38. *Uloborus* sp.	2♀

SA—Sub adult | J—Juvenile | Y—Young | VY—Very young | SUBIOZ—Saurashtra University, Museum of Department of Biosciences, Zoology.

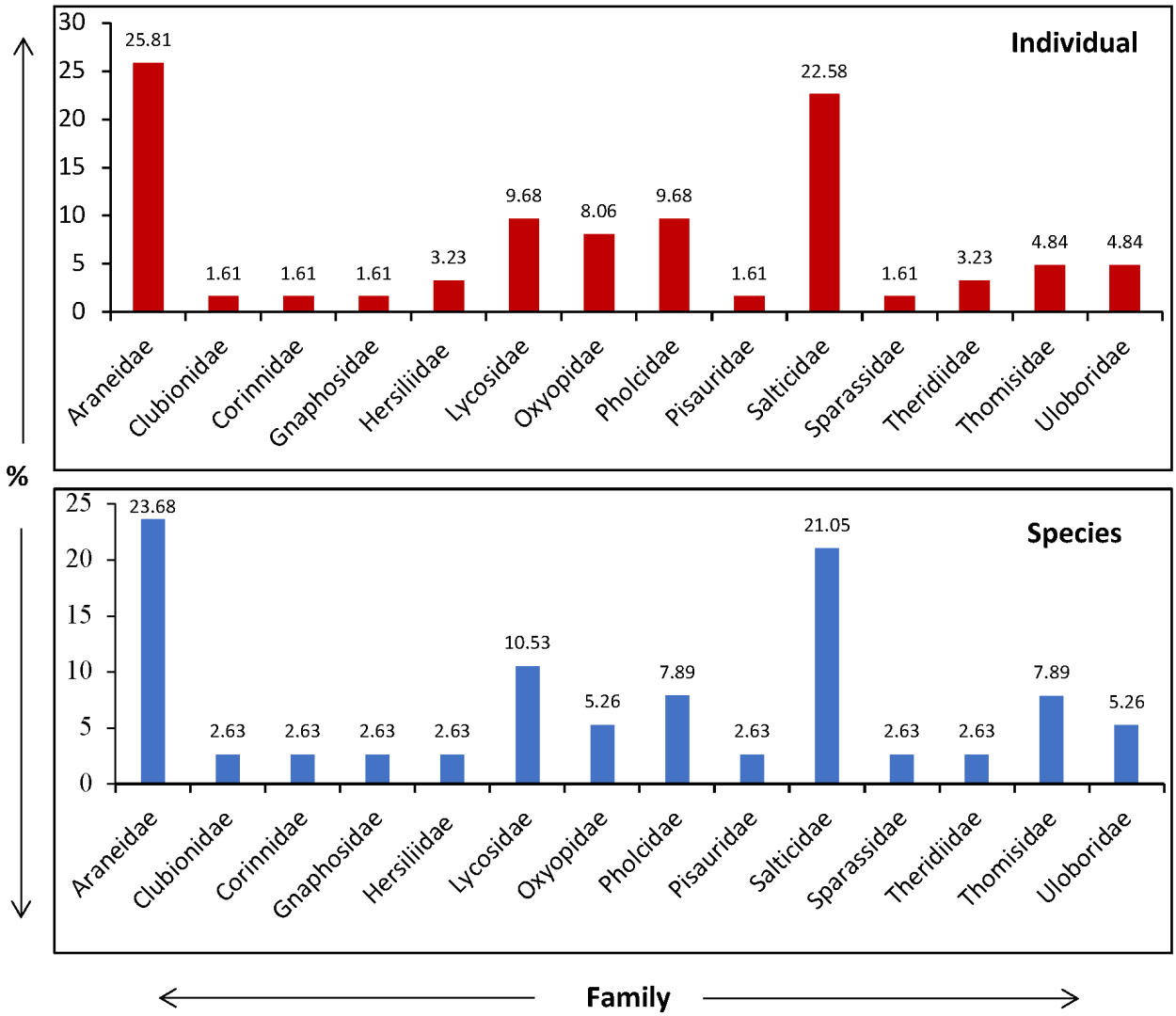

Figure 2. Familial percentages of individuals and species of spider during monsoon.

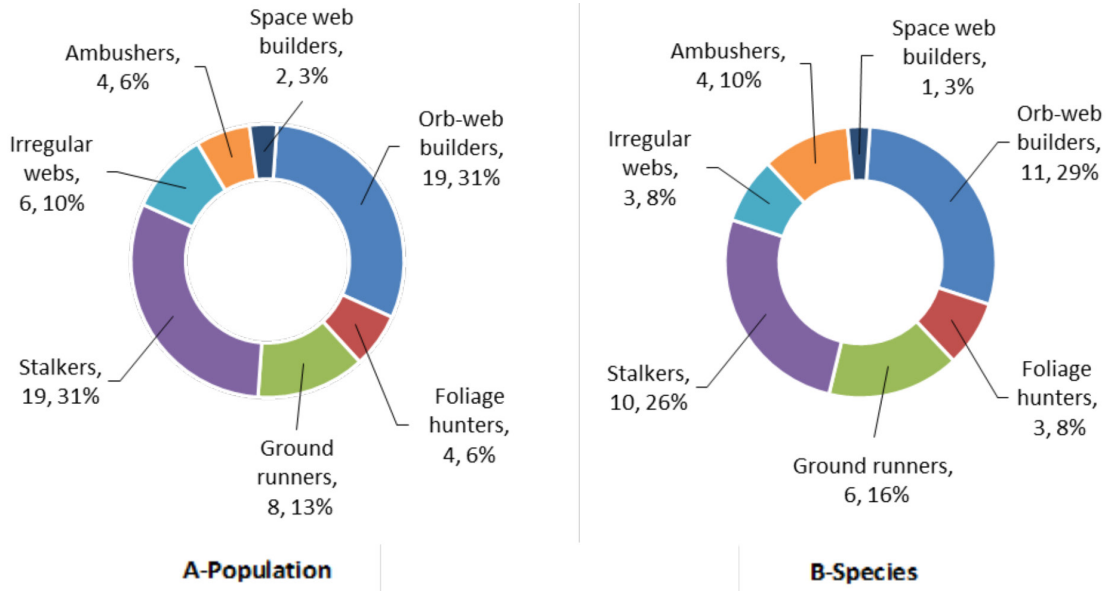

Figure 3. Predatory functional group of spiders with population (A) and species (B).

maximum representative with 16 individuals (25.81%), comprising nine species from five genera, followed by the family Salticidae with 14 individuals (22.58%), comprising eight species from eight genera (Table 1, Figure 2).

The relative abundance analysis of the age and sex status of the collected spiders revealed that females (73%) were almost three times as many as males (27%). The proportion of the potential group (adults) to non-potential individuals was almost one and a half (1.5P:1NP). Age and sexual maturity of spiders may provide a broad range of mate choice decisions for males, as males of a sexually cannibalistic spider chemically assess relative female quality and mate with adaptive females (Cory & Schneider 2020).

Seven feeding guild structures (Uetz et al. 1999), including orb-web builders (31%), stalkers (31%), ground runners (13%), irregular webs (10%), ambushers (6%), foliage hunters (6%) and space-web builders (3%) were recorded. Among these, the most dominant were orb-web builders (19 individuals from 11 species) and stalkers (19 individuals from 10 species). Among orb-web builders, araneids were dominant with nine species compared to Uloboridae (two species), while stalkers (31%) were primarily from the families Oxyopidae and Salticidae. Ground runners (13%) included members from the families Corinnidae, Gnaphosidae and Lycosidae, while irregular webs (10%) included pholcids. Ambushers (6%) included Pisauridae and Thomisidae. Foliage hunters (6%) include clubionids, hersiliids and sparassids and only 3% were space web builders (theridiids) (Table 1, Figure 3).

Among the 38 spider species, 21 were habitat-specific and were found in the Miyawaki forest in the botanical garden and Nandanvan forest areas. Species such as *Poltys* sp., *Clubiona* sp., *Evippa shivajii* Tikader & Malhotra, 1980, *Hippasa* sp., *Hyllus semicupreus* (Simon, 1885), *Mogrus* sp., *Thyene imperialis* (Rossi, 1846), *Olios obesulus* (Pocock, 1901), *Thomisus* sp., *Tmarus kotigeharus* Tikader, 1963, and *Miagrammopes* sp. were among those found. Another 17 species, including *Guizygiella* sp., *Castianeria* sp., *Eilica tikaderi* Platnick, 1976, *Perenethis* sp., *Langona* sp., *Phintelloides undulatus* (Caleb & Karthikeyani, 2015), *Monaeses* sp., and *Uloborus* sp. were found near buildings, parking lots and ground surface areas. *Latrodectus geometricus* C.L.Koch, 1841, was found to be more common at parking spots along the corners of iron pole joints.

The Shannon Weiner Index (H') in the current study was high (H'= 3.526). A high H' value would indicate an even distribution of species. It allows us to not only know the number of species but also the abundance of the community. Typical values of the Shannon-Weiner Index (H') are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. The Shannon index increases as both the richness and the evenness of the community increase. It can be concluded that the abundance of spider species at this study site is high. The evenness index (e) was high (e >0, 0.8944). As the evenness index increases with a decrease in stress (Pielou 1966), this indicates that the study areas have very minimal to no stress elements.

Margalef's species richness indicated a higher value (d = 8.97), and this minimizes the effect of sample size bias (Odum 1971). Species richness as a measure on its own takes no account of the number of individuals of each species present. It gives as much weight to those species that have very few individuals as compared to those that have many individuals (Magurran 2004). Fisher's alpha diversity (α = 41.73) is also significantly high. This may reflect comparatively less stress in their environment.

The feeding guild analysis represents 31% of orb-web weavers and stalkers. This may be due to flourishing vegetation layers during monsoon, including trees, shrubs, grasses and herbs landscapes that provide a healthy environment and shelters to other faunal invertebrate and vertebrate organisms; vegetation stratifications reveal ideal substrate for orb-web weaver spiders such as araneids and uloborids. The web-spinning activities are usually influenced by physiological factors, i.e., temperatures, humidity and rainfall (Barghusen et al. 1997). Stalkers, including salticids and oxyopids, feed on similar prey. Web-weavers are almost strictly insectivorous, while stalkers and wandering spiders exhibit a mixed strategy of insectivorous and araneophagic foraging patterns (Nyffeler 1999). The presence of diverse spider species (Table 1) indicates healthy surroundings, availability of food resources, habitat structures, prey occurrence and feeding activities during the study period at Saurashtra University Campus.

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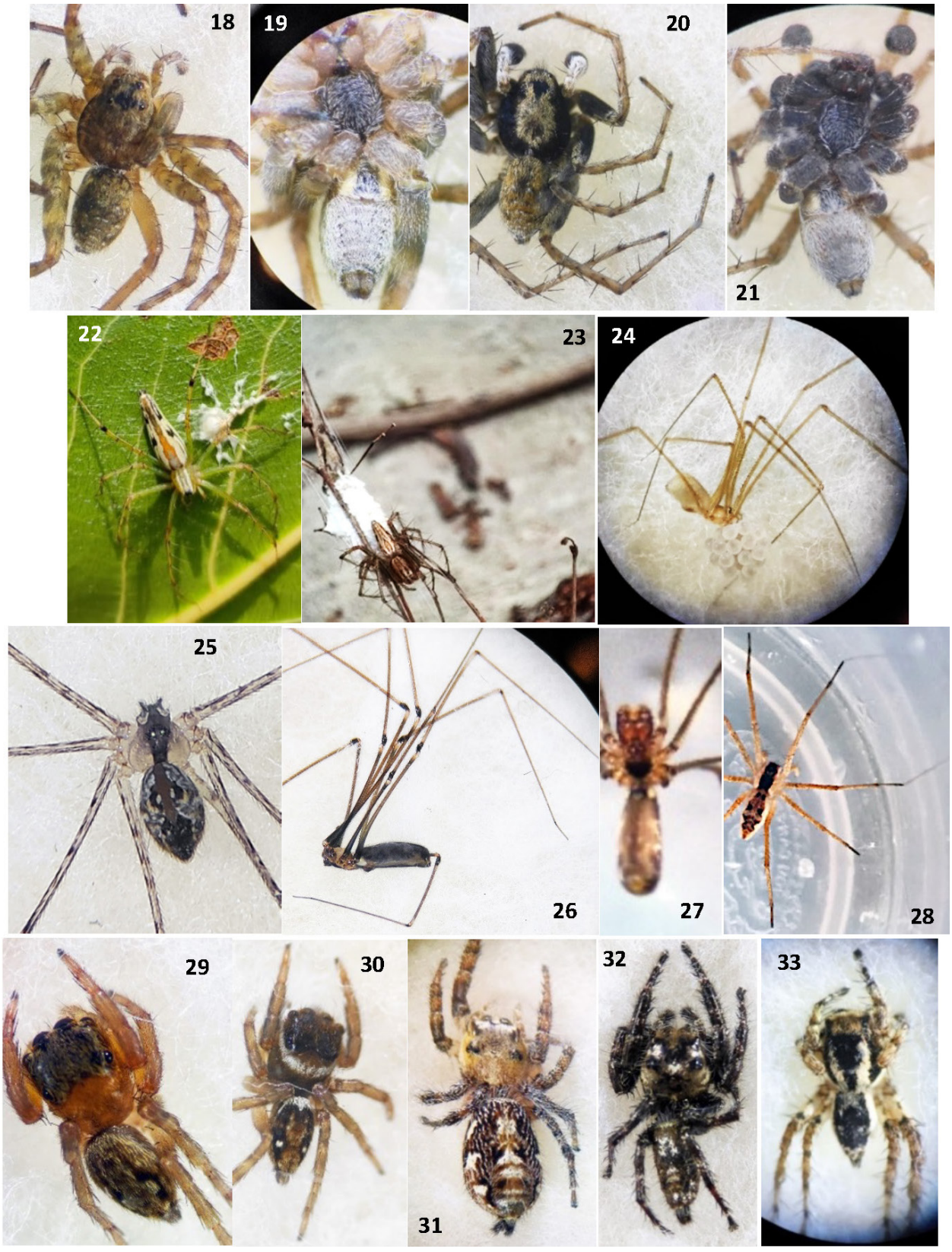
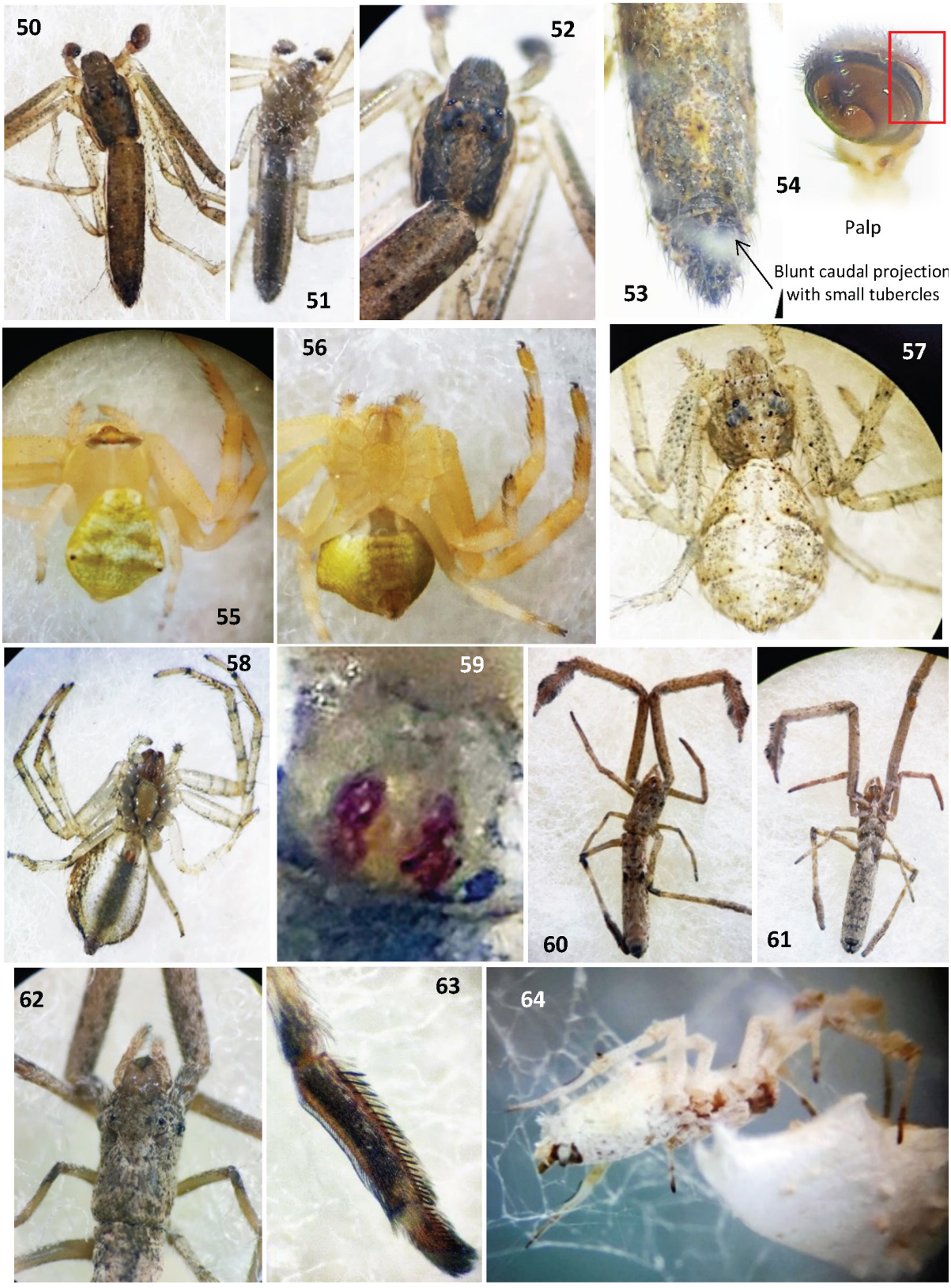
Images 1 to 17 represent spiders of SUC.
1—*Argiope anasuja* ♀ dorsal | 2— Same, ventral | 3—*Argiope* sp.2 | 4—*Eriovixia excelsa* ♀ reddish brown dorsal | 5—*Eriovixia excelsa* ♀ yellowish white dorsal | 6—*Eriovixia excelsa* ♀ ventral | 7—*Guizygiella* sp. | 8—*Neoscona theisi* ♀ dorsal | 9— Same, ventral | 10—*Poltys* sp. ♀ | 11—*Clubiona* sp. ♀ | 12—*Casteineria* sp. ♀ | 13—*Elica tikaderi* ♂ | 14—*Hersilia savignyi* ♀ dorsal dark brown | 15—*Hersilia savignyi* ♀ dorsal white brown | 16—*Evippa shivajii* ♀ dorsal and external epigyne in the inset | 17—*Hippasa* sp. ♀. © Jyotil Dave & Varsha Trivedi.



Images 18 to 33 represent spiders of SUC.
18—*Wadicosa fidelis* ♀ dorsal | 19—Same, ventral | 20—Wadicosa fidelis ♂ dorsal | 21—Same, ventral | 22—*Oxyopus bhartae* ♀ with eggs | 23—*Oxyopus hindostanicus* ♀ with eggs | 24—*Aretema atlanta* ♀ with eggs | 25—*Crossopriza lyoni* ♀ | 26—*Pholcus phalangioides* ♀ lateral | 27—*Pholcus phalangioides* ♂ ventral | 28—*Perenethis* sp. | 29—*Hasarius* sp. ♀ | 30—*Hasarius* sp.♂ | 31—*Hyllus semicupreus* ♀ dorsal | 32—*Hyllus semicupreus* ♂ dorsal | 33—*Langona* sp. ♂.

Images 34 to 49 represent spiders of SUC.
34—*Menemerus* sp. ♀ dorsal | 35—*Menemerus* sp. ♂ dorsal | 36—*Mogrus* sp. ♀ dorsal | 37—*Mogrus* sp. ♀ ventral | 38—*Phintelloides undulatus* ♂ dorsal | 39—Same, ventral | 40—*P. undulatus* ♂ ventral palp | 41—*Plexippus paykulli* ♀ | 42—*Plexippus paykulli* ♂ | 43—*Thyene imperialis* ♀ dorsal | 44—*Thyene imperialis* ♀ ventral | 45—*Olios obesulus* ♀ dorsal | 46—Same, ventral | 47—*O. obesulus* ♀ external epigyne | 48—*Latrodectus geometricus* ♀ dorsal | 49—*Latrodectus geometricus* ♂.



Images 50 to 64 represent spiders of SUC.
50—*Monaeses* sp. ♂ dorsal | 51—Same, ventral | 52—Same, carapace | 53—Same, caudal abdomen dorsal | 54—Same, ventral palp | 55—Thomisus sp. ♀ dorsal | 56—Same, ventral | 57—*Tmarus kotigehrus* ♀ dorsal | 58—Same, ventral | 59—Same, external epigyne | 60—*Miagrammopes* sp. ♀ dorsal | 61—Same, ventral | 62—Same, carapace | 63—Same, calamistrum on 4th leg | 64—*Uloborus* sp. ♀ with egg mass.

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