Article

Spatial and temporal variabilities in distribution of spiders of Chincholli Wildlife Sanctuary, India

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Abstract

Numerous micro-invertebrates' biodiversity fluctuates throughout time according to seasonal and temporal patterns year after year depending on various important components including the prevalence of microhabitats, the availability of food sources (preys), the complexity of the flora, etc. The current research looked into the temporal and spatial variation of spider species over a two-year period at four sampling sites within Chincholli Wildlife Sanctuary in Kalaburagi, Karnataka, India.A total of 48 species and 20 families were recorded via alternate methodologies, and the data obtained was then subjected to conventional diversity indexes. Observations indicated that Konchavarm (Site II) and the winter and early winter exhibit the greatest diversity (M1 and M4). Through the use of MANOVA, our study examined how sites and dates affected alpha diversity. The results showed that while dates had no significant impact on alpha diversity, variations in sites impacted. Our findings indicated a substantial positive link between similarity in the spider community and similarity in plant species, distance from one another geographically, and negative correlation between altitudinal separation. The research region had no prior resources in this setting, and these findings shed light on how vegetation complexity supports spiders by creating favourable microclimate and a multiplicity of prey species.

Keyword spatial and temporal; Araneidae; Chincholli Wildlife Sanctuary; vegetation complexity; diversity of spider.

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1 Introduction

The importance of biodiversity and ecosystem functioning in spatial and temporal context has been topic of great interest and progressively acknowledged in recent years. Temporal and spatial variability can be partitioned into local(alpha), landscape (Beta), region(gama) component concept for biological diversity

(Whittaker, 1972; Wang and Loreau, 2014) which depends on dispersal of species between local ecosystem- a combination of geographic distance, dispersal ability and barrier to movement (Patrick et al., 2021). Spiders have good powers of dispersal, they are diverse and abundant in agricultural landscapes and they consume a wide range of insect prey (Nyffeler and Sunderland, 2003). Furthermore, they have no negative effects on the crop plants. These traits make them potentially useful natural enemies of insect pests in crops. Spiders are sensitive indicator and model group to determine environmental change (Jocqué et al., 2005; Kapoor, 2008) and they are considered as a yardstick in conservational studies (Řezáč et al., 2015). Spiders are potential predators of insect pest in terrestrial ecosystem and also serving as food sources for arthropod preferring predators (Nyffeler and Birkhofer, 2017).

Synecological on spider with regard to its association with microclimate, spatial and temporal distribution and vegetation complex are infrequently studied in India.However, here we set out to examine the relation between effect of spatial and temporal variation on spider distribution and maintain their density in four different habitats of ChincholliWildlife Sanctuary.

2 Materials and Methods

2.1 Study area

Chincholli Wildlife Sanctuary is situated in North Eastern sector of the Karnataka state and physiographically defined as Deccan Plateau. It lies between the north latitudinal parallels of 16°41' and 17°46' and east longitudinal parallels of 76°3' and 77°41' (Fig. 1). This is the first dry land Wildlife Sanctuary of India, established in 28th November 2011 to protect the distinctive geological topography and natural resources and also to protect wolf and hyena habitats. Being one of the typical Deciduous and semi evergreen forests mixed with grassland patches majorly having acacia and teak plantation.

2.2 Sampling Sites

Spiders were sampled from different collection methods from four different habitats in Chincholli wildlife sanctuary. The first site was (Site I): Chikkalingadalli forest, is secondary forest with moderate thickness of vegetation where small amount of gathering activity by local peoples and visitors to the forest are allowed. Second site (Site II): Konchavarm forest- thick in vegetation, no human interference and only research activities are allowed. Third site (Site III): Gottamgotta forest thick in vegetation with elevations and hills, no human interference and only research activities are allowed. The fourth site (Site IV): Chandrampalli dam-area of aquatic habitat has human activity and agricultural area. From each sites spider sample were collected six time: December 2016-January 2017, March 2017-April 2017, June 2017-July 2017, November 2017-December 2017, April 2018- May 2018, September 2018-October 2018. Hereafter, the sampling date will be referred as M1, M2, M3, M4, M5 and M6 respectively.

2.3 Sampling

Different collection methods like active search, sweep net, beating methods, pitfall trap have been used to survey spiders. In each site, 10 collection spots, followed quadrate method. The minimum distance between the each collection spot was about 100 m. From February 2016 to February 2018, in each month (Middle 3 days of month) collections were carried out. Specimens obtained from each station were pooled together for analysis. Specimens collected were first sorted according to the development stage and sex. Adult spiders were sorted into morphospecies and most of them identified to species level by papal organ and epigynum by referring available literature on world spider catalogue, only few are identified till genus level. Most immature were identified to family and were not included in analysis. Voucher Specimens were deposited in Zoological Survey of India, Kolkata. India.

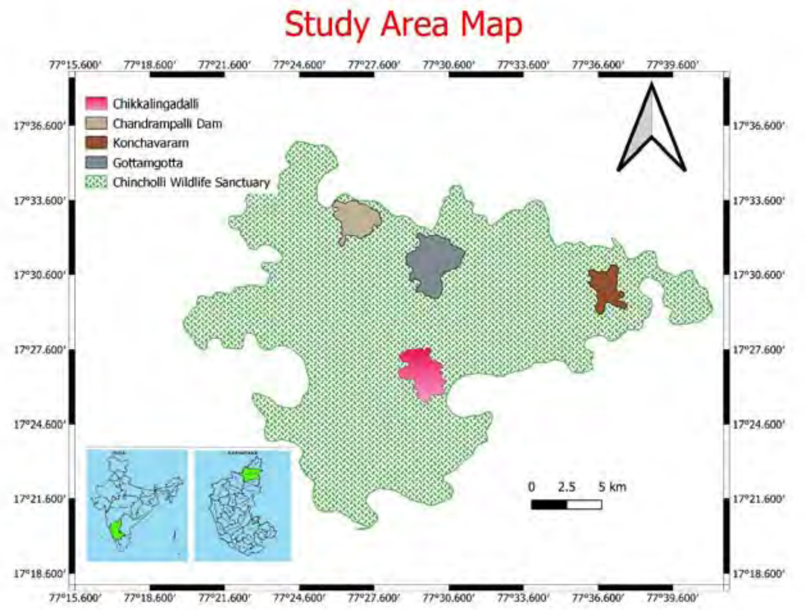

Fig. 1 Study area. Site I: Chikkalingadalli, Site II: Konchavaram, Site III: Gottamgotta, Site IV: Chanadrampalli Dam.

2.4 Analysis of data

The Shannon-weaver function and Simpson index were used to compare the community structure of spiders among different sites. The Shannon-weaver function expressed as:

$$H = -\sum (P_i) \times (\ln P_i)$$

where P_i is the percentage of species i in the total community. Samples having high species richness and equal abundance between species will generate higher H Value. The Simpson Index (D) is expresses as:

$$D = \sum P_i^2$$

Samples represented by a few dominant species and many are rare species will generate large D values, therefore, the Simpson index can be used to assess the degree of dominance of the sample. The value of the Shannon-Weaver function is more sensitive to the presence of rare species in the sample. On the other hand, the value of the Simpson index is less affected by rare species. We also calculated the evenness index, which is expressed as

$$E = \frac{H}{\ln S}$$

where S is the species number of the community. The value of evenness range from 0 to 1, which measures the degree of homogeneity in abundance between species. For all three indices one way ANOVA tests were used to compare value derived from the four sampling sites.

Species accumulation curve built (Gotelli and Colwell, 2001) using three sampling effort surrogates, which are number of individual (*N*), the number of subsamples. Multivariate analysis of variance (MANOVA) was conducted using species richness, Simpson's diversity index and Berger-Parker dominance index, while using site as a fixed factor and date as a covariates and vice versa. If MANOVA indicates significant differences between sites and dates, univariate analysis of variance (ANOVA) was performed for each variable. Non-matric multidimensional scaling (NMDS) in PAST version 4.05 was used to represent the sampling site across six sampling time and six sampling date across four sampling sites in two-dimensional ordination space. The stress value measured how well NMDS fitted the multidimensional data into two-dimensional space. Permutational multivariate analysis of variance (PERMANOVA) in PAST version 4.05 used to test for differences in composition of spider species among different sampling sites and main test were conducted across two random factor and 9999 unidirectional permutations were performed. Mantel test were used to test for correlation between the similarity of spider community structure, the similarity of tree community composition, geographical distances and altitudinal differences among sites.

3 Results and Discussion

3.1 The hitherto studies on spatial and temporal variabilities on diversity of spider in Chincholli wild life sanctuary was carried out and the total 6008 individuals represented 48 spider species. The average spider density was 50 individuals m^{-2} of area. The species represent in 20 families and 48 genera (Table 1). The most common morphospecies were *Theridion varians* (20.72%), *Cyclosa insulana* (16.44%), *Cyrba ocellata* (12.89%), *Pardosa birmanica* (11.9%), *Oxyopes kohensis* (11.8%) which all together represents 73.85% of all individuals. Out of all 16.32% were represented by only one individual, 22.44% were represented by 2 individuals (Table 1).

Table 1 Spider species recorded during the study period along with investigated sites and dates. ✓= represents the presence of species.

Sl. No.	Species name	Site I						Site II						Site III						Site IV					
		M1	M2	M3	M4	M5	M6	M1	M2	M3	M4	M5	M6	M1	M2	M3	M4	M5	M6	M1	M2	M3	M4	M5	M6
1	*Cyclosa insulana*	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
2	*Nephila pilipes*	✓		✓	✓						✓		✓				✓			✓					
3	*Poltys nagpurensis*			✓																					
4	*Neoscon theisi*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓
5	*Castianeira zetes*	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	0	✓	✓	0	✓
6	*Gnaphosa sp1*	✓	✓	✓	✓	✓	✓	✓		✓	✓			✓			✓								
7	*Gnaphosa sp2*										✓														
8	*Hersilia savignyi*	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓						
9	*Pardosa birmanica*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
10	*Arctosa himalayensis*	✓	✓	✓	✓	✓	✓						✓	✓		✓									
11	*Hippasa holmera*								✓			✓			✓			✓		✓	✓	✓	✓	✓	✓

12	*Geolycosa carli*							✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓						✓
13	*Lycosa sp1*									✓								✓		✓					
14	*Oxyopes kohaensis*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
15	*Peucetia yogeshi*							✓	✓		✓	✓		✓	✓		✓	✓		✓	✓		✓	✓	
16	*Perenethis venusta*							✓																	
17	*Cyrba ocellata*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓
18	*Plexippus paykulli*		✓	✓		✓			✓			✓				✓		✓	✓		✓	✓		✓	✓
19	*Stenaelurillus arambagensis*		✓	✓		✓	✓			✓			✓		✓			✓	✓		✓	✓		✓	
20	*Aelurillus sp1*							✓	✓		✓	✓		✓											
21	*Longona bristowei*									✓			✓		✓	✓		✓	✓		✓	✓		✓	✓
22	*Asianellus potanini*	✓		✓	✓		✓	✓		✓	✓		✓			✓			✓						
23	*Harmochirus brachiatus*							✓						✓											
24	*Menemerus bivittatus*		✓	✓		✓	✓						✓								✓	✓		✓	✓
25	*Hyllus sp1*	✓		✓	✓		✓						✓		✓			✓							
26	*Heteropoda sp1*							✓	✓	✓	✓	✓		✓			✓								
27	*Oliostener*																				✓				
28	*Guizygiella shivui*		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
29	*Leucauge decorata*							✓		✓	✓	✓		✓		✓	✓	✓	✓	✓		✓	✓	✓	✓
30	*Tetragnatha gressitti*							✓		✓	✓	✓			✓										
31	*Tetragnatha sp2*	✓																							
32	*Achaearanea sp1*			✓																					
33	*Theridion varians*	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
34	*Steatoda sp1*			✓			✓			✓			✓			✓			✓						✓
35	*Argyrodes fasciatus*	✓			✓			✓			✓			✓			✓			✓			✓		
36	*Rhomphaea sp*								✓																
37	*Ozyptilia sp*																✓								
38	*Thomisus whitakeri*	✓			✓			✓	✓		✓			✓	✓		✓		✓	✓			✓		
39	*Runcinia sp*	✓		✓	✓		✓		✓			✓	✓							✓		✓	✓		✓
40	*Uloborus sp1*																							✓	
41	*Euryodionkatepagae*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓						

42	*Tropizodium kalami*										✓														
43	*Pandava sp*																✓								
44	*Clubiona*		✓																						
45	*Dictyna sp*																								✓
46	*Indothele dumicola*									✓															
47	*Palpimanus sp*													✓											
48	*Oecobius marathaus*																				✓				

The highest number of individuals were found from Konchavaram forest (Site II) (1900) andlowest from Chandrampalli dam (Site IV) (956) (Table 2 and Fig. 2). Out of all sampling months the number of individuals was highest during November to January(pre-winter) (average 1231) and lowest during March and May (spring and summer season) (Table 3 and Fig. 3). The species accumulation curve did not reach an asymptote when all sites were pooled.

The data was subjected to the traditional diversity indices i.e. Shannon-wiener index, Simpson’s Diversity index and Berger-Parker dominance index to measure alpha diversity across different sites and dates. Among sites, Site II represents highest and Site IV represents lowestabundance and diversity of species (Table 2). Among dates M1 and M4 shows highest and M2 and M5 shows lowest abundance and diversity of species (Fig. 3).

The overall effect of sampling sites on alpha diversity indices and density of spider was statistically significant (MANOVA F=3.2; P=0.01; Wilk’s lambda=0.44; Table 4). This was caused by density of spiders which varies among sampling sites (ANOVA: F=2.76, P=0.0014), while species richness, Shannon and Berger-Parker dominance index wasdiffered significantly among sites (ANOVA: F=7.53, P=0.001; F=6.61, P=0.002; F=4.17, P=0.01, respectively).

The overall effect of sampling date on alpha diversity indices and density of spiders was significant (MANOVA: F=3.82, P=0.001& Wilk’s lambda: 0.49; Table 4). This was caused by species richness which varied among sampling dates (ANOVA F=1.80, P=0.40), while Shannon and Berger-Parker dominance index was not differed significantly among dates (ANOVA: F=0.91, P=0.49; F=1.00, P=0.44, respectively).

The compositions of spiders community differs significantly among sampling sites and dates. There was significant interaction between sites and dates. Site S2 and S3 has the highest number of shared spider species while S4 had least shared spider species with other sites. Based on sampling dates M1 and M4; M2 and M5 had highest number of shared species.

The result of non-metric multidimensional scaling represents that spider community shows moderate difference in species composition across sampling date and sites (Figs 5 and 6). Faunal and floristic similarity, distance among sites and altitudinal difference among sites correlate with each other. Similarity with spider community composition positively correlated with similarity of tree community (Mantel test r=0.437, P=0.003). Spider community similarity was positively correlated with geographic distance and negatively correlated with altitudinal separation (Mantel test r=0.274, P=0.002; r=-0.076, P=0.538, respectively). Geographic distance and altitudinal differences among the sites positively correlated and significant (Mantel test: r=0.040, P=0.004).

Table 2 Measured diversity index variables of spider species in different collection sites of Chincholli Wildlife Sanctuary, Kalaburagi, Karnataka, India.

Sites	Abundance in No.	Species Richness	Density	Simpson	Shannon	Berger-Parker
Site-I	1503	25	5.0	0.98	2.84	0.05
Site-II	1900	34	6.3	0.98	3.13	0.03
Site-III	1704	30	5.6	0.98	3.00	0.04
Site-IV	956	22	3.1	0.97	2.61	0.06

Table 3 Measured diversity index variables of spider species in different collection dates of Chincholli Wildlife Sanctuary, Kalaburagi, Karnataka, India.

Dates	Abundance in No.	Species Richness	Density	Simpson	Shannon	Berger-Parker
M1	1230	27	4.1	0.96	3.27	0.04
M2	695	26	2.3	0.95	3.16	0.06
M3	1165	29	3.8	0.96	3.29	0.04
M4	1232	27	4.1	0.97	3.23	0.05
M5	634	26	2.1	0.95	3.19	0.03
M6	1052	24	3.5	0.95	3.13	0.05

Table 4 PERMANOVA main test for difference in community composition of spider among sampling sites and dates. df: Degree of freedom; F: Pseudo F value; p: Permutational p value.

	Sum of squers	df	Mean squres	F	P
Sampling dates	0.172	5	0.034	37.20	0.0001
Sampling sites	0.153	3	0.041	55.03	0.0001
Dates X Sites	0.035	15	0.002	2.57	0.0026

3.2 The two years of survey conducted in Chincholi Wildlife Sanctuary yields good representation of spider diversity which incorporate 6008 individuals representing 20 families, 48 genera and 48 spider species. As 48 species were collected from entire study area, more than 15 species were distributed in all the sites. Diversity and richness is also good in all sampled sites but indicates highest diversity in Site II (Konchavaram forest) which is due to high vegetation complexity. This is in accordance with the findings of Muma (1973), Gertsch and Riechert (1976), Uetz (1979), Wise (1993), Rypstra et al. (1999), Valverde and Lobo (2007) which show that vegetation structure is widely recognized as one of the main determinant of spiders which have different association with their composition and assemblage. As result suggested by study (Nardi and Marini, 2021) spider species richness and activity density lower in forest than other open habitats but we found less species composition in Site II where agriculture activity is prominent. Most abundant species in study area are belongs to the Family Theridiidae, Araneidae and Salticidae. Similarly site II composed of more web builders, hunters this implies the fact that vegetation complexity provides availability of structures for attachment of web and ambush and refuge sites creates suitable microclimates by assisting to predation (Uetz, 1991; Marc et al., 1999). This finding is also supported by the investigations of (Nardi and Marini, 2021; Lia et al., 2022) where wider vegetation diversity significantly enhance habitat complexity and provide wider selection of web attachment site for spider species.

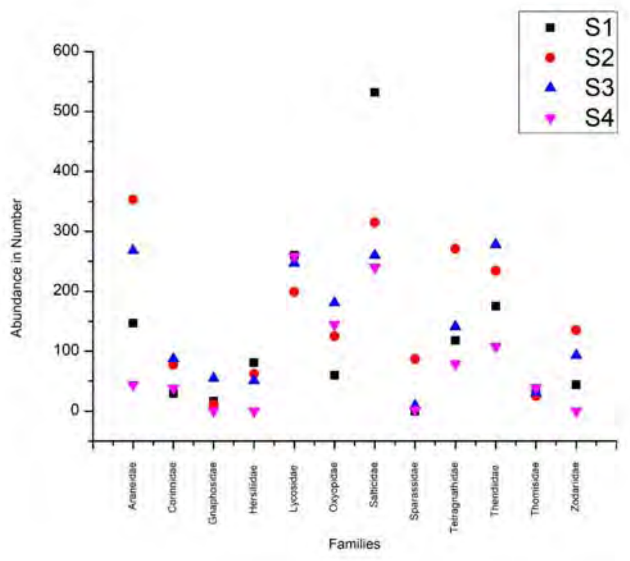

Fig. 2 Relative abundance of family in different collection sites of Chincholli Wildlife Sanctuary, Kalaburagi, Karnataka, India. Spider species belong to top 12 families are listed and clustered.

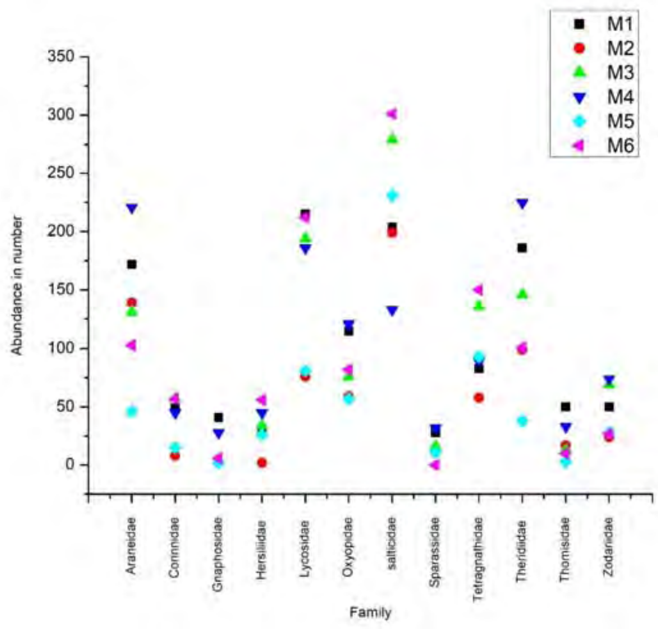

Fig. 3 Relative abundance of Family in different collection dates of Chincholli Wildlife Sanctuary, Kalaburagi, Karnataka, India. Spider species belong to top 12 families are listed and clustered.

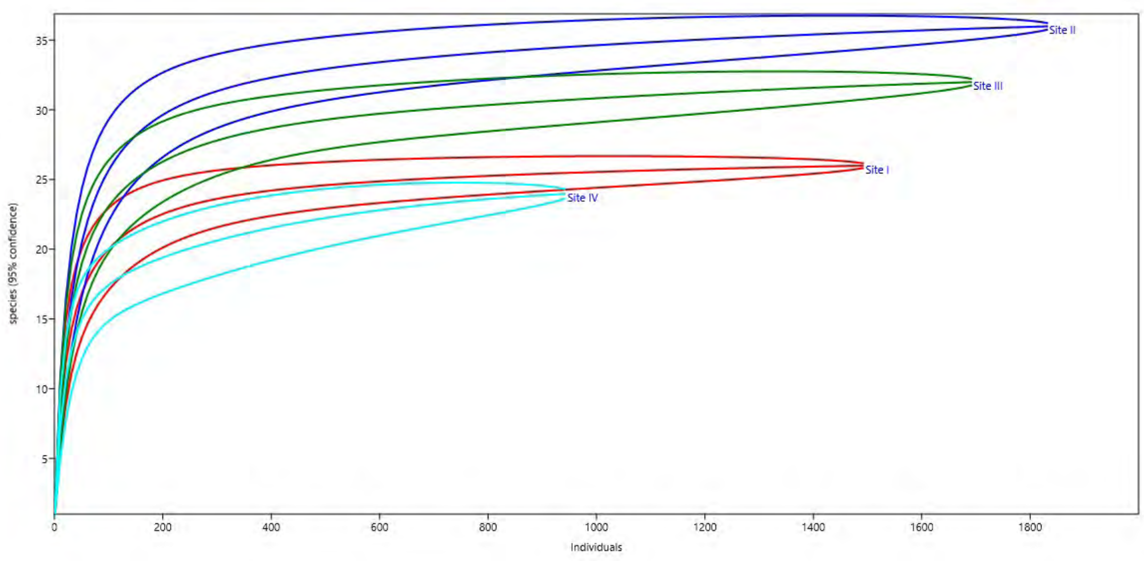

Fig. 4 Species accumulation curve of spider species in of Chincholli Wildlife Sanctuary, Kalaburagi, Karnataka, India, with 95% confidence interval for listed sites pooled.

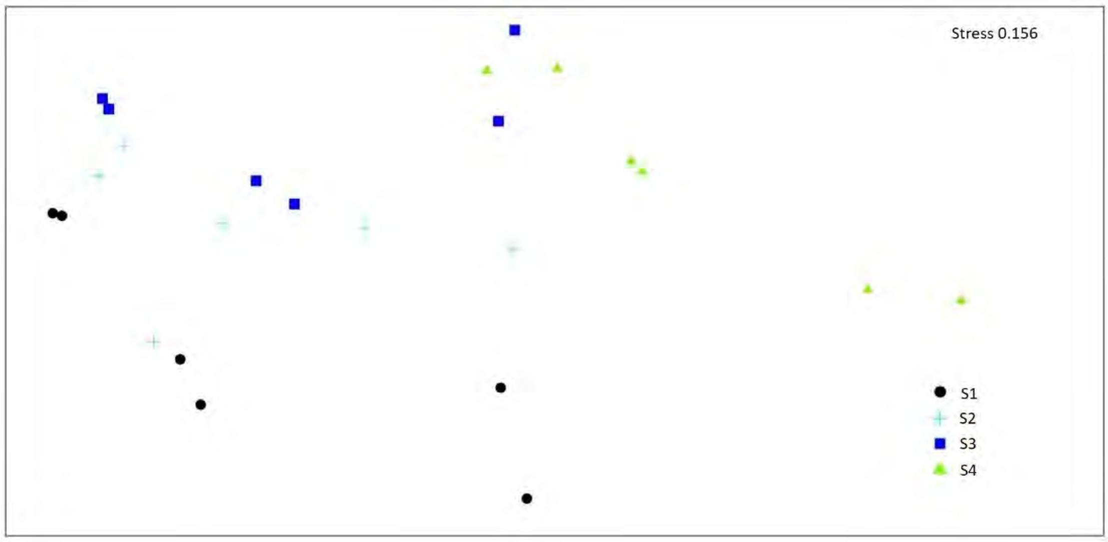

Fig. 5 Non-metric multidimensional scaling ordination of study sites during study period in of Chincholli Wildlife Sanctuary, Kalaburagi, Karnataka, India. The distance among centriole of sampling sites were used.

As spider exhibits seasonal variation, maximum number of individuals and species are found in pre-winter and less in spring and summer. This pattern of seasonal variation also found in other studies of spider community includes Mac Mohan and Trigg (1972), Abraham (1983), Jimenez-Valverde and Lobo (2006). Observation of Mavasa et al. (2022) indicated that species richness and abundance is high in summer than winter according to Resource-Ratio hypothesis (Tilman, 1985) which states that low resource requirement will outcompete with other species when the resources are limited, resulting in reduction of number of species (Tilaman, 1985). This results supports our study in two points, Firstly in summer our study area becomes completely dry which reduces resource availability. Site I (Chikkalingadalli) is dominated by *Cyrba ocellata* (13.10%); Site II (Konchavarm) dominated by *Cyclosa insulana* (12.4%); Site III (Gottamgotta) is dominated by *Theridion varians* (13.55%); and Site IV (Chandrampalli Dam) is dominated by *Oxyopes kohensis* (13.59%). This indicates that dominant spiders were often habitat generalists (Post and Riechert, 1977).

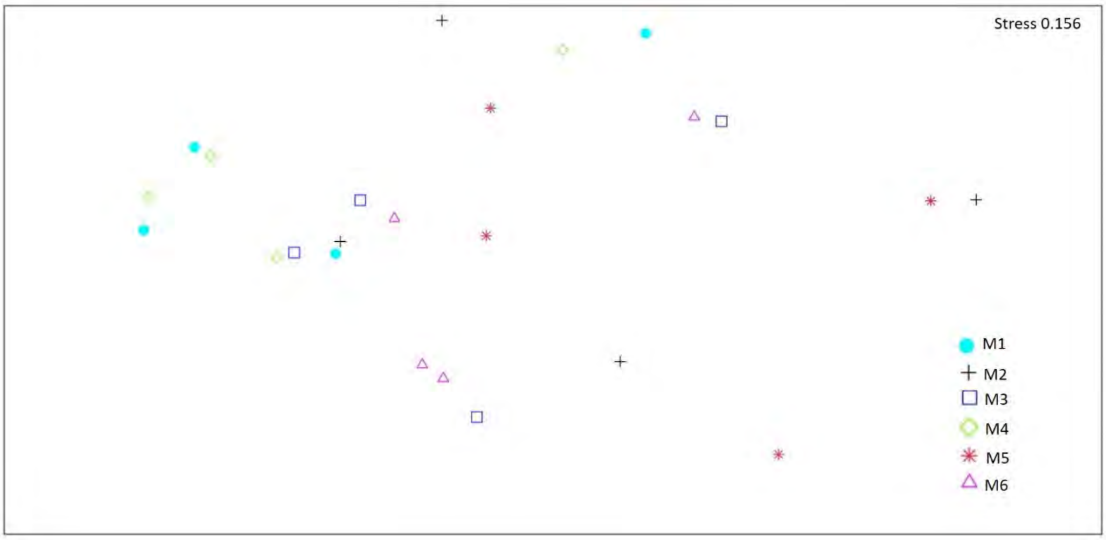

Fig. 6 Non-metric multidimensional scaling ordination of study dates during sampling period in of Chincholli Wildlife Sanctuary, Kalaburagi, Karnataka, India. The distance among centriole of sampling dates were used.

The presence of one dominant species can greatly affects the value of Simpson's diversity index (Davies, 1997). According to many researchers, measures of traditional diversity indices are inadequate to understand diversity of particular locality (Horner-Devine et al., 2003; Summerville et al., 2003; Uehara-Prado et al., 2007). Thereupon, to analyze effect of sites and dates on alpha diversity estimated MANOVA which specified that change of site had significant effect on alpha diversity however dates does not have significant effect. Variation of alpha diversity among sites influenced by proximate characteristics of the environment includes availability of microclimates and vegetation complexity (Hatley and Macmahon, 1980; Abraham, 1983), prey species distribution (Waldorf, 1976; Viera, 2003), productivity and predation (Polis et al., 1998).

Present study made an effort to scrutinize association between biotic factors (Spider and tree community) and abiotic factors (altitude and latitude distance) to appraise spatial pattern of species composition and temporal variability in spider assemblage. Our result suggested the similarity in spider community has significant positive correlation withsimilarity in plant species, geographic distance and negatively correlate altitudinal separation. Comparing these results to those of other studies shows some similarities.The production and predation are general factors affecting spider abundance within same system depending on spatial and temporal variation (Polis et al., 1998). Spatial and architectectural properties of habitat can be a very important for species diversity, distribution and density of predatory invertebrates in community (Hatley and Macmahon, 1980). The present findings on negative correlation in temporal variability is supported by studies of Root (1973), Proulx et al. (2010), Haddad et al. (2011) where spider response differs in change of different environmental condition over time stands richer in plant species might be expected to exhibit lower temporal variability in richness of spider over sampling period. Interval of sampling was also important with increasingly broad temporal scales being less effective in seasonal differences in richness (Churchill and

Arthur, 1999). It should be therefore expected that negative correlation between spiders' assemblage and temporal variation. Our result contrast with the diversity pattern observed in a tropical mountain cloud forest, Mexico (Campuzano et al., 2020) demonstrated that seasonal pattern of spider communities have differed among strata revealing a complex spatiotemporal dynamics. This variation in result may be due to change in habitat structure and sampling methods and duration.

Globally most important reason for species extinction is the destruction of their habitats (Pimm and Raven, 2000), Mortality and dominancy of other community (Abraham, 1983). Further examination is required on microclimate availability, foraging strategies, prey preference and guild structure of spiders in the study area which plays significant role in conservational plans.

4 Conclusion

The presented research illustrates how spider dispersal is impacted by biotic factor flora as well as abiotic factor geographical and temporal variability. The dearth resources in the study area and these outcomes shed light on how vegetation complexity sustains spiders by creating a favorable microclimate and making prey species available. According to our findings, there is a strong positive link between similarity in the spider community and similarity in plant species, geographic distance, and altitudinal separation.

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