HNUE JOURNAL OF SCIENCE
Natural Sciences 2025, Volume 70, Issue 2, pp. 138-150
This paper is available online at http://hnuejs.edu.vn/ns
DOI: 10.18173/2354-1059.2025-0029

DIVERSITY OF GROUND-ACTIVE SPIDER COMMUNITY ACROSS DIFFERENT TROPICAL FOREST HABITATS AND CLIMATE CONDITIONS IN NORTHERN VIETNAM

Do Thi Ha[1], Dinh Thi Thu Ha[2] and Pham Dinh Sac[3,*]

[1]*Faculty of Education, Thai Nguyen College, Thai Nguyen province, Vietnam*

[2]*Faculty of Basic Knowledge, Vietnam Dance Academy, Hanoi city, Vietnam*

[3]*Vietnam National Museum of Nature, Vietnam Academy of Science and Technology, Hanoi city, Vietnam*

[*]Corresponding author: Pham Dinh Sac, e-mail: phamdinhsac@gmail.com

Received April 5, 2025. Revised May 19, 2025. Accepted June 30, 2025.

Abstract. A year-long survey of ground-active spiders was conducted in three typical tropical forest areas of Northern Vietnam, each characterized by distinct climatic conditions: Cuc Phuong National Park (CPNP, tropical monsoon climate of the Red River Delta), Tam Dao National Park (TDNP, high-elevation tropical monsoon climate), and Cat Ba National Park (CBNP, maritime climate). Four types of habitats were selected in each region: natural forest and disturbed forest (both with multi-layered vegetation structures), and shrubland and acacia plantation (both with simple-layer vegetation structures). Spiders were sampled using pitfall traps. Cursorial hunters and ground-level web builders were the dominant guilds in all study areas. Spider diversity was compared across the study areas. Cluster analysis showed that the species composition in the maritime climate area (CBNP) was significantly different from that in the other areas. Spider diversity was also compared between habitats with multi-layer vegetation structures (multi-LVS) and those with simple-layer vegetation structures (simple-LVS). Both species composition and spider abundance were higher in habitats with multi-LVS than those with simple-LVS. The results of this study highlight the importance of preserving natural ecological processes to conserve biodiversity in multi-VLS habitats and to aid in the restoration of biodiversity in simple-LVS habitats.

Keywords: ground-active spiders, regional climate, Northern Vietnam.

1. Introduction

Large-scale assessments of biodiversity patterns are critical for informing strategies aimed at mitigating biodiversity loss [1]. Spiders represent one of the most diverse

taxonomic groups on Earth and appear to be good subjects for studying biodiversity patterns, as their distribution and occurrence are closely associated with habitat structure [2].

Stretching more than 1650 kilometers north to south along Tonkin Bay and the South China Sea, Vietnam encompasses three major biogeographic zones, four Endemic Bird Areas (EBAs), and a wide variety of unique habitats. Vietnam's high levels of species diversity and endemism are attributed to its size, location, and the historical interplay of complex topographic, climatic, and ecological factors. To date, research on spiders of Vietnam has been sporadic. Current knowledge of the country's spider fauna merely scratches the surface [3]. A comprehensive checklist of spiders from Vietnam was first compiled by Pham et al. (2007) [4], who listed 320 spider species in 32 families and 159 genera. The number of spider species in Vietnam was later increased to 456 species of 41 families by Ono et al. (2012) [5]. Few studies on spiders of Vietnam were made after 2012, other than Lin et al. (2023) [6] and Wang et al. (2023) [7]. However, the true number of Vietnam spider taxa is probably much higher than currently known. Furthermore, information on the relationship between species diversity and habitat types in tropical regions, particularly in Vietnam and more broadly in Indochina, remains limited. Almost no studies have reported on differences in spider communities, diversity, and abundance across regions or habitat types in this area. To address this gap, we collected ground-active spiders in three areas, of which one was on an island and two on the mainland. We also sampled ground-active spiders in habitats that have different vegetation structures. The relationship between vegetation structure and spider community is especially well documented [8], [9]. Many studies have shown that a correlation exists between the structural complexity of habitats and species diversity [10]-[13]. However, most of these studies demonstrate that the factors of structural complexity, such as the cover of vegetation, the vertical layering, and the degree to which habitats are open or closed, affect diversity. Our study demonstrates various structural complexities associated with vertical stratification.

This paper presents the first study on ground-active spiders in the tropical forests of Northern Vietnam. We aimed: 1) to compare the composition and abundance of spiders in three areas with different climate conditions; 2) to compare the composition and abundance of spiders between habitats with multi-LVS and simple-LVS.

2. Content

2.1. Materials and methods

**** The research time***

The fieldwork was carried out over one year, from March 2007 to April 2008.

**** Study area***

The study was conducted at three locations (CPNP, TDNP, and CBNP) in Northern Vietnam, which are approximately 180 km apart (Figure 1).

CPNP is located between 20º14' and 20º24'N latitude, and 105º29' and 105º44'E longitude. It covers an area of approximately 22,200 ha. The park belongs to Ninh Binh province and lies at an elevation of 154 to 636 m above sea level. It is located in the

Red River Delta tropical monsoon climate area, characterized by stable weather conditions such as temperatures and humidity gradient (Table 1).

Table 1. Meteorological data collected in 2007 from three study areas (provided by the National Centre for Hydro-Meteorological Forecasting)

	CPNP	TDNP	CBNP
Average annual temperature (°C)	22.7	18.0	25.6
Maximum daily temperature (°C)	31.9	33.1	40.0
Minimum daily temperature (°C)	15.2	-0.2	10.0
Average annual rainfall (mm)	1569	2630	2065
The annual number of rainy days	87.4	193.7	120.6
Highest daily rainfall (mm)	164.1	299.5	209.2
Average relative humidity (%)	84.0	87.0	81.0
Lowest relative humidity (%)	47.0	6.0	7.3
Annual evaporation (mm)	638.0	561.5	700.0

TDNP (21°21' - 21°42'N, 105°23' - 105°44'E) belongs to Vinh Phuc province with a total area of 36,833 ha, and it ranges in elevation from 900 to 1388 m. With typical characteristics of a high mountain tropical monsoon climate, TDNP has high humidity and very low temperatures. Mist and rain often occur simultaneously, and strong winds are common in this area.

CBNP differs from the other national parks in Vietnam because it is located on an island, situated 20 km east of Hai Phong province. Due to the isolated nature of the island, the diversity and abundance of mammals at CBNP are low compared to those in other national parks in Vietnam. The park is located between 20°44'- 20°51'N and 106°58'-107°10'E and covers an area of 15,200 ha, at elevations from 25 to 331 m. The CBNP is affected by the maritime climate characterized by frequent weather fluctuations. In addition, typhoons and tropical storms are common during the rainy season.

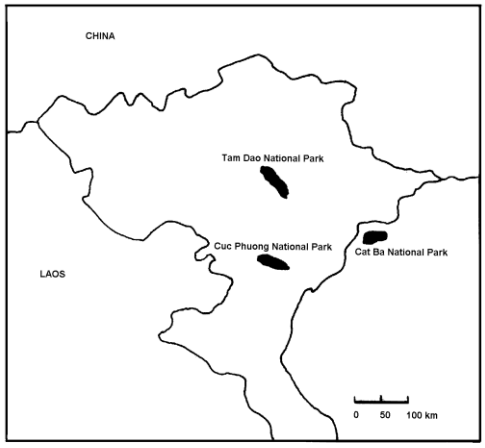

Figure 1. Map of study areas in Northern Vietnam

**** Sampling sites***

Spiders were sampled at four types of habitats in each region. Both natural forests and disturbed forests are classified as types of multi-LVS with four or five vegetation layers. Shrubland and acacia plantation belong to types of simple-LVS with one vegetation layer. The characters in each habitat type are described as follows:

Natural forests. According to Thai (2000) [14]. The vegetation in natural forests of Northern Vietnam has a five-layer structure as follows: The highest layer (A1) or emergent canopy consists of woody trees with a height of over 30 m, with scattered distribution. The layer A2 is composed of woody trees 20 - 30 m high and forms a big ecological dominant canopy. Layer A3 is a canopy with plants 8 - 20 m high and discontinuously distributed, with some frequently observed species. Layer A4 consists of plants below 8 m high. Layer A5 (forest floor) consists of weedy and shrubby plants.

*Disturbed forests***.** The disturbed forest is adjacent to the natural forest. The vegetation has four distinct plant layers, including A2, A3, A4, and A5. The highest layer (Al) was absent in the disturbed forest due to logging by humans in the past.

Shrublands. The shrubland is not natural but is derived from forest loss. The vegetation comprises only the shrub layer with 2 - 8 m.

Acacia plantation. Two species of acacia commonly planted are *Acacia auriculiformis* and *A. mangium*. This species has been grown in Vietnam for many years. It covers an area of 926 ha in CPNP, 1530 ha in TDNP, and 784 ha in CBNP [15], [16]. The acacia plantation has one tree layer of acacia, with an average canopy height of 15 - 25 m.

**** Sampling methods***

Pitfall traps were used to collect and measure the relative abundance of ground-dwelling spiders. In each area, four habitats were selected with five replicates each. Each replicate was established at least 50 m from the forest edge to reduce edge effects and approximately 1.0 km away from each other. Eight pitfall traps were placed in two rows, with 3 m spacing between traps within each replicate. Pitfall traps include the outer cup and inner cup. The outer cups are plastic tubes (8 cm in diameter and 14 cm in depth), and an inner cup was placed in each plastic tube for easy retrieval of specimens. The traps were buried in the soil so that the lip of each trap was flush with the soil surface. A plastic plate was secured above each trap using sticks to protect it from the rainfall. The solution in the pitfall trap consists of 95% ethanol, distilled water, and ethylene glycol in a ratio of 70:15:15.

All adult spiders were identified to family and morphospecies. Juveniles were excluded from this study due to the extreme difficulties of identification to species level, however, a quantitative assessment of their identities at the family level suggested a similar frequency distribution to that of the adults [17].

Based on hunting methods and web building types from the literature of Corey et al. (1998) [18], we grouped the families of ground-active spiders collected in Northern Vietnam into the following four guilds: (1) aerial web spinners: Araneidae, Theridiidae,

and Pholcidae; (2) ground-level web builders: Linyphiidae, Scytodidae, Psechridae, Nesticidae, Haniidae, Dipluridae, Hexathelidae, Liphistiidae, and Amaurobiidae; (3) ambush predators: Oonopidae, Thomisidae, Ctenidae, Ctenizidae, Atypidae, Nemesiidae, Segestriidae, Pisauridae, Oxyopidae, Sparassidae, and Sicariidae; (4) cursorial hunters: Clubionidae, Liocranidae, Corinnidae, Lycosidae, Salticidae, Gnaphosidae, Philodromidae, Caponiidae and Zodariidae. Among them, web-building spiders include aerial web spinners and ground-level web builder guilds, while the remaining guilds belong to non-web-building spiders.

**** Statistical analyses***

Spider density (D), Margalef's species richness index (d), Shannon-Wiener index (H'), Simpson's index (1-lambda), and evenness (J) were calculated for each habitat. The similarity of species composition and guild composition among different habitats was measured using the Bray-Curtis similarity index. Primer v5 software was used for these calculations. Species accumulation curves were employed to compare the completeness of our sampling for each region. These were compared with the theoretical or expected species accumulation curve, which represents the distribution of species when data are randomly distributed among samples. SPSS 15.0 software (SPSS Inc., USA) was used to perform this test.

2.2. Results and discussion

A total of 12,920 spider individuals were collected from three regions in Northern Vietnam, 4324 of which were adults. From these adult individuals, 184 species belonging to 32 families were identified. The two most abundant families were Corinnidae (18.59% of all adult individuals collected) and Amaurobiidae (17.95%), followed by Lycosidae (11.08%), Zodariidae (11.01%), Haniidae (6.50%), Salticidae (6.08%), and the remaining families each accounted for less than 5%each. Among these, seven families newly recorded in Vietnam are Caponiidae, Dipluridae, Atypidae, Haniidae, Nemesiidae, Segestriidae, and Sicariidae.

The materials collected from CPNP included 1745 adults, representing 99 species and 29 families; those from TDNP included 1465 adults, 86 species, and 23 families, and those from CBNP included 1114 adults, 63 species, and 23 families. A total of twenty families of ground-active spiders were collected from all three regions. Among them, six families were unique to CPNP (Nemesiidae, Segestriidae, Pisauridae, Sicariidae, Nesticidae, and Philodromidae), two families were unique to TDNP (Atypidae and Psechridae), and one family was unique to CBNP (Dipluridae).

Cursorial hunters (56.48% of total capture) and ground-level web builders (32.88% of total capture) were the dominant guilds with the highest number of individuals. They were followed by ambush predators (6.68%), while aerial web spinners had the lowest proportion (3.96%).

The species accumulation curves for each region approached an asymptote (Figure 2), indicating that the sampling was nearly complete at three areas. This suggests that our comparisons of species richness between the three areas are reliable.

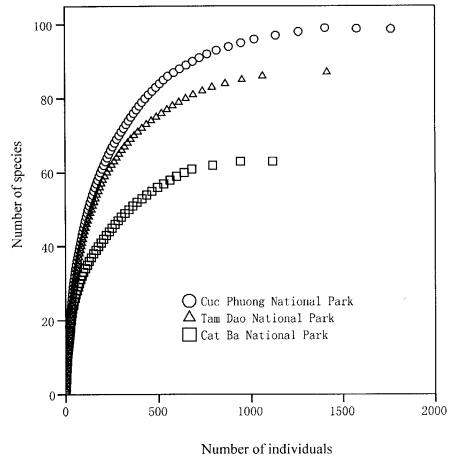

Figure 2. Rarefaction curves of ground-active spiders in the three study areas

**** Comparison of the spider fauna among the three study areas***

Cluster analysis was used to examine the species composition similarity between the study sites (Figure 3). The habitats are grouped into two main clusters, each further divided into two sub-clusters: the habitats from the CPNP and TDNP cluster together, while the habitats from CBNP form a distinct and separate cluster.

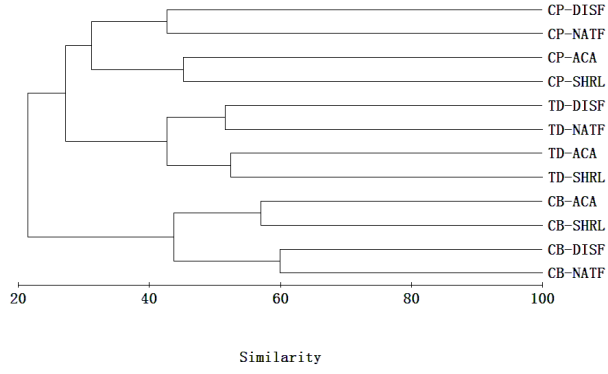

Figure 3. Spider community relationships based on species composition and abundance across habitat types in the study areas

(CP: Cuc Phuong National Park, TD: Tam Dao National Park, CB: Cat Ba National Park, DF: Disturbed forest, NATF: Nature forest, ACA: Acacia plantation, SHRL: Shrubland)

The three areas harbored 21 species in common, accounting for 11.4% of the total. Thirteen percent of all species were found unique to the two areas of CPNP and TDNP (Figure 4), while this proportion was very low between CBNP and CPNP (1.6%) and between CBNP and TDNP (1.6%). These results indicate that the species composition of ground-active spiders differed significantly among the three areaswith the greatest difference observed between CBNP and the other two areas.

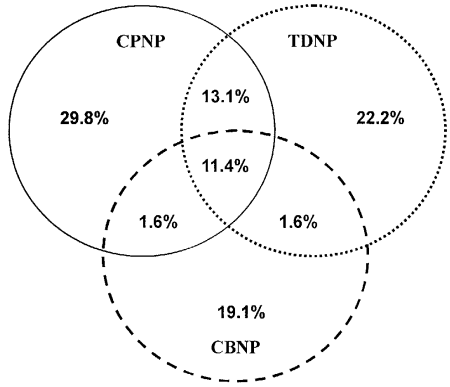

Figure 4. Venn diagram of ground-active spider species collected among the three study areas

Evenness and Simpson's index did not differ significantly between the three areas, while the abundance, Margalef's species richness, and Shannon-Weiner index were significantly higher in CPNP and TDNP than in CBNP (Table 2).

Table 2. Family number, species number, abundance, richness (D), evenness (J'), Shannon-Weiner diversity index (H'), and Simpson's index (1-lambda') of ground-active spiders collected in the three study areas

Region	Family	Species	Abundance	D (Margalef)	J'	H' (loge)	1-lambda'
CPNP	29	99	1745	13.40	0.79	3.64	0.95
TDNP	23	86	1465	12.48	0.81	3.56	0.94
CBNP	23	63	1114	9.14	0.79	3.36	0.91
Total	32	184	4324				

The assemblages of ground-active spider guilds across the three study areas were presented in Figure 5. In all areas, cursorial hunters and ground-level web builders were the dominant guilds based on the number of individuals collected.

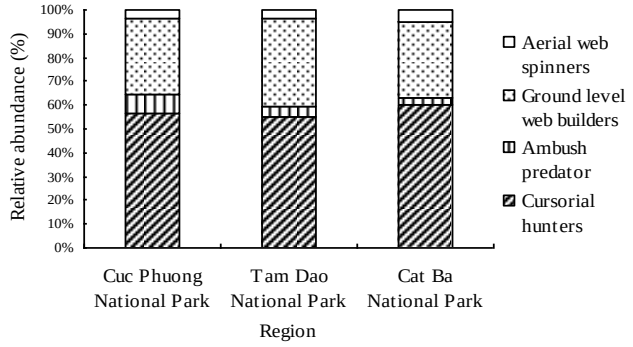

Figure 5. Variation in the guild structure of ground-active spider assemblages across the three study areas

**** Comparison of the spider fauna among habitats***

The spider species composition similarity among habitat types is shown in Table 3. At each region, the habitats are grouped into two clusters. The first cluster comprises habitat types with simple-LVS, while the second cluster includes habitat types with multi-LVS. The results showed that spider species composition was similar between habitats with the same vegetation structure and significantly different between habitats with different vegetation structures.

The assemblages of ground-active spiders were dominant in habitat types with multi-LVS and lower in habitat types with simple-LVS. Evenness and Simpson's index did not differ significantly among the four habitat types, while the abundance, Margalef's species richness, and Shannon-Weiner index were significantly higher in habitats with multi-LVS than those with simple-LVS across all three study areas (Table 3).

Table 3. Species number, abundance, richness (D), evenness (J'), Shannon-Weiner diversity index (H'), and Simpson's index (1-lambda') of ground-active spiders collected from different habitats across the three study areas

Habitat	Species	Abundance	D (Margalef)	J'	H' (loge)	1-Lambda'
CPNP						
Natural	59	711	8.83 ± 0.38	0.87 ± 0.01	3.16 ± 0.10	0.92 ± 0.01
Forest	60	650	9.02 ± 0.42	0.86 ± 0.01	3.13 ± 0.06	0.91 ± 0.02
Disturbed	33	268	5.61 ± 0.24	0.82 ± 0.01	2.88 ± 0.02	0.91 ± 0.01
forest	22	116	4.41 ± 0.25	0.90 ± 0.02	2.8 ± 0.04	0.93 ± 0.02
Shrubland						
Acacia	53	559	8.21 ± 0.39	0.89 ± 0.02	3.03 ± 0.12	0.90 ± 0.02
plantation	51	438	8.22 ± 0.22	0.87 ± 0.01	3.18 ± 0.02	0.94 ± 0.01
TDNP	36	264	6.27 ± 0.28	0.88 ± 0.01	2.93 ± 0.12	0.94 ± 0.02
Natural	32	204	5.82 ± 0.22	0.84 ± 0.02	2.91 ± 0.07	0.91 ± 0.01
Forest						
Disturbed	42	372	6.95 ± 0.47	0.83 ± 0.01	3.01 ± 0.10	0.93 ± 0.02
forest	40	347	6.66 ± 0.32	0.84 ± 0.02	2.93 ± 0.07	0.89 ± 0.02
Shrubland	30	225	5.35 ± 0.36	0.86 ± 0.02	2.78 ± 0.06	0.93 ± 0.01
Acacia	26	170	4.86 ± 0.23	0.88 ± 0.02	2.73 ± 0.06	0.92 ± 0.01
plantation						
CBNP						
Natural						
Forest						
Disturbed						
forest						
Shrubland						
Acacia						
plantation						

The assemblages of ground-active spider guilds in different habitats are shown in Figure 6. Cursorial hunters were the dominant guild with the highest number of individuals and were abundant across all habitats. Ground-level web builders were abundant in habitats with multi-LVS, but showed a significant decrease in habitats with simple-LVS across all three study areas.

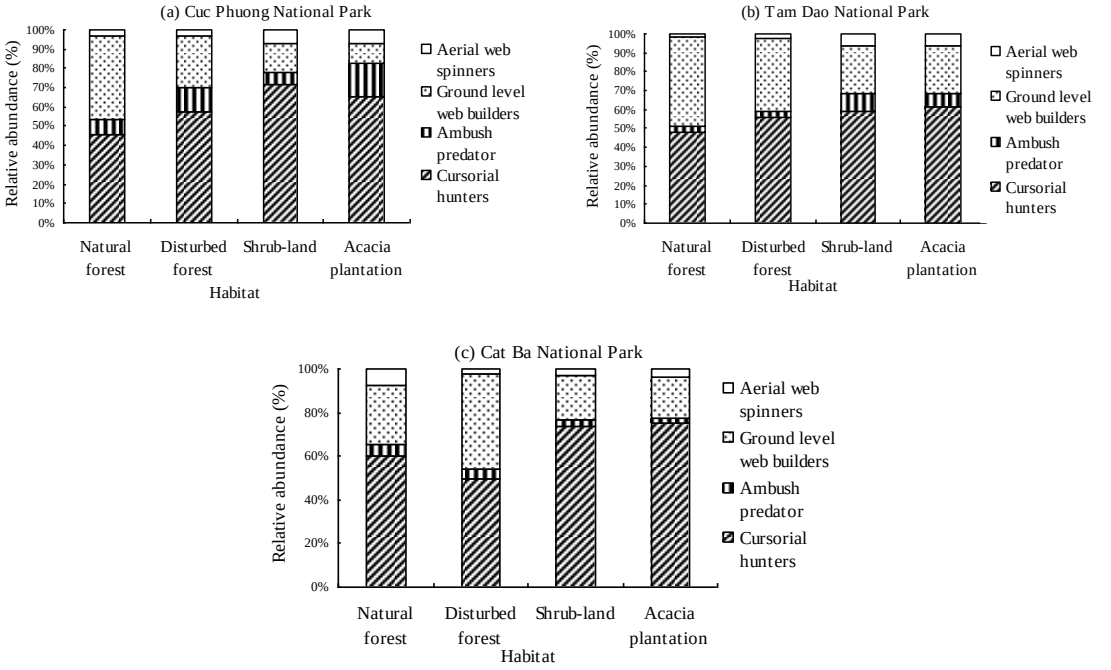

Figure 6. Variation in guild structure of ground-active spider assemblages across habitats in the three study areas

**** Discussion***

This is the first study in Vietnam to systematically examine the diversity and community structure of ground-active spiders. Furthermore, this study presents a comparison of ground-active spider fauna among three areas that have different climate conditions, along with another comparison between habitats that have a multi-layer vegetation structure and a simple-layer structure of vegetation structure. With a total of 184 spider species collected across the three areas, this may not reflect the full diversity of ground-active spider species in the sampling area. However, the inventory protocol utilized here provided a sufficiently thorough sample of local and regional spider species to permit an accurate comparison of species richness and abundance in the area.

This study showed that the spider assemblages were different among the study areas, with CBNP being particularly distinct from CPNP and TDNP in terms of species composition. The number of spider species collected in CBNP (63 species) was rather low as compared to TDNP (86) and TDNP (99). CBNP is located in an island area isolated from the mainland. The distribution of spider species depends on their aerial dispersal potential and the interplay between patch connectivity and habitat area [19]. Over time and with isolation, the number of species on islands created by fragmentation will, if anything, decline. The common characteristic uniting all island systems is isolation, which can result in properties such as a microcosmic nature and a uniquely evolved biota. Not only are they discrete units within which the biota can be quantified and compared, but the interaction of isolation and time has allowed the development of uniquely derived faunas, comprising neo-endemics in the case of Darwinian islands and

paleo-endemics in the case of fragment islands [20]. One possible reason may be isolation affecting the share in the species composition of spiders between CBNP and others in the mainland. Spiders of the genus *Tetragnatha* are known across many islands worldwide and have undergone adaptive radiation only on the most remote islands; Gillespie et al. (1997) [21] shows the relationship between isolation and endemism for this genus in the Pacific. Among the arthropods in the Hawaiian Islands, 98% are neo-endemics [22]. About 50% of the invertebrates in the Canary Islands are also neo-endemics [23]. Our study results supported a suggestion by Smith (1995) that a high level of endemism exists among spiders on different islands in the Southeast Asian region.

The abundance of spiders was higher in CPNP (40.36% of all captures) compared with TDNP (33.88%) and CBNP (25.76%). If it is assumed that the differences in assemblages of spiders between areas are real rather than an artifact of undersampling, what factors might account for the variation? The quality of vegetation structure, such as vegetation height or cover, did not differ among the parks, which are strictly protected areas in the Red River Delta and Northeastern of Vietnam, including CPNP, TDNP, and CBNP, despite differences in plant species composition. Three areas are situated at different elevations, with TDNP being the highest (900-1388 m), followed by CPNP (154 - 636 m) and CBNP (25 - 331 m). Russell-Smith & Stork (1994) [24] indicated that species richness and density of spiders tend to increase with elevation and as the climate becomes more temperate. However, in our study, although TDNP was highest in elevation, species richness and abundance of spiders were lower than those of CPNP. This suggests other factors may have had a strong influence on spider assemblages in these areas.

A comparison of climate conditions showed the differences among the three areas (Table 1). CPNP belongs to the Red River Delta tropical monsoon climate with stable weather such as temperatures, humidity gradient, which may support the assemblages of spiders in this area. Spider assemblages are highly influenced by ecosystem dynamics such as disturbance, and abiotic factors like ambient humidity and temperature [25]. Temperature, humidity, and other abiotic factors have been shown to influence the abundance and distribution of spiders. Russell-Smith (2002) [26] showed that spider diversity is related to mean annual rainfall. In addition, CBNP is affected by the maritime climate with typhoons and storms often happening in summer. TDNP typifies the climate of high mountain areas with strong winds, heavy rainfall, and frequent fog. These factors may also have influenced the spider assemblages in the study area.

The differences detected for both species richness and abundance among habitats with complex vegetation structure suggest a marked spatial pattern in the distribution and diversity of ground-active spiders. The assemblages of spiders did not differ between natural forest and disturbed forest, both of which have multi-LVS, nor between shrubland and acacia plantation, which both have simple-LVS. In contrast, the species composition and abundance of spiders were significantly different between habitats with multi-LVS and those with simple-LVS. The assemblages of ground-active spiders in habitats with multi-LVS were higher than in habitats with simple-LVS. The vegetation

structure could have a marked influence on the distribution of arachnid fauna through the provision of suitable microhabitats, including the availability of refuges and appropriate substrata for web attachment. Moreover, significantly more vegetation structural complexity in natural forests and disturbed forests is likely associated with greater stability and more suitable microclimates. Changes in vertical arrangements in plant communities can lead to changes in processes and habitat parameters such as microclimate, nutrient cycles, arthropod diversity, and others [27].

Ground-level web builders are one of the dominant guilds in terms of the number of individuals in the study areas. This spider guild had a higher proportion in habitats with multi-LVS, while showing a significant decrease in habitats with simple-LVS. Ground-level web builders often build funnel webs or sheet webs in weedy and shrubby plants on the ground of the forest. The layer A5 (forest floor), which is only present in habitats with multi-LVS, supported the spider assemblages with a high proportion in these habitats.

In the study area, each habitat has a different vegetation structure supporting distinct spider assemblages that reflect major differences in both environmental conditions and management regime. Habitats with multi-LVS are shaped by natural ecological processes. Although a disturbance occurred in the years of 1970s due to logging by humans in disturbed forests, these forests have since been protected and have recovered. In contrast, areas where natural recovery does not occur include habitats have simple-LVS, and impacts of humans, such as clearing weedy and shrubby plants on the ground, occur frequently. The clearing leads to the suppression of vegetation on the ground. The low biodiversity value of ground-active spider fauna in habitats with simple-LVS in general may mean that variation in clearing regime or vegetation structure within this habitat may be of little consequence.

Clearing are impact of anthropogenic disturbance; however, there are different opinions on the relationship between biodiversity and disturbance. The studies by Tsai et al (2006) [28] and Connell (1978) [29] showed that diversity will be highest under intermediate levels of disturbance, according to the Intermediate Disturbance Hypothesis (IDH). In contrast, other studies by Holloway et al. (1992) [30], and Goehring et al. (2002) [31]. Indicated that diversity and abundance of arthropods decrease with increasing disturbance. Therefore, differences in diversity and abundance are likely to occur due to various factors, including habitat vegetation structure and microclimate conditions in addition to the level of disturbance proposed by IDH.

Our study supported the suggestion by Pinkus-Rendon et al. (2006) that the physiognomy of vegetation communities is an important determinant of spider community composition, as it influences the types of habitats available to spiders. Other studies by Almquist (1973) [32] and Downie et al. (1999) [33] have demonstrated the importance of microclimatic conditions in shaping observed spider distributions. Undoubtedly, these two factors are closely tied; one might expect changes in microclimate to accompany changes in vegetation structure. Therefore, changes in vegetation structure during succession are likely to lead to corresponding changé in the composition of resident spider communities.

3. Conclusions

In conclusion, the results of this study show that climatic conditions are one of the key factors affecting the diversity of ground-active spiders at the regional level, while vegetation structure plays a major role in shaping spider assemblages at the habitat level. The isolation of the island region has led to a spider fauna that is particularly distinct from that of mainland areas. Vegetation clearing in habitats with simple-LVS may contribute to a decline in structural quality, which in turn negatively affects spider diversity. This study also suggests that maintaining natural ecological processes is essential for conserving biodiversity in habitats with multi-VLS and for restoring biodiversity in habitats with simple-LVS.

REFERENCES

[1] Ceballos G & Ehrlich PR, (2002). Mammal Population Losses and the Extinction Crisis. *Science,* 296(5569), 904-907. DOI: 10.1126/science 1069349.

[2] Buddle CM, Spence JR & Langor DW, (2000). Succession of boreal spider assemblages following wildfire and harvesting. *Ecography,* 23, 434-436.

[3] Vu DT, Vu QG, Tran QK, Tran T, Bui MH & Pham DS, (2023). Diversity and ecology of spiders (Araneae) in the buffer zones of three national Parks in northern Vietnam. *HNUE Journal of Science*, 68(2), 173-182.

[4] Pham DS, Xu X & Li SQ, (2007). A Preliminary note on Spider Fauna of Vietnam (Arachnida: Araneae). *Acta Arachnologica Sinica,* 16(2), 121-128.

[5] Ono H, Ta HT & Pham DS, (2012). Spiders (Arachnida, Araneae) Recorded from Vietnam, 1837-2011. *Memoirs of the National Science Museum,* Tokyo, 48, 1-37.

[6] Lin Y, Li SQ & Pham DS, (2023). Taxonomic notes on some spider species (Arachnida: Araneae) from China and Vietnam. *Zoological Systematics*, 48 (1), 1-99.

[7] Wang C, Li SQ & Pham DS, (2023). Thirteen species of jumping spiders from Northern Vietnam (Araneae, Salticidae). *Zookeys*, 1148: 119-165.

[8] Rypstra AL (1983). The importance of food and space in limiting web-spider densities: A test using field enclosures. *Oecologia,* 59(2), 312-316.

[9] Gunnarsson B, **(**1992). Fractal dimension of plants and body size distribution in spiders. *Function Ecology,* 6, 636-641.

[10] Morse DR, Lawton JH, Dodson MM & Williamson MH, (1985). Fractal dimension of vegetation and the distribution of arthropod body lengths. *Nature,* 314, 731-733.

[11] Andow DA, (1991). Vegetational diversity and arthropod population response. *Annual Review of Entomology,* 36, 561-586.

[12] Hawksworth DL & Kalin-Arroyo MT, (1995). *Magnitude and distribution of biodiversity.* In "Global Biodiversity Assessment". (Heywood, V.H. ed). United Nations Environment Programme. Cambridge University Press, London, 107-192.

[13] Rosenzweig ML, (1995). *Species diversity in space and time*. Cambridge University Press, New York, p. 436.

[14] Thai VT, (2000). *Forest vegetation of Vietnam.* Science and Technology Publishing House, Hanoi, Vietnam, p. 276.

[15] Do DT, (2001). *Tam Dao National Park.* Agricultural Publishing House, Hanoi, p. 102.

[16] Vo Q, Nguyen BT, Ha DT & Le VT (1996). *Cuc Phuong National Park*. Agricultural Publishing House, Hanoi, Vietnam, p. 76.
[17] Sørensen LL, (2004). Composition and diversity of the spider fauna in the canopy of a montane forest in Tanzania. *Biodiversity and Conservation*, 13, 437-452.
[18] Corey DT, Stout IJ & Edwards GB, (1998). Ground surface *spider* fauna in sandhill communities of Florida. *Journal of Arachnology*, 26, 303-316.
[19] Bonte D, Baert L, Lens L & Maelfait JP, (2004). Effects of aerial dispersal, habitat specialisation, and landscape structure on spider distribution across fragmented grey dunes. *Ecography*, 27(3), 343-349.
[20] Gillespie RG & Roderick GK, (2002). Arthropods on islands: colonization, speciation, and conservation. *Annual Review of Entomology*, 47, 595-632.
[21] Gillespie RG, Croo HB & Hasty GL, (1997). Phylogenetic relationships and adaptive shifts among major clades of *Tetragnatha* spiders (Araneae: Tetragnathidae) in Hawaii. *Pacific Scientific*, 51, 380-394.
[22] Miller SE & Eldredge LG, (1996). Numbers of Hawaiian species: supplement 1. *Bishop Museum Occasional Papers*, 88, 62-79.
[23] Juan C, Ibrahim KM, Oromi P & Hewitt GM, (2000). Colonization and diversification: towards a phylogeographic synthesis for the Canary Islands. *Trends in Ecology & Evolution*, 15, 104-109.
[24] Russell-Smith A & Stork NE, (1994). Abundance and diversity of spiders from the canopy of tropical rainforests with particular reference to Sulawesi, Indonesia. *Journal of Tropical Ecology*, 10, 545-558.
[25] Bonte D, Leon B & Maelfait JP, (2002). Spider assemblage structure and stability in a heterogeneous coastal dune system. *Journal of Arachnology*, 30, 331-343.
[26] Russell-Smith A, (2002). Comparison of diversity composition ground-active spiders Mkomazi Game Reserve, Tanzania Etosha National Park, Namibia. *Journal of Arachnology*, 30(2), 383-388.
[27] Zehm A, Nobis M & Schwabe A, (2003). Multiparameter analysis of vertical vegetation structure based on digital image processing. *Flora*, 198(2), 142-160.
[28] Tsai ZI, Huang PS & Tso IM, (2006). Habitat management by aboriginals promotes high spider diversity on an Asian tropical island. *Ecography*, 29, 84-94.
[29] Connell JH, (1978). Diversity in tropical rainforests and coral reefs. *Science*, 199, 1302-1310.
[30] Holloway JD, Kirk-Spriggs AH & Khen CV, (1992). The response of some rainforest insect groups to logging and conservation in plantation. *Philosophical Transactions of the Royal Society B*, 335, 425-436.
[31] Goehring D, Daily GC & Sekercioglu CH, (2002). Distribution of ground-dwelling arthropods in tropical countryside habitats. *Journal of Insect Conservation*, 6, 83-91.
[32] Almquist S, (1973). Spider associations in coastal sand dunes. *Oikos*, 24, 444-457.
[33] Downie IS, Wilson WL, Abernethy VJ, McCracken DI, Foster GN, Ribera I, Murphy KJ & Waterhouse A, (1999). The impact of different agricultural land use on epigeal spider diversity in Scotland. *Journal of Insect Conservation*, 3, 273-286.