SPECIES

First study on spider diversity in three distinct habitats in Federal University Wukari, Taraba State, Nigeria

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ABSTRACT

Spiders are vital biological control agents and environmental change indicators in the ecosystem. Therefore, it is imperative to conduct studies on spider biodiversity, monitor their ecological activities, and work towards preserving them to prevent extinction. This research aimed to assess the diversity of spider families present at Federal University Wukari, Taraba State, Nigeria. Using handpicking, beating trays, and pitfall traps, we collected spiders from three habitats, namely, grasslands, trees, and residential buildings. A total of 164 spiders were collected, representing nine families: Araneidae, Salticidae, Lycosidae, Nephilidae, Thomisidae, Gnaphosidae, Pholcidae, Theridiidae, and Tetraghanthidae. Among these families, Araneidae exhibited the highest frequency of occurrence (100%) as they were present across the three (3) sampling sites. Pholcidae had the highest abundance in residential buildings, while Thomisidae, which was a rare family represented by a single spider taxa, was found only in the grassland habitat. The grassland habitat had the highest Shannon diversity index with a value of 1.332. On the other hand, the tree habitat had the highest species evenness of 0.998, while residential buildings had the highest species richness and lowest evenness values of 1.327 and 0.478, respectively. The Jaccard's similarity index shows low similarity (< 0.5) among the three sites studied. This study indicates that spider families have varying levels of loyalty to their habitats. While some were widespread, others were restricted to specific areas/habitats. Each habitat has its species, and spiders' diversity, evenness, and richness vary depending on the habitat type.

Keywords: Araneidae, beneficial arthropods, Shannon diversity index, Theridiidae, Wolf spiders

1. INTRODUCTION

Spiders are beneficial arthropods in studying biodiversity patterns, and their significance stems from their high species richness, comprising over 45,000 described species and even more awaiting discovery (Platnick, 1999). Spiders play a vital role in controlling insect pests within agricultural ecosystems. They feed on a diverse range of prey species, capturing significant numbers of prey through various foraging strategies. For example, wolf spiders offer promising potential for biological control of pests due to their efficient predatory behavior in cropping systems (Bambaradeniya and Edirisinghe, 2001; Okrikata et al., 2019).

Further, web-building Spiders whose main diet is aphids have helped minimise crop damage (Nyffeler and Sunderland, 2003; Okrikata et al., 2019). By examining spider diversity, we can provide valuable information about their role in shaping the abundance and diversity of terrestrial arthropods which consequently affects the overall ecosystem functional dynamics (Michalko et al., 2019). Certain Spider species exhibit habitat specificity, primarily restricted to habitats with distinct characteristics, while others are everywhere, adapting to diverse habitats. For example, the lycosid spiders are commonly found in grassland habitats and rarely occur in forests, while the nocturnal wandering spiders in the family Ctenidae has an ubiquitous distribution (Jocqué and Alderweireldt, 2005). Furthermore, human-induced modifications to natural environments, such as construction and other activities, can also impact spider assemblages (Ayansola, 2012).

Research has shown that such alterations can increase spider abundance in human or residential areas but reduce species richness (Shochat et al., 2008). Therefore, investigating spider assemblages within specific habitats can provide valuable insights into the ecological requirements of different spider species, the interdependencies within their habitats, and their ecological roles (Cardoso et al., 2011). Despite the global significance of spider diversity in ecosystem services, Nigeria needs comprehensive data on spider diversity. Hence, there are still significant research gaps in our understanding of the common spider species in Nigeria. Some authors have explored the diversity of spiders in South-western Ayansola, (2012), Oyewole and Oyelade, (2014), Odejayi et al., (2022) and South-eastern Wesolowska and Edwards, (2012), Nwankwo et al., (2019), Ezeonyejiaku et al., (2019) Nigeria.

For example, Ayansola, (2012) studied the diversity of spiders in the forest reserves and tree parks in South-western Nigeria, while Nwankwo et al., (2019) and Ezeonyejiaku et al., (2019) reported that distinct habitat types were responsible for the spider assemblages in south-eastern Nigeria. However, there is hardly any study conducted in the northern part, leaving a lacuna on spider diversity in the northern region of Nigeria. By addressing this knowledge gap, we can better understand spider diversity patterns and their ecological significance in Nigeria and contribute to broader scientific knowledge.

This study explored the diversity of spiders in different habitats in Federal University Wukari, Taraba state, Nigeria. By examining the spider diversity and the specific habitat preferences of different species, we seek to provide insights into their ecological roles and contribute to the global spider inventory. The findings of this research have the potential to inform habitat management strategies and guide conservation initiatives for spiders and their associated ecosystems.

2. MATERIALS AND METHODS

Description of the Study Area

This study was carried out in the Federal University Wukari situated in Wukari local government area of Taraba State, Nigeria. Wukari is located at latitude 7.85o North, longitude 9.78o East, and 152m elevation above sea level in the north-eastern part of Nigeria. The area is characterized by a warm tropical climate with distinct wet and dry seasons, an annual average temperature of 26.8°C, and 1205 mm of rainfall (Okrikata and Yusuf, 2016).

Study Duration

This survey was carried out from November 2022 to January 2023. Samplings were collected in the morning hours between 6:30 to 10:30 am within Federal University Wukari Campus.

Sampling Sites

The sites sampled are:

Sampling Site A – Trees

The trees are situated in different areas within the campus. Common trees found in the area are *Mangifera indica*, *Citrus sinensis*, *Vitellaria paradoxa*, *Pakia biglobosa*, *Gmelina arborea*, *Moringa oleifera*, *Azadiracta indica* and *Anacardium occidentale*.

Sampling Site B – Residential buildings

This comprises the classrooms, hostels, and office buildings as well as buildings that are not in use. Samples were also collected along walkways and staircases.

Sampling Site C – Grassland area

This site borders the University animal farm. Grasses are usually cleared here either using a mower or by applying herbicides during the rainy season. Common grasses found in this area are *Rottboellia cochinchinensis*, *Imperata cylindrica*, *Digitaria horizontalis*, *Andropogon gayanus*, *Tridax procumbens*, *Commelina benghalensis*, *Ipomoea triloba*, *Cyperus rotundus*, and *Gomphrena celosoides*.

Sampling Techniques

Pitfalls, handpicking, and jarring methods were used to collect spiders from the sampling sites. The pitfall trapping technique was used to collect ground-dwelling spiders on the grassland. Various studies have reported the efficiency of pitfall traps in collecting ground-dwelling arthropods (Császár et al., 2018; Privet and Pétillon, 2020). Twenty pitfall traps were made of 85ml disposable cups, half-filled with water mixed with a scentless liquid soap to break the surface tension and prevent trapped insects from escaping (Okrikata and Yusuf, 2016). The cups were placed in the ground at a 2m spacing interval set on a straight line transect (Oyewole and Oyelade, 2014). Traps were opened once a week to collect the spiders and left open for twenty-four hours. The trapped spiders were collected and stored in 70% ethanol. After each weekly sampling, traps were covered and opened 24hrs before the next collection.

The traps were covered to prevent unwanted catches that can disrupt the diversity of arthropods within the sites. Sampling was done weekly for eight weeks. To collect samples from trees, twenty trees were marked out for spider collection. The trees were inspected and leaves jarred for a minute over a beating tray, and spiders that dropped on the tray were collected by handpicking and placed into a vial containing 70% ethanol. Jarring was done five times for each tree. We collected spiders from the buildings by handpicking. When a spider is spotted, they are carefully picked up to prevent the spider limbs from breaking. If spiders were in a place not easily accessible, we used a cobweb stick to bring them down and then quickly pick them up carefully. To standardize sampling effort, we spent 10 minutes in each building and ensured that collection was done by the same individuals and at the same time weekly from 6:30 to 10:30am (Ayansola, 2012).

Spider Identification

The collected specimens were sorted into morphospecies using their morphological characteristics. Further identification to family level was done using African Spiders Identification Manual (Dippenaar-Schoeman and Jocqué, 1997; Harwood et al., 2004). Also, spiders were compared with the data available on the world spider catalog for further identification (Nwankwo and Ewuim, 2019). Samples were further sent to Dr Daniel Nwankwo, an arachnologist from the University of Calgary, Canada for further authentication.

Statistical Analysis

Data on spider abundance using the various sampling methods were collated to compute the frequency of occurrence (FO) and relative abundance (RA) of the spider families collected from the selected locations. Taxa with FO ≥ 25% and RA ≥ 1% were regarded as dominant species, while those with FO < 25% and/or RA < 1% were regarded as rare species, as described by Okrikata et al., (2019). Species diversity (H), richness (R), and evenness (H) were computed for the different collection sites using the Paleontological Statistical Tool – Past3. Graphical representation of the abundance of spider families/family in each location was done using Microsoft Excel package. In addition, Jaccard's similarity index model was used to determine the similarity of the spider in the distinctive habitats:

$$Jaccard\ index\ (Cj) = a/a + b + c$$

Where:

a = Number of taxa found on both locations

b = Number of taxa found on location A and not on B

c = Number of taxa found on location B and not on A

3. RESULTS

Table 1 shows that a total of 32 spiders, belonging to two families (Araneidae and Nephilidae) were collected from sample site A (on trees) within the eight weeks sampling period. The family Araneidae (Figure 1) had a higher relative abundance (RA = 53.13%), while the family Nephilidae (Figure 2) had a higher frequency of occurrence (FO = 75.0%). Both families were, however, occupying a dominant status on trees.

Table 2 shows that a total of 92 spiders were collected from the residential buildings belonging to seven families. Pholcidae (Figure 3) had the highest FO (100%) and RA (57.6%), whereas Araneidae had an FO and RA of 75% and 26.08%, respectively. However, only families Araneidae, Salticidae, Pholcidae, and Theridiidae were dominant, as their FO and RA were ≥ 25% and ≥ 1%, respectively.

Table 1 Abundance of Spiders in Sampling Site A (Trees)

Specimen	Weeks								Abundance	FO%	RA%	S.D
	1	2	3	4	5	6	7	8				
Araneidae	-	-	3	5	1	4	-	4	17	62.5	53.13	D
Nephilidae	2	1	2	2	-	3	5	-	15	75.0	46.88	D
Total	2	1	5	7	1	7	5	4	32			

FO% = Frequencies of occurrence
RA% = Relative abundance
S.D = Status of dominance
D = Dominant
R = Rare

Figure 1 Members of Family Araneidae

Figure 2 Members of Family Nephilidae

Table 2 Abundance of Spiders in Sampling Site B (Residential buildings)

Specimen	Weeks								Abundance	FO%	RA%	S.D
	1	2	3	4	5	6	7	8				
Araneidae	6	9	-	2	-	3	2	2	24	75.0	26.08	D
Salticidae	2	3	-	-	-	-	-	-	5	25.0	5.43	D
Lycosidae	-	4	-	-	-	-	-	-	4	12.5	4.34	R
Nephilidae	1	-	-	-	-	-	-	-	1	12.5	1.08	R
Pholcidae	5	10	3	7	9	6	6	7	53	100.0	57.60	D
Theridiidae	-	-	2	1	-	-	-	-	3	25.0	3.26	D
Tetraghanthidae	-	2	-	-	-	-	-	-	2	12.5	2.17	R
Total	14	28	5	10	9	9	8	9	92			

FO% = Frequencies of occurrence
RA% = Relative abundance
S.D = Status of dominance
D = Dominant
R = Rare

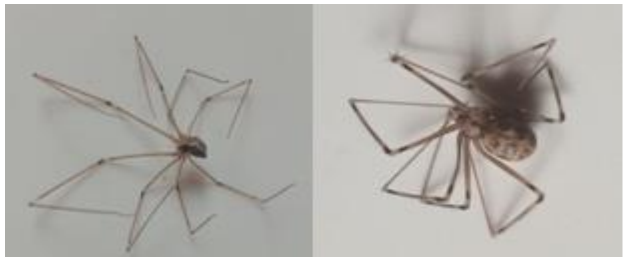

Figure 3 Members of Family Pholcidae

Table 3 shows that a total of 40 spiders belonging to five (5) families were collected from sampling site C (grassland). Salticidae (Figure 4) was the most dominant, with FO of 87.5% and RA of 57.6%. It was followed by Lycosidae (Figure 5), which had FO and RA of 62.5% and 25%, respectively. Of the five (5) families, only Thomisidae (Figure 6) and Gnaphosidae (Figure 7) were rare as their FO was < 25%.

Table 3 Abundance of Spiders in Sampling Site C (Grassland)

Specimen	Weeks								Abundance	FO%	RA%	S.D
	1	2	3	4	5	6	7	8				
Araneidae	-	-	-	-	-	1	5	3	9	37.5	22.50	D
Salticidae	-	1	4	4	1	1	4	2	17	87.5	42.50	D
Lycosidae	1	2	3	-	1	3	-	-	10	62.5	25.00	D
Thomisidae	-	-	-	1	-	-	-	-	1	12.5	2.50	R
Gnaphosidae	-	3	-	-	-	-	-	-	3	12.5	7.50	R
Total	1	6	7	5	2	5	9	5	40			

FO% = Frequencies of occurrence

RA% = Relative abundance

S.D = Status of dominance

D = Dominant

R = Rare

Figure 4 Members of Family Salticidae

Figure 5 Members of Family Lycosidae

Figure 6 A Member of the Family Thomisidae

Figure 7 A Member of the Family Gnaphosidae

Table 4 shows that nine (9) spider families were collected across the sampling sites. Of the nine (9) families, only Thomisidae has rare dominance status. Concerning their guild; Therididae (Figure 8) and Pholcidae were space builders, while Tetraghanthidae (Figure 9), Nephilidae and Araneidae are orb weavers.

Table 4 Overall Families of Spiders Retrieved across Sampling Sites with their Guild and Dominance Status

Specimen	Guild	Tree branches	Residential buildings	Grassland	Total Individuals collected	FO%	RA%	S.D
Araneidae	Orb weavers	17	24	9	50	100.0	30.48	D
Salticidae	Stalkers	-	5	17	22	66.7	13.41	D
Lycosidae	Ground runners	-	4	10	14	66.7	8.53	D
Nephilidae	Orb weavers	15	1	-	16	66.7	9.75	D
Thomisidae	Ambushers	-	-	1	1	33.3	0.60	R
Gnaphosidae	Ground runner	-	-	3	3	33.3	1.82	D
Pholcidae	Space builders	-	53	-	53	33.3	32.31	D
Theridiidae	Space builders	-	3	-	3	33.3	1.82	D
Tetraghanthidae	Orb weavers	-	2	-	2	33.3	1.21	D
Total		32	92	40	164			

FO% = Frequencies of occurrence
RA% = Relative abundance
S.D = Status of dominance
D = Dominant
R = Rare

Figure 8 A Member of the Family Theridiidae

Figure 9 A Member of the Family Tetraghanthidae

Figure 10 shows the distribution of spider families across the sampling sites. While Araneidae, Pholcidae, Theridiidae and Tetraghanthidae predominated residential buildings; Salticidae, Lycosidae, Thomisidae and Gnaphosidae were predominant in the grassland. The tree branches however, had Nephilidae as its predominant family.

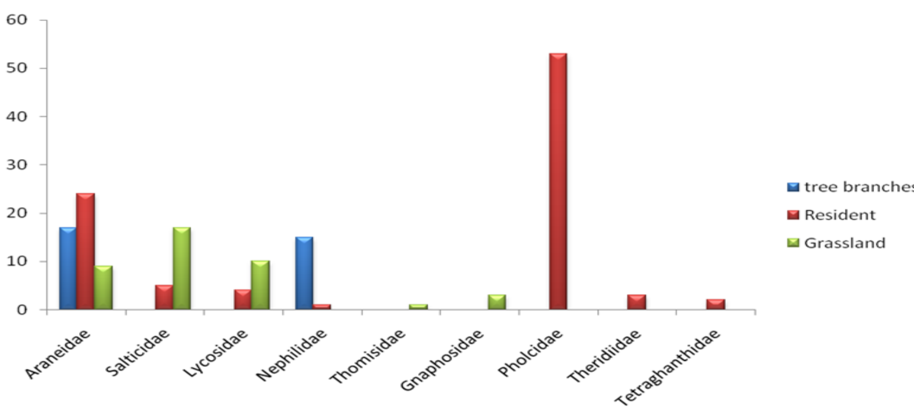

Figure 10 Distribution of Spider Families in Numbers across the Sampling Sites

Table 5 shows that Araneidae was present in all the micro-habitats sampled. Thomisidae and Gnaphosidae were restricted to residential buildings; while Pholcidae, Theridiidae and Tetraghanthidae were restricted to the grassland. While members of Salticidae and Lycosidae were not retrieved from tree branches, the Nephilids were recovered from the tree branches and residential buildings.

Table 6 shows that the Shannon Weiner's diversity index was generally low with the grassland accommodating the highest diversity of spiders (1.332), and the tree branches, the least (0.6912). The richness index was also low across the sampling sites. However, the tree branches were comparatively richer in spiders than the other sampling sites. The even distribution of spider taxa was high but for residential buildings (0.4776). Table 7 shows that the Jaccard's similarity index ranged from 0.17 when comparing tree branches and grassland spider diversity to 0.33, when comparing residential building to grassland. That the similarity index was < 0.5 in the comparisons conducted (Table 7), is an indication that the spider taxa have high preferences with respect to habitat choice.

Table 5 Inter-dwelling of Spider families in the Study Area

Family	Micro-habitats/Sampling sites			Total
	A	B	C	
Araneidae	•	•	•	3
Salticidae		•	•	2
Lycosidae		•	•	2
Nephilidae	•	•		2
Thomisidae			•	1
Gnaphosidae			•	1
Pholcidae		•		1
Theridiidae		•		1
Tetraghanthidae		•		1

Total	2	7	5	14

A - Tree branches
B – Residential buildings
C – Grassland

Table 6 Diversity Indices of Spiders Collected from the Study Locations

Diversity indices	Sampling sites			Inference
	A	B	C	
Taxa	2	7	5	-
Individual	32	92	40	-
Shannon Weiner Index (H)	0.6912	1.207	1.332	Generally low. However, C has the highest diversity while A has the lowest
Margalef Richness Index (R)	0.2885	1.327	1.084	Generally low. However, B has the highest and A the lowest
Buzas and Gibson's Evenness Index (E)	0.998	0.4776	0.758	Generally high except for B

A - Tree branches
B – Residential building
C - Grassland

Table 7 Jaccard's Similarity Index of Spider taxa collected from the Sampling Sites

Description	Level of similarity	Inference
A n B	0.29	Low similarity indices
B n C	0.33	Low similarity indices
A n C	0.17	Low similarity indices

A - Tree branches
B – Residential building
C - Grassland
Where: < 0.5 level of similarity = low; > 0.5 level of similarity = high

4. DISCUSSION

This study presents the first comprehensive checklist of spiders in Taraba State, Nigeria, and explores the relationship between spider diversity and different micro-habitats. In our investigation, we identified nine spider families within the study area. However, the number of spider families recorded in this study is comparatively lower than those reported in previous studies conducted by (Ezeonyejiaku et al., 2019; Odejayi et al., 2022; Oyewole and Oyelade, 2014; Nwankwo et al., 2019). This discrepancy in spider family counts may be attributed to the shorter sampling duration employed in our study. To attain a more comprehensive understanding of spider diversity, an increased sampling effort for an extended period could potentially result in higher species richness, as previously suggested by (Grey et al., 2018).

Consistent with the species sampling relationship proposed by Rosenzweig and Lomolino, (1996), a positive correlation between species richness and sampling effort exists, indicating that more tremendous sampling effort or duration is likely to lead to higher species richness. This has been demonstrated in a study by Ayansola, (2012), wherein repeated sweeps across foliage over a longer period led to the discovery of more spider species. Among the families recorded in the study, Araneidae emerged as the most dominant family, found in all three habitats while Pholcidae was the most abundant family in residential buildings. This finding corroborates the studies conducted by (Odejayi et al., 2022; Oyewole and Oyelade, 2014). The presence of spiders across diverse habitats, regardless of the habitat structure, suggests that they serve as valuable ecological indicator species, providing insights into the effects of disturbances within the ecosystem.

The ability of spiders to offer insights into recovery patterns following major ecological disruptions makes them particularly relevant (Arganaraz et al., 2020). Nonetheless, other studies have reported Salticidae, Pholcidae, and Lycosidae as dominant families as they were retrieved across sampling sites (Ezeonyejiaku et al., 2019; Nwankwo et al., 2019; Odejayi et al., 2022). This variation in spider families across studies can be attributed to the distinct habitat structures of the respective study areas. Despite being ubiquitous and active generalist predators, the type of vegetation plays a significant role in determining the distribution and occurrence of spider species in specific habitats. Our study demonstrated the influence of vegetation type, where Thomisidae was relatively rare in grassland habitats. The lower abundance of Thomisidae is not surprising, considering that land modification practices, such as weeding and herbicide application, can alter grassland structure and affect prey-predator dynamics.

Notably, our findings revealed that residential buildings exhibited the highest spider richness but the lowest species evenness. This pattern can be adduced to several factors, including habitat fragmentation, simplified habitat structures, limited resource availability, presence of non-native species, and human disturbance, which are characteristic of residential areas (Carvalho et al., 2011; Barton et al., 2017). The fragmentation of natural habitats in residential areas disrupts connectivity and reduces habitat continuity, leading to reduced species evenness (Cardoso et al., 2011). The simplified habitat structure, encompassing building architecture and agricultural landscapes, provides fewer niches for different species, while limited resource availability, such as food sources and shelter options, further restricts species diversity that can thrive in residential areas.

The presence of non-native species, introduced through human activities, can also influence species composition. Additionally, human disturbances in residential areas, such as sanitation and artificial lighting, can disrupt spider behavior and deter certain species from inhabiting these areas, further contributing to lower species evenness (Oyewole and Oyelade, 2014). Our study's Jaccard's similarity index revealed generally low similarities between the three habitats studied, emphasizing the pivotal role of habitat structure and composition in shaping spider diversity (Cardoso et al., 2011). Additionally, factors such as sanitation, herbicide use, and farming activities in the study area likely contributed to spider species adapting to specific habitats that enhance their chances of survival (Liu et al., 2016).

5. CONCLUSION

In conclusion, this study highlights how habitat type significantly influences the diversity of spiders within the study area. We identified a rich diversity of spider families, distributed across various habitats. While some spider species were found to be ubiquitous, others exhibited preferences for specific habitats. It is essential to acknowledge that our identification was conducted only up to the family level, and a more comprehensive study, spanning several months and seasons, could yield further insights into other spider families and species not covered in this investigation. The findings of this study contribute valuable baseline data for understanding spider diversity in Taraba state, Nigeria, and emphasize the significance of considering habitat characteristics when assessing spider populations in different environments.

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Authors' contribution

Titus Tanko, Jane I Otabor and Emmanuel Okrikata, designed the study and drafted the manuscript; Jane I Otabor and Titus Tanko prepared the images and tables; and Emmanuel Okrikata reviewed the draft manuscript.

Ethical approval

The Animal ethical guidelines are followed in the study for species observation & identification.

Informed consent

Not applicable.

Conflicts of interests

The authors declare that there are no conflicts of interests.

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Data and materials availability

All data associated with this study are present in the paper.

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