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Diversity and species composition of spiders (Arachnida: Aranaeae) at different habitats in Mount Tumpa Forest Park, North Sulawesi, Indonesia

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Abstract

The complexity of the vegetation habitats of spiders affects their diversity. An analysis of diversity and species composition of spiders (Arachnida: Araneae) in Mount Tumpa Forest Park, North Sulawesi was done by sampling them in three habitats: primary forest, secondary forest and agricultural land, from April to August 2015 using pitfall traps for spiders on the ground and sweep nets for spiders that live in the canopy. A total of 2218 spiders belonged to 17 families consisting of 62 genera and 137 morphospecies. Araneidae being most commonly occurring family (24.75%) followed by Tetragnathidae (24.48%) while the least common was Scytodidae (0.09%). The families with the most species were Theridiidae (14 morphospecies) then Araneidae, Salticidae each having 11 morphospecies. Indices of abundance (N = 186), species richness (S = 51.75), species diversity (H = 3.28) and species evenness (E = 0.83) was the highest in primary forest and the lowest in agricultural land. Spider community similarity between habitats showed the greatest similarity index between primary forests and secondary forests (IS = 68 %). It was concluded that the highest diversity of spider species among all types of habitat are in the primary forest. Therefore complexity of vegetation in these habitats need to be preserved to maintain the survivorship of the spider.

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Introduction

Mount Tumpa Forest Park is an integrated conservation area between natural forests and agricultural land in the province of North Sulawesi, Indonesia. Spiders are one of the fauna found in Mount Tumpa Forest Park. Spiders belong to the phylum Arthophoda, class Arachnida and order Araneae (Miller and Sac, 2011). These spiders are the largest group and have a very high diversity among the phylum arthropods. The Spiders have globally more than 40,000 identified species (Rana *et al*., 2016), classified into 111 families and 3600 genus (Anjali and Prakash, 2012). It is estimated that the number of species of spiders in the entire world can reach 170,000 (Lalisan *et al.,* 2015).

Spiders can play a pivotal role in keeping insect and pest populations in check and balance and they are also serve as food for birds, snakes, fish and other animals. They eat insects and bugs which destroy different crops and consequently safe guard the agro-ecosystems (Rana *et al.,* 2016). Because they are at the top of the invertebrate trophic chain these arachnids can regulate decomposer populations. Spiders are also good bio-indicators for evaluating the impact of anthropogenic disturbance on natural ecosystems and they are useful components in regulating insect population in many terrestrial habitats (Enriquez and Nuneza, 2014).

Changes in Mount Tumpa Forest Park can affect the diversity of spiders and affect nutrient cycling and materials in the ecosystem. Some research on the diversity of spiders has been done, including the spider diversity and its relationship with habitat heterogeneity (Abdelmoniem *et al*., 2003); diversity of spiders in a variety of habitats in Taiwan (Chen and Tso, 2004); the composition and diversity of spiders in the tree canopy (Sorensen, 2004); spider diversity in primary forest and disturbed forests in the tropics (Floren, 2005); the composition and diversity of spiders in five types of vegetation (Uniyal and Hore, 2008), and research using spiders as ecological indicator species (Clauseu, 1986; Maelfait and Hendrick, 1998).

Spider research previously done in Indonesia includes the abundance and diversity of spiders in the canopy of Sulawesi tropical rain forests (Smith and Stork, 1994), composition and spider communities in Borneo tropical rain forest (Smith and Stork, 1995), bio-ecology of spiders in rice field of Cianjur, West Java (Suana, 2005), and community spiders on cocoa plantations in Central Sulawesi (Stenchly, 2010). However, the number of studies of spiders in Indonesia, especially in North Sulawesi, is still very small when compared to other countries as well as in Asia. Data available to date was taken a few years ago and was only performed at a few specific locations. Meanwhile, recent data about the overall distribution and diversity is not yet available. As for Sulawesi, the last two decades have shown a high rate of deforestation, about 67 % productive moist forest habitat has been converted for lumber agricultural (Lee *et al.,* 2001). Moreover, the diversity of spiders in the area of Mount Tumpa Forest Park has not yet been studied and published. This study aimed to analyze the diversity and species composition of spiders (Arachnida: Araneae) at different habitats in Mount Tumpa Forest Park, North Sulawesi, Indonesia

Materials and methods

Study area

The sampling was carried out from April through Juny 2015, in Mount Tumpa Forest Park, North Sulawesi. Geographically Mount Tumpa Forest Park, North Sulawesi, geographically, is located at the coordinate position 01°33'16,82 " to 01°34'31,86 "North Latitude and 124°49'57, 63” to 124°5'06, 05" East Longitude (Fig.1) at an altitude of 100-627 m above sea level, having total area of 215 hac.

Primary forests are used as sampling sites located with a height ranging between 475-507 meters above sea level. Temperatures in these habitats range from 27-28°C with humidity between 70-71%. Secondary forests are forests that grow and develop naturally after damage/change to the primary forests, with a height ranging between 376-393 m above sea level. Agricultural land are located outside the Mount Tumpa Forest Park and the agricultural land is managed by the community and planted with various types of agricultural crops. Agricultural land used as sampling sites were located at an altitude between 119-196 m above sea level. The average air temperature in the plantations ranges between 31.8° 32.5°C, with humidity of 62.5 to 68%.

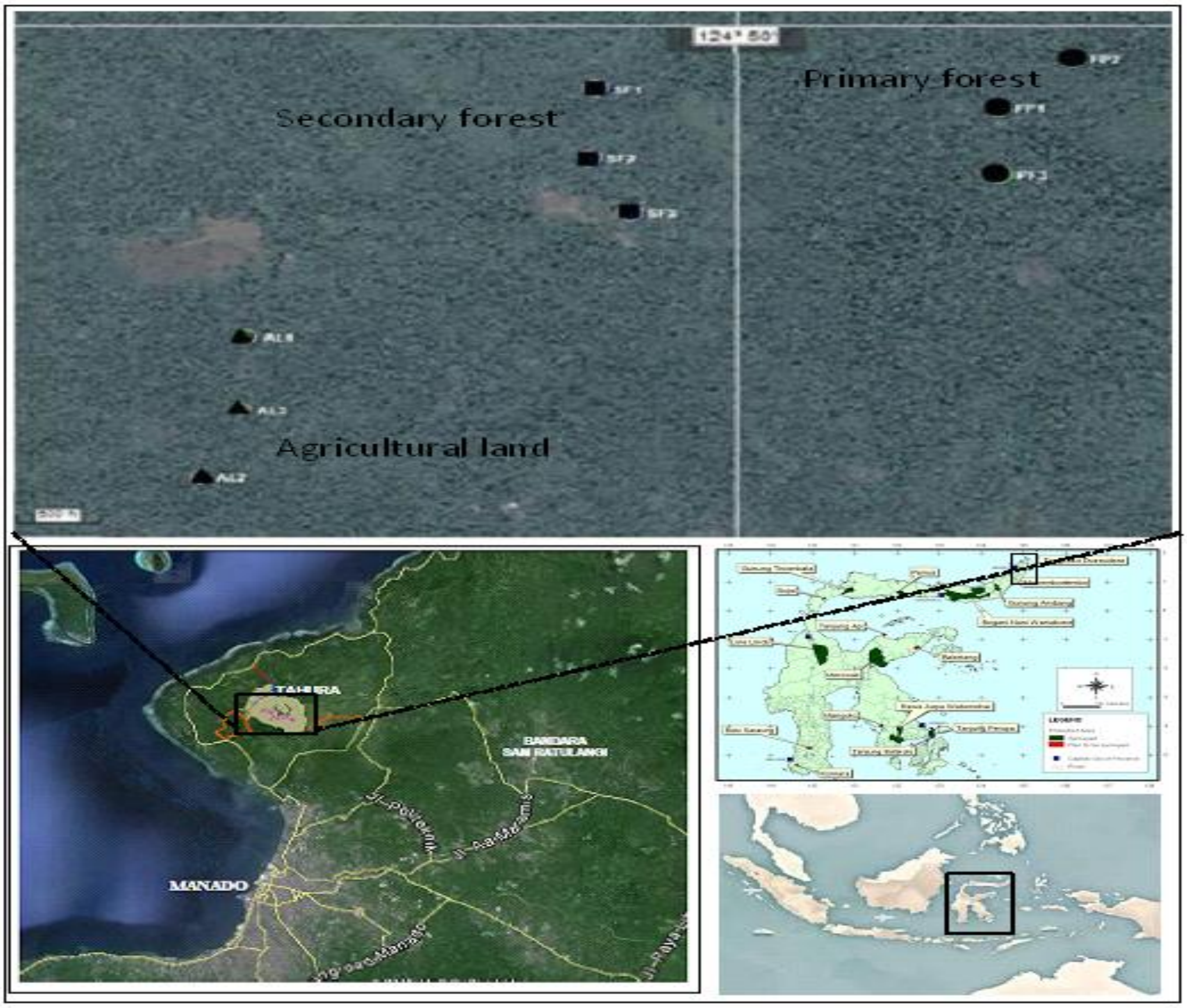

Fig. 1. Map of the study area.

Collection and identification

Samples were differentiated into two by using pitfall traps to trap spiders that move on the ground, while the spiders in the canopy were collected by the method of sweep netting (Vincent and Hadrien, 2013). Pitfall traps used in this study consisted of plastic cups (220 ml volume: diameter = 5.3 cm and height = 9.8 cm) placed in the ground, half filled with a solution of 69 % water,30 % ethylacetate; and 1 % detergent (Uniyal *et al.,* 2011), and top was made flat to the ground. To avoid the entry of rain water, plastic cups were given shade. Spiders entering the trap become stuck and die in the cup containing detergent and acetyl acetate.

A total of 5 traps were mounted on one transect with distance between the traps as far as 100 m. The traps in each type of habitat numbered as many as 20. Traps were kept operating for 3 × 24 hours (Uniyal,*et al.,* 2011). Sample spiders trapped were stored in eppendorf tubes filled with 95% alcohol.

Net sweeping of spiders was done above the vegetation (herbaceous, shrub, shrubs and trees) by swinging a 60cm cone-shaped net, 300-380 cm in diameter, and length adjustable rod nets to the plant height hundred times or 30 minutes/transect (Uniyal *et al.,* 2011). Spider collection was done on four transects in each habitat type and was repeated 2 times, in each of three months. Spiders collected in the field were stored in eppendorf tubes filled with 95% alcohol for counting and identification, latter was done following Spiders and Their Kin (Levi and Levi, 1990), Riceland spider of South and Southeast Asia (Barrio and Litsinger, 1995) and Borror *et al.* (1996).

Statistical analysis

The level of species diversity was calculated by Shannon and Weaner diversity index (H) (Magurran, 1988), using the following formula: Species diversity index (H ') = - (Pi) (ln Pi).

Description: Pi = proportion of each species; ln = Logarithm natural (natural number). Species evenness were calculated using Shannon evenness index (E) (Magurran, 2004), as follows: Species evenness index (E) E = H / ln (S); S = number of species.

Statistica Version 6 program was used for the statistical analysis, one-way ANOVA and Tukey's test with 95% level of confidence was used to determine differences in species richness, abundance of species, and the value of species diversity and evenness of species in each habitat type (StatSoft, 2001; Ohsawa, 2005).

Analysis of spider community similarity between habitat types used Sorensen similarity index and data used are the presence and absence of spider species (Magurran, 1988). The value of similarity (Sorensen index) is used to create a cluster analysis (Krebs, 1999; Ludwig and Reynolds, 1988). Analysis of each community groups was arranged hierarchically in the form of a dendogram using Statistica for Windows program 6 (StatSoft, 2001). Grouping using the unweighted pair group method with arithmetic mean (UPGMA) and the Euclidean distance (Lewis, 2001).

Results

The results showed as many as 17 families consisting of 62 genera, 137 species and 2218 individual morphospecies spiders. Most common family was Araneidae with 24.75%, followed by Tetragnathidae (24.48%) and the Salticidae family (13.98%). Theridiidae family was the most abundant species (14 morphospecies), followed by Araneidae and Salticidae 11 morphospecies respectively (Table 1). The most common species was *Araneus diadematus* (Araneidae), then *Leucage decorate* (Tetragnathidae), *Euryattus* Sp2 (Salticidae) and *Storena formosa* (Zodaridae) (Fig. 2).

Spider distribution by type of habitat was found to be 17 families, with 11 families found in all types of habitat. Two families (Pisauridae and Uloboridae) are only found in primary forests and secondary forests. Family Lycosidae and Oxyopidae was found in secondary forests and agricultural land, while Pholcidae was found in primary forests and agricultural land (Table 1).

Table 1. Number of family, genera, morphospecies and individuals found in three types of habitat at Mount Tumpa Forest Park, North Sulawesi (PF: Primary forest; SF; Secondary forest; AL: Agricultural land).

Family	∑	∑	Habitats/Number of Individuals						Total	
	Genera	Morpho Species	PF		SF		AL			
			∑	%	∑	%	∑	%	∑	%
Araneidae	11.00	27.00	150.00	6.87	170.00	7.78	229.00	10.49	549.00	24.75
Tetragnathidae	2.00	8.00	241.00	11.03	252.00	11.54	50.00	2.29	543.00	24.48
Salticidae	11.00	27.00	73.00	3.34	86.00	3.94	151.00	6.91	310.00	13.98
Theridiidae	14.00	29.00	163.00	7.46	61.00	2.79	14.00	0.64	238.00	10.73
Thomisidae	6.00	13.00	30.00	1.37	51.00	2.34	110.00	5.04	191.00	8.61

Oxyopidae	1.00	5.00	0.00	0.00	43.00	1.97	90.00	4.12	133.00	6.00
Zodaridae	2.00	3.00	13.00	0.60	19.00	0.87	19.00	0.87	51.00	2.30
Sparassidae	2.00	2.00	12.00	0.55	14.00	0.64	21.00	0.96	47.00	2.12
Clubionidae	1.00	5.00	14.00	0.64	13.00	0.60	18.00	0.82	45.00	2.03
Linyphiidae	1.00	1.00	14.00	0.64	6.00	0.27	6.00	0.27	26.00	1.17
Lycosidae	2.00	4.00	0.00	0.00	4.00	0.18	20.00	0.92	24.00	1.08
Agelenidae	1.00	1.00	11.00	0.50	7.00	0.32	2.00	0.09	20.00	0.90
Uloboridae	3.00	6.00	13.00	0.60	3.00	0.14	0.00	0.00	16.00	0.72
Pholcidae	1.00	1.00	7.00	0.32	0.00	0.00	2.00	0.09	9.00	0.41
Pisauridae	1.00	2.00	1.00	0.05	7.00	0.32	0.00	0.00	8.00	0.36
Ctenizidae	2.00	2.00	1.00	0.05	3.00	0.14	2.00	0.09	6.00	0.27
Scytodidae	1.00	1.00	1.00	0.05	1.00	0.05	0.00	0.00	2.00	0.09
Grand total	62.00	137.00	744.00	34.07	740.00	33.88	734.00	33.61	2218.00	100.00

Spider community structure, indicated abundance (N = 186.00), species richness (S = 51.75), diversity (H = 3.28) and species evenness (E= 0.83), was found to be highest in primary forests, while the lowest was in agricultural land (Fig. 3). Richness and diversity of species in Mount Tumpa show significant differences between habitats (spesies rihcness = Anova: F2; 9 = 20.09; p = 0.0005 and species diversity = Anova : F2 ; 9 = 7.38 ; p = 0.017), whereas abundance richness and abundance is same and species evenness was not significantly different (ANOVA : F2 ; 9 = 0.016 ; p = 0.98) (Anova: F2 ; 9 = 1.70 ; p = 0.24) (Fig. 3).

Mount Tumpa Forest Park spider communities showed that greatest similarity index between primary forests and secondary forests, with a similarity index of 0.68 (68%). Sorensen similarity index was smallest between primary forests and agricultural land with a value of 0.55 (55%)(Table 2).

Table 2. Sorensen similarity index of spider communities among habitats in Mount Tumpa Forest Park.

Habitat	Primary forest	Secondary forest	Agricultural land
Primary forest	-	0.68	0.55
Secondary forest	0.68	-	0.66
Agricultural land	0.55	0.66	-

Dendogram results by using the unweighted pair group method with arithmetic mean (UPGMA) show there are two clear groupings of primary forests with secondary forest (Fig. 4).

Discussion

The number of spider morphospecies found in Mount Tumpa Forest Park reached 7.01% of all spiders estimated to be in Indonesia (1954 species) and 12.28 % of genera found in Indonesia (505 genera). The family obtained 29.31% of the 58 families that were reported in Indonesia which family (Stenchly, 2010). These results are not very different from the research of Deshmukh and Raut (2014) with as many as 18 families consisting of 104 species, 52 genera and 1874 individuals of spiders.

Due to the high abundance of Araneidae abundant was other family, this spider has the largest group distribution and almost all of its members live in a circular nest. This family varies in size, color and shape (Hawkeswood, 2003). Several investigators have reported families of the dominant Araneidae spider found throughout the study (Cetia and Kalita, 2012; Wankhade *et al.*, 2012; Bhat *et al.*, 2013; Deshmukh and Raut, 2014).

Based on the type of habitat, the habitat that has the most abundance, richness, diversity and evenness of species of spider is primary forest. The presence of spiders in an ecosystem is strongly influenced by environmental factors such as temperature, humidity, wind and intensity of light. The high abundance and diversity of species in primary forest is due to its complex structure and relatively undisturbed state, allowing for the creation of niches that can sustain more individual spiders (Floren, 2005). Foelix (1996) states that overgrown dense vegetation habitat is the dominant habitat populated by spiders. Hsieh *et al.* (2003) reported that the number of individual spiders in primary forest is greater than the number of individual spiders in the meadow.

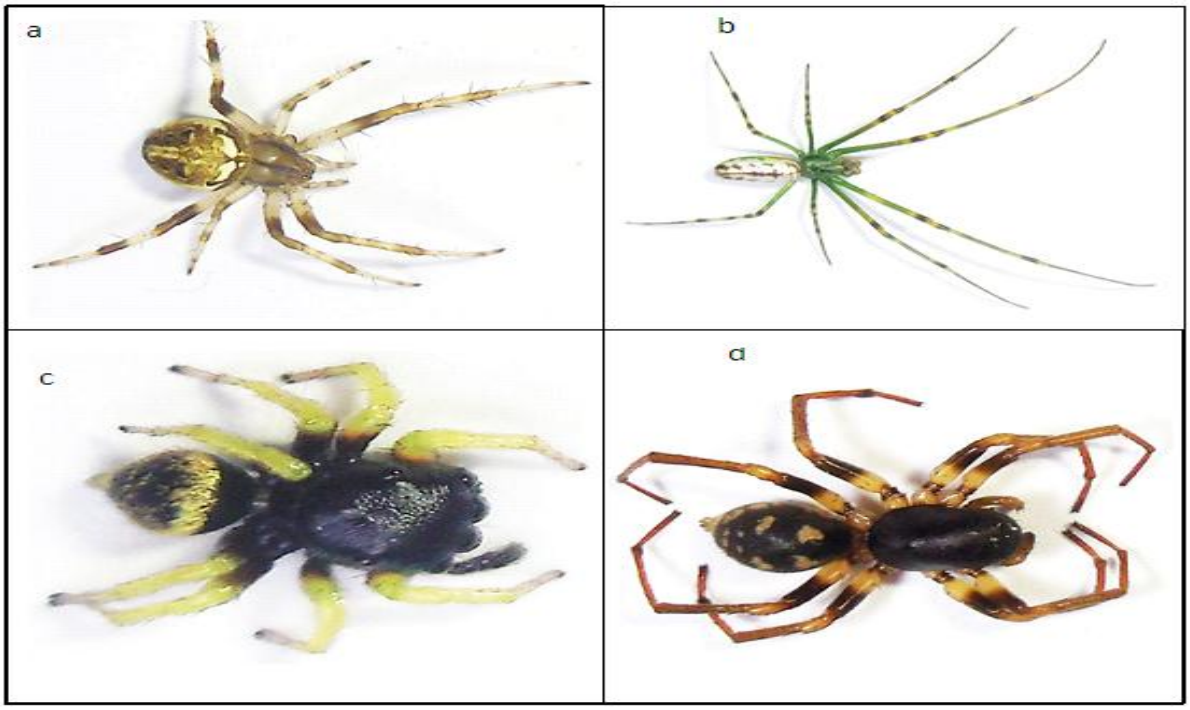

Fig. 2. Dominant spider species in Mount Tumpa Forest Park a. *Araneus diadematus* (Araneidae), b. L*ucage decorate* (Tetragnathidae), c. *Euryattus* Sp 2 (Salticidae) dan d. *Storena formosa* (Zodaridae).

Biological factors such as vegetation type, food availability, competitors and enemies are all factors that limit the presence of spiders only or of other animals as well in an ecosystem. The physical structure of the habitat such as leaves, twigs and other plant parts where spiders may spin their webs is also important. Spinning webs is an early stage of selection of spider habitat.

Habitat with a complex structure will have a higher variety of spiders (Uniyal and Hore, 2008). Suana (2005) states that the structure of complex landscapes will provide a diversity of habitat types, creating a growing number of spiders that can coexist in it. Herbaceous trees and plants will cause more and more complex structure, therefore it will have an impact on the diversity of spiders (Cetia and Kalita, 2012; Galle, 2014). Heterogeneous vegetation structure and complex habitats provide niches for fauna and will form food webs (Uniyal and Hore, 2008). Vegetation structure may be an important determinant of spider community attributes because it provides different types of substrate that may influence the preys available to it and also dictates the method by which they are obtained (Ayansola, 2012).

Suana (2005) and Kamal *et al.* (2011) states that the diversity of species generally will increase in line with the increasing diversity of habitat structure.

The high value of the primary forest species evenness showed dominance of the species found in primary forests lower than agricultural land and secondary forests. Suana (2005) states that evenness value species will tend to be lower when the samples contain one or several dominant species while most other species have very small amounts.

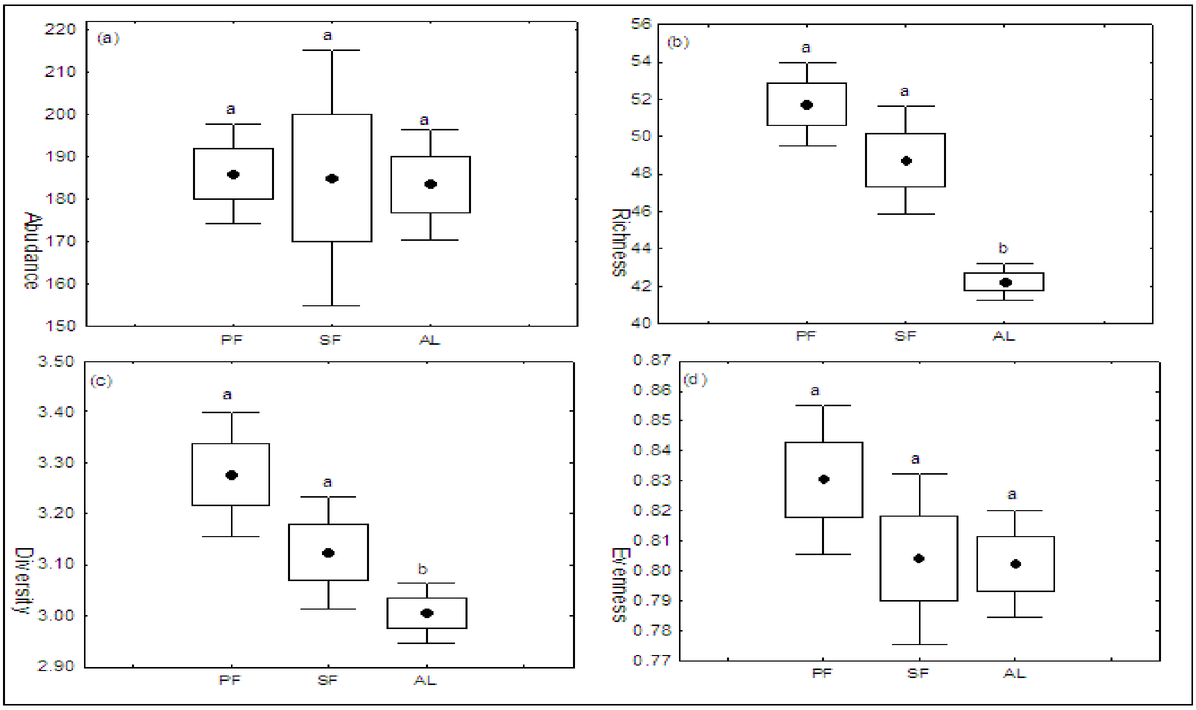

Fig. 3. (a) Abundance, (b), richness, (c), diversity and (d) species evenness of spiders at three types of habitat in Mount Tumpa Forestst Park (PF: Primary forest; SF; Secondary forest; AL: Agricultural land; (●) : Mean, (□) : ±SE,(⌶):±SD. The same letter in the same plot did not differ significantly according to Tukey's test at 95% confidence level).

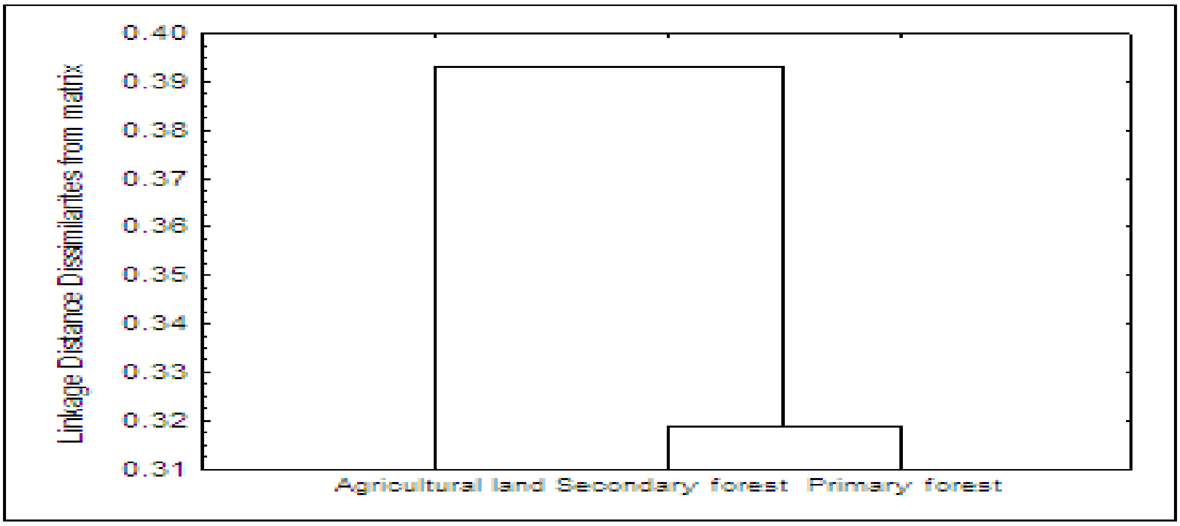

Fig. 4. Dendogram of spider community similarity in three habitat types (Primary, secondary and agricultural land) in Mount Tumpa Forest Park, North Sulawesi.

Community similarity analysis showed that spider species composition between primary forests and secondary forests are more similar than those of the agricultural land. The index also shows that the composition of spiders found in primary forests and secondary forests similarity was approximately 68%. This also shows that the composition of spiders in primary forests and secondary forests have more similarity compared to those of agricultural land. Community similarity index between habitats can be said to be low because it is not close to 100 %. However the spider community that was composed by the same community has an index value greater than 50 %. According to Krebs (1999) a community is considered different if the compared community similarity index is less than 50%. The similarity of spider community composition in primary forest and secondary forest is due to the similarity of vegetation types of primary forest habitat with secondary forests.

Conclusion

Spiders discovered during the research included 17 families consisting of 62 genera, 137 species and 2218 individual morphospecies.

The most common family found was the Araneidae, followed Tetragnathidae and Salticidae. The highest abundance, richness, diversity, and evenness spider species are found in primary forests, whereas the lowest are in agricultural land. Spider community similarity between habitats showed the greatest similarity index between primary forests and secondary forests.

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