

Diversity of spiders (Araneae) in the anthropic land covers of Davao City, Philippines

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Abstract

In addition to protected landscapes, anthropic land covers (ALCs) can also harbor spiders in human-modified landscapes (HMLs). This study determined the diversity of spiders in seven different ALCs within the University of the Philippines Mindanao campus in order to identify ALCs with the highest priority for spider conservation. Direct sampling methods were employed to collect specimens within 2,000 m² belt transects. A total of 364 spider individuals belonging to 69 morphospecies from 40 genera and 13 families were documented. Highest species richness was observed from the family Araneidae. *Nephila pilipes* Fabricius (Araneidae) and *Heteropoda venatoria* Linnaeus (Sparassidae) were found across sampling sites. Among the ALCs, site 5OGSF (old-growth and secondary forest) had the highest species richness (q^0 (26)) while site 7AF (agroforest) had the highest species diversity (q^1 (17.16); q^2 (13.83)). Site 3CTP (cacao tree plantation) was consistently the least species-rich (q^0 (10)) and least diverse (q^1 (6.92); q^2 (5.54)). The different vegetation density and structural complexity of ALCs on the campus support spider communities in which the highest species richness and diversity were observed in the secondary forest and agroforest, respectively. This paper highlights that spider communities have varying levels of diversity in different small-scale ALCs.

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Introduction

Tropical forests have the most diversified flora and fauna and act as vital regulators of climatic conditions (Brandon, 2014). However, dramatic loss of tropical biodiversity in natural habitats has been recorded in recent years due to impacts of anthropogenic activities

such as deforestation and fragmentation, overexploitation, invasive species, and climate change (Morris, 2010). As a result, these human pressures simultaneously compel some terrestrial biota to thrive in human-modified landscapes (HMLs) composed of various anthropic land covers (ALCs) (Gálan-Acedo et al., 2019; Arroyo-Rodríguez et al., 2020). Evidence suggests that ALCs

have selective effects on the species utilizing it, including reduced extinction risk for some adaptive species (Gascon et al., 1999; Nielsen et al., 2014; Ferreira et al., 2018; Ripp et al., 2018; Gálan-Acedo et al., 2019). Therefore, ALCs should be incorporated in management and protection plans for biodiversity conservation along with the ongoing efforts to preserve natural environments.

Spiders are one of the megadiverse invertebrate groups thriving in unprotected terrestrial ecosystems. Spiders are important predatory arthropods and ecological indicators that can show significant changes to the environment (Lee and Kim, 2001; Rajeswaran et al., 2005; Cera et al., 2010). This arthropod group can inhabit various disturbed habitats including human-managed ecosystems (synanthropic spiders) (Szinetár et al., 2020), agricultural lands (Barrion, 2001; Rosa et al., 2018), and riparian zones (Graf et al., 2019), primarily feeding on a wide range of prey. Spiders can also serve as a model organism in studying the life history of invertebrates being affected by habitat modifications due to urbanization (Lowe et al., 2017). Many spiders have successfully adapted to urban ecosystems, which have been long recognized as providing essential refuge to diverse flora and fauna (Gaston et al., 2005; Nielsen et al., 2014; Ripp et al., 2018; Salinitro et al., 2018). In fact, previous studies have reported the persistence of synanthropic spiders in different urban habitat types (e.g., Shochat et al., 2004; Moorhead and Philpott, 2013; Rodríguez-Rodríguez et al., 2015). However, spiders have varying responses in terms of abundance, distribution, and diversity in different urban habitats due to alterations in environmental factors such as temperature, food resources, and vegetation structure (Li and Jackson, 1996; Teixeira de Souza and de Souza-Modena, 2004; Lowe et al., 2014; Argañaraz et al., 2018; Lowe et al., 2018; Ripp et al., 2018). For instance, Rodríguez-Rodríguez et al. (2015) recorded high spider diversity in an urban zone with a garden in Mexico, but Anindita et al. (2017) noted lower spider diversity in habitats with human habitations in India. According to Philpott et al. (2014), the abundance and richness of many terrestrial arthropods, including spiders, are generally distinct depending on habitat characteristics and other local factors. Thus, it is also necessary to assess the occurrence of spiders and its potential significance in small-scale HMLs to enhance conservation strategies.

The Philippine Archipelago is known for its high levels of spider diversity and endemism (Barrion and Litsinger, 1995; Barrion-Dupo et al., 2014; Dacanay et al., 2014). Despite the high endemism, limited works have been done on the spider communities in urban ecosystems (Barrion and Litsinger, 1995; Achacoso et al., 2016). With the baseline checklist from the study of Barrion and Litsinger (1995), species identifications of spiders in the country are now continuously rising as more researchers have conducted field surveys of the microhabitats of spiders (Barrion-Dupo, 2008; Barrion-Dupo et al., 2014; Chua et al., 2014; Dacanay et al., 2014; Elias and

Nuñeza, 2015; Rasalan et al., 2015; Achacoso et al., 2016; Mondejar and Nuñeza, 2016; Quiñones et al., 2016; Responde and Nuñeza, 2016; Barrion-Dupo and Barrion, 2019; Chang et al., 2019). However, most of these reports examined spider fauna in protected, natural environments and only a few focused on disturbed habitats, largely overlooking spider communities within Philippine urban settings.

In this paper, we provide information on the composition and diversity of spiders in the ALCs of Davao City, Philippines. We questioned whether the composition and diversity of spiders vary between different altered landscapes. In particular, we hypothesized that habitats with reduced vegetation cover have lower spider diversity, while habitats with dense vegetation cover have higher species diversity. In addition, monoculture habitat structures may have negative effects to spider diversity. Thus, we conducted surveys of spiders in small-scale ALCs including tree plantations, garden croplands, and other areas of remnant vegetation, in order to identify the ALCs that should have the highest priority for conservation in the Philippines.

Material and Methods

Spider sampling

Specimens were collected from seven selected anthropic land covers (ALCs) inside the University of the Philippines Mindanao (UP Mindanao) campus. The campus is located between two urban areas in Davao City: Mintal and Bago Oshiro. Different types of ALCs on the campus were classified based on the studies of Gardner et al. (2009) and Galán-Acedo et al. (2019) and included human settlements, open areas such as annual crops and cattle pastures, tree plantations, connectors (i.e., isolated trees and linear landscape elements such as hedgerows and live fences), and secondary or regenerating forests. The seven ALCs in this study are the following: (1SF) a secondary forest with a small riparian zone; (2MTP) a tree plantation with mahogany (*Swietenia macrophylla* King) as the dominant plant species; (3CTP) a cacao (*Theobroma cacao* L.) tree plantation; (4GC) a garden cropland; (5OGSF) a mix of old-growth and secondary forest; (6LF) a live fence and hedgerow; and (7AF) an agroforest (Table 1).

We used a modified belt transect in each ALC for species collection with a length of 200 meters and a width of 5 meters on each side for a total area of 2,000 m². Spiders that were opportunistically found outside the ALCs were also recorded but excluded from the analyses. Day and night sampling were conducted from February to March 2018, wherein a total of 24 person-hours were spent per ALC for a total of 168 person-hours throughout the overall survey. Different direct sampling methods such as cryptic searching and ground and aerial hand collecting were performed with modifications (Sorensen et al., 2002; Coddington et al., 2009) based on what could be applied in a specific ALC.

Table 1: The seven anthropic land covers (ALCs) within the UP Mindanao campus, Philippines.

Sampling sites	Description	Coordinates
1SF	Secondary forest with a small riparian zone	7°05'03.5" N 125°29'15.0" E
2MTP	Mahogany tree plantation (<i>Swietenia macrophylla</i> as the dominant species)	7°05'10.6" N 125°29'11.0" E
3CTP	Cacao tree plantation	7°05'04.0" N 125°28'25.4" E
4GC	Garden cropland	7°05'15.1" N 125°28'09.6" E
5OGSF	Mix of old-growth and secondary forest	7°05'30.8" N 125°28'09.9" E
6LF	Live fence and hedgerow along the road	7°05'03.7" N 125°28'45.1" E
7AF	Agroforest (e.g., <i>Artocarpus</i> spp., <i>Durio zibethinus</i>)	7°05'05.2" N 125°28'53.8" E

The collected specimens were placed in plastic containers and were transferred to vials filled with 75% ethyl alcohol for permanent storage. Spider identification was performed to morphospecies level using available identification guides and published articles (e.g., Barrion and Litsinger, 1994; Barrion and Litsinger, 1995; Saariisto, 2006; Chen, 2007; Dippenaar-Schoeman and van Harten, 2007; Jocqué et al., 2007; Barrion-Dupo, 2008; Liu et al., 2010; Anju et al., 2021; Jäger, 2022). Morphospecies designation was also determined using other morphological characters and web patterns (Barrion and Litsinger, 1995; Lawania and Mathur, 2017).

Data analyses

The spider families recorded from different ALCs inside UP Mindanao campus were ranked according to their abundance and were displayed using the *ggplot2* R package (Wickham, 2011). Moreover, we determined the species diversity and the sample completeness of the entire study area using the *iNEXT* R package (Hsieh et al., 2016). The sample size-based rarefaction and extrapolation curves plot the first Hill number (q^0 ; species richness; Chao et al., 2014). The reference sample from the seven sampling sites ($n=343$) was doubled ($n=686$) to create an extrapolation curve and to check for an asymptote. Bootstrap replicates (200) were used to estimate a 95% confidence interval. In addition, the sample completeness curve plots the relationship between sample size and coverage (Hsieh et al., 2016). The coverage estimates the proportion of individuals in a particular community that belongs to the species detected in the samples (Chao and Jost, 2012).

For each of the ALCs, sample size-based rarefaction and extrapolation sampling curves (Colwell et al., 2012) were generated using the three Hill numbers of order q : species richness (q^0), exponential of Shannon entropy (Shannon's diversity, q^1), and inverse Simpson concentration (Simpson's diversity, q^2) (Chao et al., 2014). All extrapolated curves were plotted using the maximum reference sample size among the seven sampling sites (5OGSF; $n=99$), and 200 bootstrap replicates were used to estimate 95% confidence intervals. Diversity estimates with no overlapping 95% confidence intervals indicate significant differences (at $p=0.05$) (Chao and Jost, 2012; Chao et al., 2014).

We also classified the sampling sites through cluster analysis, based on Bray–Curtis similarity coefficients, which was performed in the same *vegan* R package (Oksanen et al., 2013) using the number of species and individuals collected from each ALC. Pairwise comparisons of the Bray–Curtis similarity coefficients yield a value ranging from 0 (no species is/are common) to 1 (indicates identical composition) (Magurran, 2004). Individuals we observed and collected from outside the transects were excluded from all the analyses.

Results

Species composition of spiders in the ALCs of UP Mindanao Campus

A total of 364 spiders were recorded from the seven anthropic land covers (ALCs) and the vicinity, consisting of 69 morphospecies that belong to 40 identified genera from 13 families (Table 2). Family Araneidae composed 41.5% of the total morphospecies, followed by Sparassidae (27.2%), Tetragnathidae (9.9%), Oxyopidae (6.6%), Salticidae (5.5%), Pisauridae (3.6%), Theridiidae (2.8%), Lycosidae (1.1%), Thomisidae (0.8%), Clubionidae (0.3%), Corinnidae (0.3%), Ctenidae (0.3%), and Hersiliidae (0.3%). These families were ranked according to their decreasing abundance in the sampling sites (Fig. 1). Araneidae (i.e., *Nephila pilipes* Fabricius, 1793) and Sparassidae (i.e., *Heteropoda venatoria* Linnaeus, 1767) were found across the seven ALCs while Clubionidae, Corinnidae, Ctenidae, and Hersiliidae, each represented with a single individual, were found only in one sampling site: 7AF, 6CN, 5OGSF, and 2MTP, respectively.

Species richness estimates

At 93% sample completeness, results showed an increasing slope which means additional species of spiders can still be found (Fig. 2A-B). If the reference sample size is increased twice, sample completeness can reach up to 97%. Moreover, a total of 91 spider species may be found in the study area based on the computed species richness estimator.

Based on the rarefaction and extrapolation curves, asymptotic species diversity can be reached for most of the ALCs if the sample size is increased beyond the interpolated sample (Fig. 3).

Table 2: Species richness and relative abundance of spiders in the seven anthropic land covers (ALCs) of UP Mindanao campus, Philippines.

Family	Genus	Morphospecies	1 SF	2 MTP	3 CTP	4 GC	5 OGSF	6 LF	7 AF
Araneidae RA= 41.48%	<i>Acusilas</i>	sp.					•		•
	<i>Arachnura</i>	<i>melanura</i>				•		•	
	<i>Argiope</i>	<i>aemula</i>							
	<i>Argiope</i>	<i>appensa</i>	•					•	•
	<i>Bijoaraneus</i>	cf. <i>mitificus</i>	•						
	<i>Cyclosa</i>	<i>insulana</i>					•		
	<i>Cyrtophora</i>	cf. <i>cylindroides</i>	•						•
	<i>Cyrtophora</i>	<i>exanthematica</i>			•		•	•	
	<i>Cyrtophora</i>	<i>parangexanthematica</i>		•				•	•
	<i>Cyrtophora</i>	cf. <i>moluccensis</i>	•						
	<i>Cyrtophora</i>	sp.				•			•
	<i>Eriovixia</i>	<i>laglaizei</i>	•			•	•		•
	<i>Gasteracantha</i>	<i>diadesmia</i>	•		•		•	•	
	<i>Gasteracantha</i>	<i>kuhli</i>		•	•			•	
	<i>Gasteracantha</i>	<i>janopol</i>					•		
	<i>Gasteracantha</i>	<i>parangdiadesmia</i>	•	•					
	<i>Neoscona</i>	<i>lipana</i>							•
	<i>Neoscona</i>	<i>molemensis</i>					•		•
	<i>Neoscona</i>	<i>punctigera</i>			•			•	•
	<i>Neoscona</i>	<i>usbonga</i>				•		•	•
<i>Neoscona</i>	<i>vigilans</i>				•	•	•	•	
<i>Nephila</i>	<i>pilipes</i>	•	•	•	•	•	•	•	
<i>Paravixia</i>	<i>dehaani</i>			•					
<i>Poltyx</i>	sp. A							•	
<i>Poltyx</i>	sp. B	•							
<i>Trichonephila</i>	<i>antipodiana</i>		•	•	•	•		•	
Salticidae RA= 5.49%	<i>Carrhotus</i>	sp. A					•		
	<i>Carrhotus</i>	sp. B*	-	-	-	-	-	-	-
	<i>Epeus</i>	<i>flavobilineatus</i>	•						
	<i>Hyllus</i>	sp. A	•						
	<i>Hyllus</i>	sp. B							•
	<i>Phaeacius</i>	sp.							•
	<i>Phintella</i>	sp.	•						
	<i>Plexippus</i>	sp.				•	•		
	<i>Portia</i>	sp.	•				•		
	<i>Pristobaeus</i>	sp.	•						
Genus 1	sp.							•	
Genus 2	sp.	•							
Sparassidae RA= 27.20%	<i>Heteropoda</i>	<i>venatoria</i>	•	•	•	•	•	•	•
	<i>Heteropoda</i>	sp. A			•		•		
	<i>Heteropoda</i>	sp. B							•
	<i>Olios</i>	sp. A				•			
	<i>Olios</i>	sp. B*	-	-	-	-	-	-	-
	<i>Olios</i>	sp. C		•				•	
<i>Pandercetes</i>	cf. <i>gracilis</i>					•		•	
Tetragnathidae RA= 9.89%	<i>Leucauge</i>	<i>decorata</i>				•			
	<i>Leucauge</i>	<i>fastigata</i>	•	•	•		•		•
	<i>Leucauge</i>	sp.	•				•		
	<i>Tetragnatha</i>	sp. A					•		
	<i>Tetragnatha</i>	sp. B		•			•		
Theridiidae RA= 2.75%	<i>Argyrodes</i>	<i>flavescens</i>		•			•		
	<i>Parasteatoda</i>	sp. A		•					
	<i>Parasteatoda</i>	sp. B	•						
	<i>Steatoda</i>	sp. A							
<i>Steatoda</i>	sp. B				•				
Pisauridae RA= 3.57%	<i>Dolomedes</i>	sp.				•	•		
	<i>Nilus</i>	<i>albocinctus</i>					•		
	<i>Pisaura</i>	sp.					•		
	<i>Hygropoda</i>	sp.					•		
Lycosidae RA= 1.10%	<i>Pardosa</i>	sp. A				•			
	<i>Pardosa</i>	sp. B	•	•					
Oxyopidae RA= 6.59%	<i>Oxyopes</i>	sp. A	•	•			•	•	•
	<i>Oxyopes</i>	sp. B*	-	-	-	-	-	-	-
Thomisidae RA= 0.82%	<i>Thomisus</i>	sp.						•	
	Genus 1	sp.	•						
Clubionidae RA= 0.27%	<i>Nusatidia</i>	sp.							•
Corinnidae RA= 0.27%	Genus 1	sp.						•	
Ctenidae RA= 0.27%	<i>Bowie</i>	sp.					•		
Hersiliidae RA= 0.27%	<i>Hersilia</i>	sp.		•					

1SF = Secondary Forest; 2MTP = Mahogany Tree Plantation; 3CTP = Cacao Tree Plantation; 4GC = Garden Cropland; 5OGSF = Mix of Old-Growth and Secondary Forest; 6LF = Live Fence; 7AF = Agroforest; RA = Relative Abundance; * species found outside the ALCs.

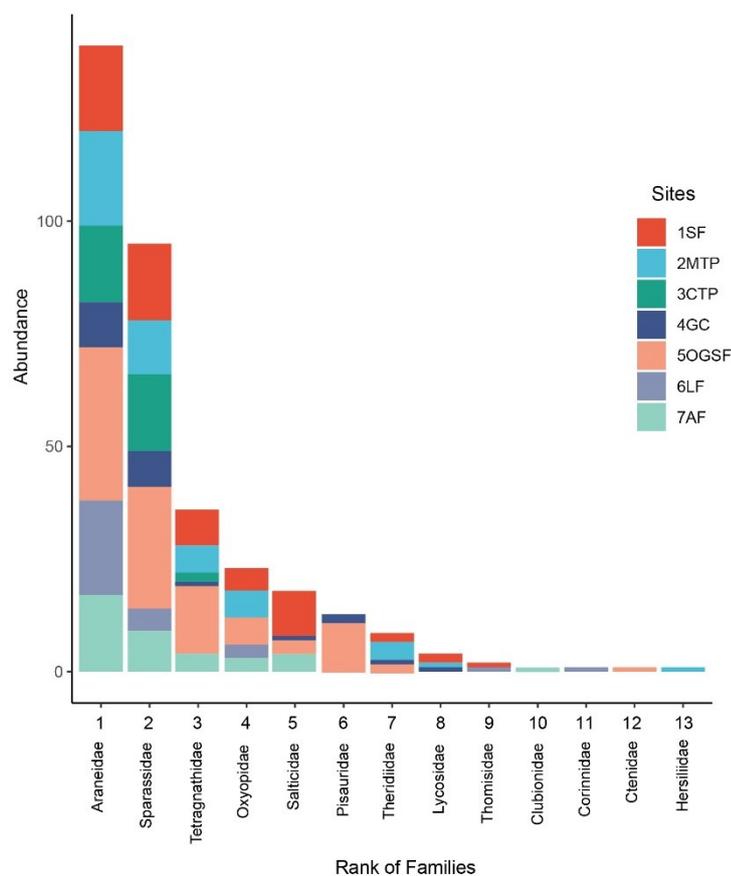


Figure 1: Rank abundance of spider families in the seven anthropic land covers (ALCs) of UP Mindanao campus. 1SF = Secondary Forest; 2MTP = Mahogany Tree Plantation; 3CTP = Cacao Tree Plantation; 4GC = Garden Cropland; 5OGSF = Mix of Old-Growth and Secondary Forest; 6LF = Live Fence; 7AF = Agroforest.

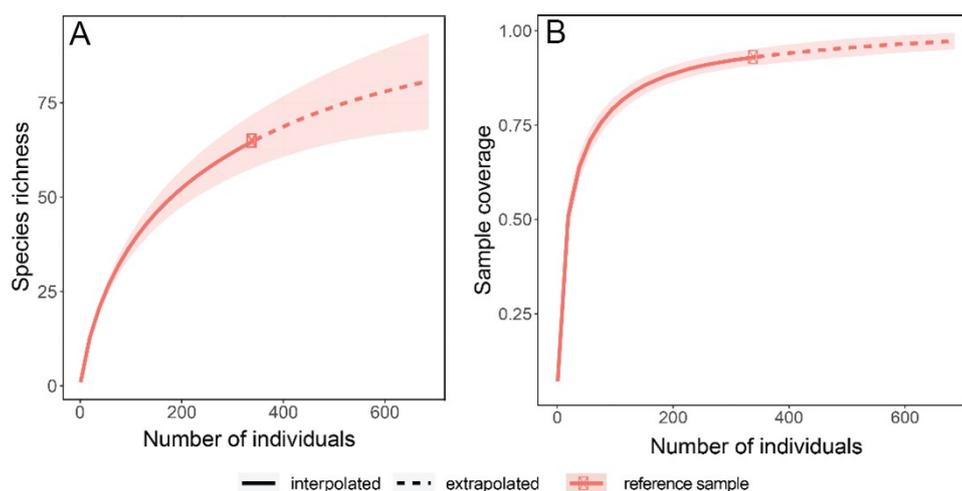


Figure 2: Sample size-based rarefaction and extrapolation curves: (A) total species richness in UP Mindanao campus; (B) sample completeness curve. Dashed lines represent extrapolation up to double reference sample size (n= 686) and shaded areas show 95% confidence limits with 200 bootstrap replicates.

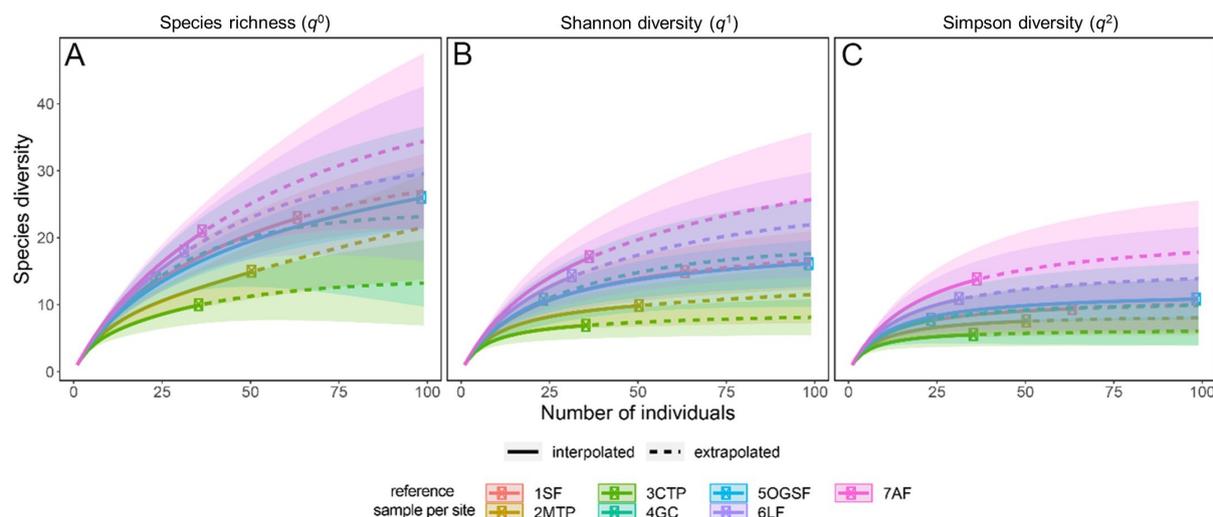


Figure 3: Comparison of sample size-based rarefaction and extrapolation curves of the spider diversity from seven anthropic land covers (ALCs) in UP Mindanao campus based on three Hill numbers ($q^{0,1,2}$): (A) species richness; (B) Hill Shannon diversity; (C) Hill Simpson diversity. Dashed lines represent extrapolation up to the base sample size of 99 individuals (the maximum reference sample size) and shaded areas show 95% confidence limits with 200 bootstrap replicates. Sampling sites: 1SF = Secondary Forest; 2MTP = Mahogany Tree Plantation; 3CTP = Cacao Tree Plantation; 4GC = Garden Cropland; 5OGSF = Mix of Old-Growth and Secondary Forest; 6LF = Live Fence; 7AF = Agroforest.

The two Hill measurements ($q^{1,2}$) showed lower diversity estimates (Fig. 3B-C) compared to the species richness measurement (q^0) (Fig. 3A) for all the ALCs. However, all the sample size-based rarefaction and extrapolation curves for the three Hill numbers revealed a consistent highest species diversity in the agroforestry landscape (Fig. 3: q^1 (17.16); q^2 (13.83)). In addition, it showed consistent lowest species richness and diversity for the cacao tree plantation (Fig. 3: q^0 (10); q^1 (6.92); q^2 (5.54)). The 95% confidence intervals for the rarefaction and extrapolation curves of the seven sampling sites overlap substantially. This indicates no significant differences in Hill species diversity among ALCs. However, we can also observe that the 95% confidence intervals of site 3CTP, the least species-rich and least diverse site, only overlap with the 95% confidence intervals of sites 4GC and 2MTP. This indicates that there is no significant difference in the species diversity between sites 3CTP, 4GC, and 2MTP; however, site 3CTP is significantly different from the other sites: 1SF, 5OGSF, 6LF, and 7AF.

Cluster analysis of the ALCs

Cluster analysis revealed two major groups of sites with an 85% similarity level (Fig. 4). The first major group comprised three sites with a 58% similarity level: 5OGSF and a subgroup of 1SF and 2MTP. The second major group consists of four sites with a 76% similarity level: 6LF, 7AF, 3CTP, and 4GC, which were further clustered into two subgroups, respectively.

Discussion

This araneofauna survey inside UP Mindanao campus showed a relatively high species diversity in seven

anthropic land covers (ALCs) with 69 identified morphospecies. In contrast with published papers on the diversity of Philippine spiders in conserved areas (Elias and Nuñez, 2015; Garciano et al., 2015; Responte and Nuñez, 2016; Alviola and Disomimba, 2017; Banaag et al. 2020), this study has emphasized the rich assemblage and ubiquitous presence of araneofauna in small-scale habitats. The surveyed ALCs served as microhabitats for spiders, allowing them to flourish in human-modified landscapes.

Among the 13 families observed in this study, Araneidae had the highest species richness (37.68%) and relative abundance (41.48%) (Table 2). Araneidae is a large family of spiders with 180 genera, a number exceeded only in Linyphiidae and Salticidae (World Spider Catalog, 2022). Similar observations of high species richness have been reported among Philippine spiders in protected (Garciano et al., 2014; Juario et al., 2016a; Alviola and Disomimba, 2017) and unprotected landscapes (Dacanay et al., 2014; Juario et al., 2016b; Patiño et al., 2016). Araneids can dwell on various habitat structures (Austin and Anderson, 1978; Jocqué et al., 2007) and are usually active both during day and night. Moreover, these spiders can be easily distinguished by their prominent orb-webs used for trapping potential prey items (Barrion and Litsinger, 1995). Such attributes may explain the richness and abundance of Araneidae across all surveyed ALCs. The four major subfamilies namely Gasteracanthinae, Araneinae, Argiopinae, and Nephilinae (Barrion and Litsinger, 1995) were also documented. The occurrence of araneids in all ALCs implies high tolerance to varying degrees of habitat alteration or disturbance.

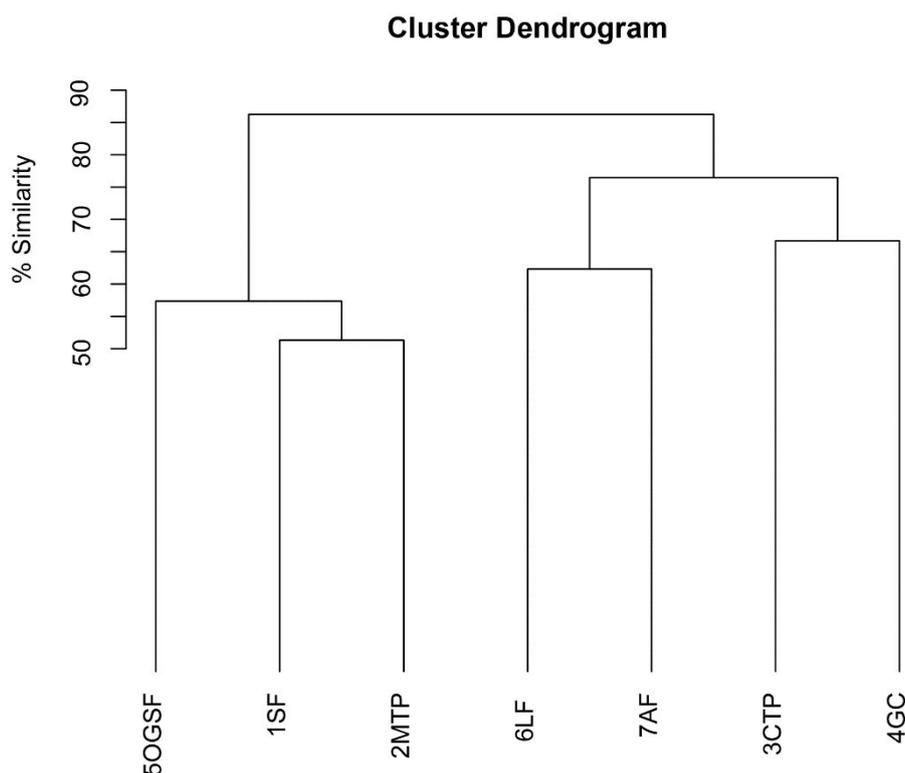


Figure 4: Cluster analysis of the seven anthropic land covers (ALCs) in UP Mindanao campus based on Bray–Curtis Similarity. Sampling sites: 1SF = Secondary Forest; 2MTP = Mahogany Tree Plantation; 3CTP = Cacao Tree Plantation; 4GC = Garden Cropland; 5OGSF = Mix of Old-Growth and Secondary Forest; 6LF = Live Fence; 7AF = Agroforest.

In terms of spatial distribution among the ALCs, *Nephila pilipes* and *Heteropoda venatoria* have the widest range of occurrence among the observed species. *N. pilipes* is a widely distributed species in Southeast Asia, including the Philippines (Su et al., 2007; World Spider Catalog, 2022). It exhibits sexual dimorphism in that females are extremely large (Kuntner et al., 2012) and can create huge orb-webs to capture various preys (Tso et al., 2007). Meanwhile, *H. venatoria* is another common species in the tropics that usually dwells in cracks and crevices and captures insect pests without using webs (Ross et al., 1982; Ntonifor et al., 2012; Neogi and Islam, 2017).

In this study, the presence of human dwellings, dense vegetation, and leaf litter in the area meets the habitat preferences of the two species, thereby occurring in all ALCs. Furthermore, singletons from four families (Clubionidae, Corinnidae, Ctenidae, and Hersiliidae) were documented in different ALCs. These cryptic spiders might have not been adequately sampled as they used mimicry to avoid predation and they also dwell on microhabitats that cannot be accessed easily such as soil, tree, and rock crevices.

The overall species richness (q^0 (69)) in this study was higher than the spider surveys conducted in secondary forest vegetation in Basilan (q^0 (28)), Tawi-tawi (q^0 (43)) (Juario et al., 2016), and Pulacan, Zamboanga del Sur (q^0 (37)) (Dacanay et al., 2014). However, our study showed considerably lower

species richness compared to Patiño et al. (2016) who reported 171 species from an unprotected mountainous landscape in Davao City. The sample size-based rarefaction and extrapolation curves for the first Hill number revealed that our study area may host 91 species if the reference sample size is increased twice. This indicates that the human-altered green spaces inside UP Mindanao campus still support a rich assemblage of spiders.

Furthermore, the most species-rich ALC among all sites was site 5OGSF (q^0 (26)). This site is a mix of old-growth and secondary forests with a denser vegetation cover compared with the other ALCs. This supports previous findings that spider abundance and composition can be influenced by the general vegetation structure of an area (Malumbres-Olarte et al., 2013; Lucman et al., 2020).

Moreover, the Hill species diversity showed that site 7AF is the most diverse site (q^1 (17.16); q^2 (13.83)), while 3CTP is the least species-rich and least diverse (q^0 (10); q^1 (6.92); q^2 (5.54)). Site 7AF is an agroforest composed of fruiting trees such as *Annona muricata* L., *Artocarpus* spp., *Citrus maxima* (Burm.) Merr., *Durio zibethinus* L., *Psidium guajava* L., *Sandoricum koetjape* (Burm.f.) Merr., and *Theobroma cacao* L.. The branches, leaves, and twigs of such plants can serve as anchors for the webs of spiders (Stenchly et al., 2011). Many spiders

can also dwell on the surface with leaf litter that has varying depths and complexity (Wagner et al., 2003). Moreover, insects also exist in this ecosystem as they facilitate the pollination of flowering plants (Calderone, 2012). As a result, site 7AF obtained the highest species diversity ($q^{1,2}$) as it provides habitats not just for spiders but also for insects that serve as their food; in turn, spiders become biocontrol agents in this environment (Barrion, 2001). Meanwhile, site 3CTP is a cacao tree plantation that is relatively less dense and less complex in terms of vegetation. Spiders also provide biocontrol services in this ALC (Hajian-Forooshani et al., 2014). However, spider richness and diversity were lowest in this site, consistent with earlier findings that also recorded declining spider communities in monocultured agricultural landscapes (Banaag et al., 2020; Potapov et al., 2020). This is due to land-use change and the potential use of insecticide in this monocultured plantation, which caused a decline of spider species thriving in this altered habitat.

Moreover, the clustering analysis of the study sites showed two major groups with 85% similarity (Fig. 4): one major group includes sites with relatively denser vegetation which are 1SF, 2MTP, and 5OGSF (58% similarity), while the other major group includes sites with relatively less dense vegetation cover which are 3CTP, 4GC, 6LF, and 7AF (76% similarity). The former major group has one subgroup (1SF-2MTP), while two subgroups were formed in the latter major group: 3CTP-4GC and 6LF-7AF. We infer that the clustering of the ALCs is influenced by the variation of their vegetation type and complexity, further supporting the claim that it affects species composition. In addition, the grouped ALCs were observed to be near each other, which imply an exchange of species communities in more than one site.

Conclusions

In this study, we highlight the importance of different ALCs as potential microhabitats of spiders in an urban area in Davao City, Philippines, wherein relatively high spider diversity can still exist. The composition and diversity of spiders in each ALC are shown to be associated with the density and structural complexity of the vegetation in human-modified landscapes. As demonstrated by our findings, spider diversity varies in different small-scale ALCs. In particular, we suggest prioritizing conservation both for the secondary forest and the agroecosystem type of ALC which potentially provide habitable environments for both spiders and their prey compared to the other surveyed ALCs. Furthermore, we have also identified the negative effect of monocultured agricultural systems on the diversity of spiders. As the Philippines is recognized as an

agricultural country, supporting an agroforestry system type of vegetation cover for farming may be the best management method to prevent the significant loss of spider communities in agricultural areas.

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Conflict of interest

All authors declare that there are no conflicting issues related to this research article.

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