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Research Article

Faunistic diversity and distribution of Wolf spiders (Lycosidae: Araneae) in Western and Northern Mindanao, Philippines

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Abstract

Despite being one of the most abundant spider families in the world, wolf/lycosid spiders are poorly studied in the Philippines. In this study, we determined the faunistic diversity and distribution of lycosid spiders from nine sampling sites in Western and Northern Mindanao. An opportunistic sampling method was used to collect samples. Non-parametric estimators and GIS mapping were utilized in this study to determine richness (genus level) and distribution. Results showed that the accumulation curves of the observed richness and non-parametric estimators did not reach an asymptotic value suggesting that the true richness of the sampling areas is much higher than the estimated values. Six genera were documented in which one genus is a new Mindanao record and another one is new to the Philippines. Distribution results showed that fewer specimens are found in forested areas and sampled specimens usually clumped in agroecosystems near water bodies. Generally, Shannon-Weiner values were found to be very low (H'= 0 to 1.29) but tend to exhibit higher values (H'= 1.23 to 1.29) in sites with field margins that are located near streams or forest patches. Results indicate the importance of riparian areas and ecotones for the diversity of wolf spiders.

Keywords: Ecotones, Lycosid, Philippines, species richness, Wolf spiders.

Introduction

With over 2,300 described species (Platnick 2005), the family Lycosidae (wolf spiders or lycosids) is one of the most abundant spider families in the world. Described with four distinct morphological characters such as eye arrangement, absence of retro lateral tibial apophysis on the male pedipalp, egg sac carried on the spinnerets of females, and young carried on specialized setae on the dorsal surface of the mother's abdomen, the said spider group tends to exhibit monophyly (Dondale 1986, Griswold 1993).

The abundance of the group is attributed to the abovementioned morphological features particularly the female traits. The female's ability to carry its young on the back enables the group to thrive in areas with high anthropogenic disturbance such as agroecosystems, grasslands, coastal, and riparian zones (McKay 1974, Manderbach and Framenau 2001, Framenau*et al*. 2002, Morse 2002). Dispersal methods of the early instars of some member species such as ballooning is also very influential in making the lycosid spiders virtually abundant in every terrestrial habitat (Murphy *et al*. 2006) by eliminating some of the problems caused by geographical factors (Richter 1970, Greenstone 1982, Greenstone *et al*. 1987, Crawford *et al*. 1995, Edwards and Thornton 2001). Some lycosid species are also considered as possible bioindicators of organophosphates due to their abundance in agro-ecosystems (Hodge and Vink 2000, Van Erp *et al*. 2000).

Like all spiders, lycosids are predatory in nature and most of the species belonging to lycosid groups do not build webs but utilize a "sit-and-wait" predatory behavior by building burrows (Kronk and Riechert 1979, Vink 2002). Some member species are also vagrant predators in which they actively hunt for prey (Murphy *et al*. 2006). In some agroecosystems like rice fields, hunting species such as *Pardosa pseudoannulata* can regulate population densities of leafhoppers and planthoppers (Barrion 2001). Due to their predatory behavior, lycosid venom peptides are also considered as pharmacologically important. One species, *Lycosa singoriensis* can initiate hemolysis of human erythrocytes (Liu *et al*. 2009). The possible importance of lycosids (wolf spiders) in agriculture and medicine is seemingly a good reason to conduct ecological studies about this spider group.

In the Philippines, ecological studies that are solely focused on wolf spiders are fairly limited. The most recent studies regarding the diversity and distribution of wolf spiders are by Barrion and Litsinger (1981a, 1995) and Barrion (2001). However, the studies were only focused on rice field ecosystems leaving other areas such as forest patch and stream ecosystems partially undocumented. Mindanao islands situated within deep-ocean channels like Camiguin were also not documented. The advent of publicly accessible mapping soft wares or methods such as GIS mapping and non-parametric estimators could provide some useful data to create a form of baseline information regarding the ecology of wolf spiders in the Philippines. As such, the general aim of this research was to determine the generic diversity and distribution of wolf spiders in selected areas of Western and Northern Mindanao.

Material and Methods

Study Area

This study was carried out in nine sampling sites on the island of Mindanao (8.4961° N, 123.3034° E) particularly on the Northern and Western regions (Fig. 1). Geographically, the island of Mindanao is located below the Visayas and is considered as the second largest Philippine island. Of the nine sampling sites established in the two regions, five can be found in the provinces of Bukidnon, two in Zamboanga del Sur, and two on Camiguin Island. Descriptions of each sampling site are shown in table 1.

Sampling and identification of specimens

Intermittent field sampling was conducted from August to December 2017 in the two regions. The sampling method was mainly opportunistic using the vial tapping method and modified from Coddington *et al*. (1991), Sørensen *et al*. (2002), and other existing spider diversity studies in the Philippines (Patiño*et al*. 2016, Dacar and Nuneza 2016, Elias and Nuñeza 2016). Specimens were collected for a total of 81 person-hours. Specimens were then preserved in 5ml screw-capped plastic vials filled with 95% ethanol. Each vial containing a specimen was labeled with information such as locality, sex of the specimen, and habitat. Identification of the specimens up to the genus level was carried out at the University of the Philippines Los Baños and voucher specimens were preserved in the Mindanao State University – Iligan Institute of Technology.

GIS Mapping and Abundance

To visualize the relative abundance and evenness of each genus in all sampling sites, a rank-abundance curve was generated (Fig. 4). GIS Mapping was utilized to determine the distribution of the specimens.

Statistical analysis

To determine the diversity of a certain species, one must first calculate the richness (Garciano*et al.* 2014, Quiñones*et al.* 2016, Maandig*et al.* 2017) and determine the abundance and evenness of the said species (Stirling and Wilsey 2001). To measure richness, accumulation curves and non-parametric estimators were utilized in this study. Asymptotic curves or values in the accumulation curve are possible indications that the species inventory is already complete (Cardoso *et al.* 2008, Responteand and Nuñeza 2016). Non-parametric estimators that were commonly used in related literature include Chao1, Chao2, Jackknife1, Jackknife2, and Bootstrap (Colwell 1999, Castanheira *et al.*2016). EstimateS, richness estimator program, version 9.1 (Colwell 2013) was used to calculate the estimator values. A rank-abundance curve was also generated to determine and visualize the abundance and evenness of the collected specimens. Finally, Shannon-Weiner Diversity Index (H') was utilized to determine the diversity of lycosid spider genera per sampling site. H' index was calculated using the Paleontological Statistics Software Package for Education and Data Analysis (PAST) version 3.14 (Hammer *et al*. 2001). The Shannon-Weiner Diversity Index (H') is commonly used in diversity studies (Krebs 1989). The computed H' index was then interpreted based on a scale modified from Fernando Biodiversity Scaling System (Fernando 1998). In a modified Fernando Biodiversity Scaling System, H' values between 3.5 and 4.0 are considered to be very high, 3.0-3.49 are considered to be high, 2.5-2.99 values are moderate, 2.0-2.49 values are low and lastly, H' values ranging from 1.99 and below are considered to be very low.

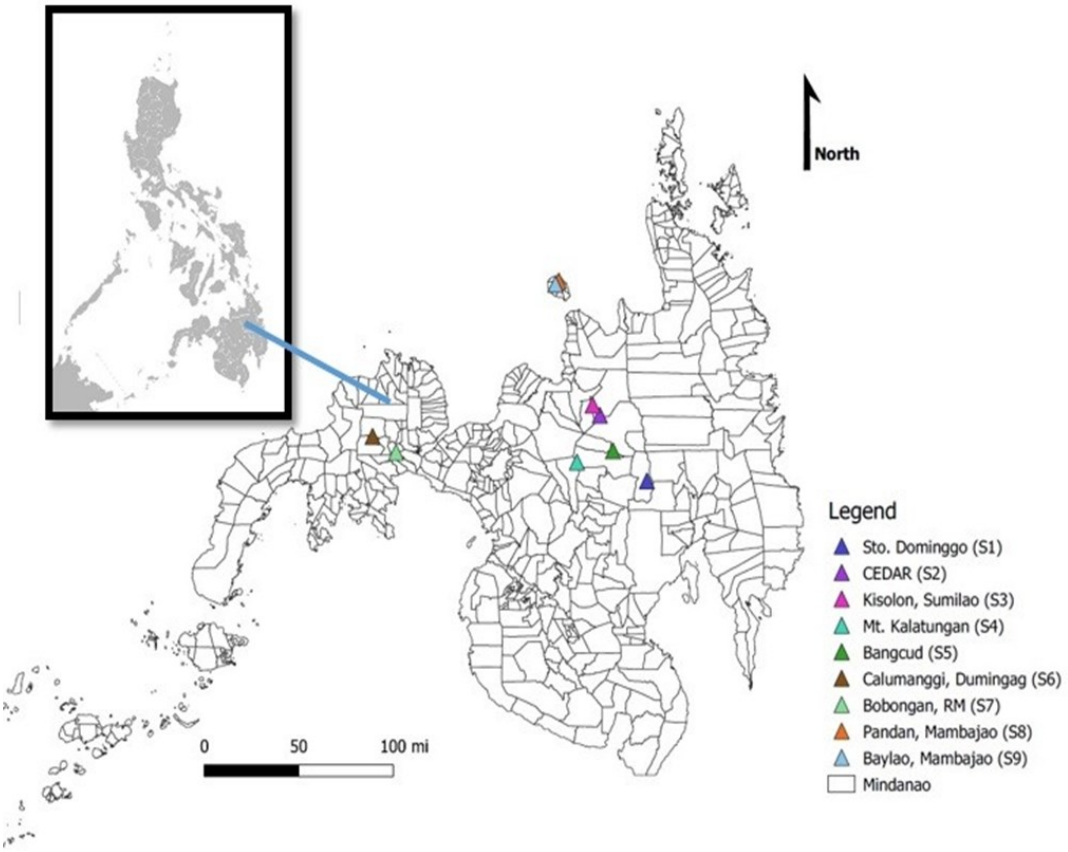

Figure 1. GIS map of the sampling sites in Northern and Western Mindanao. Sampling sites are represented by color-coded markers. The image at the top left corner shows the location of Mindanao in the Philippine Archipelago.

Table 1. A detailed description of the sampling sites based on vegetation type, dominant or common plantspecies distance to nearest body of water, and anthropogenic disturbances observed in each site.

Site Number	Site Name	Vegetation Type	Dominant/Common Plant species	Distance to nearest water bodies	Anthropogenic Disturbances
1	Sto. Domingo, San Fernando, Bukidnon	Secondary Forest/Agricultural	*Gmelina* sp., *Musa* sp., *Schismatoglottis* sp., *Homalomena* sp., *Artocarpus* sp.	Situated along a stream.	Sugarcane and cassava plantations (20 meters from the site).
2	(Center for Ecological Development and Recreation), Impasug-ung, Bukidnon	Primary/Secondary Forest	*Homalena* sp., *Schismatoglottis* sp., *Rattan* sp., *Heliconia* sp., *Shorea* sp.	Situated along a stream.	Public swimming pool (10 meters from the site).
3	Kisolon, Sumilao, Bukidnon	Agricultural	*Cocos nucifera* and *Musa* sp. Cogon Grass	50 meters from Alalum Falls	National Highway (25 meters from the site).
4	Mt. Kalatungan, Bukidnon	Agricultural	*Allium porrum,Zea* sp., cogon grass	600 meters from a stream located in the Primary Forest	Spring onion and corn plantations, hiking trails.
5	Bangcud, Malaybalay, Bukidnon	Agricultural	Corn and Sugarcane (*Saccharum* sp.) Carabao grass	Adjacent to Matin-aw spring.	Pumping Station, plantations
6	Calumanggi, Dumingag, Zamboanga del Sur	Agricultural	Rice, carabao grass	30 meters from a stream	National Highway (10 meters from the rice field).
7	Bobongan, Ramon Magsaysay, Zamboanga del Sur	Agricultural	*Cocos nucifera*, carabao grass, cassava, corn	10 meters from a dried-up stream.	Fishponds and cornfields
8	Pandan, Mambajao, Camiguin	Secondary/Agricultural	*Cocos nucifera*, *Ficus* sp., *Gmelina* sp., carabao grass	Adjacent to a stream.	Nearby spillway and cement road to Katibawasan Falls.
9	Baylao, Mambajao, Camiguin	Agricultural	*Mimosa* sp., *Paspalum* sp., Tree ferns, *Gmelina* sp.	20 meters from a stream	Abandoned cornfield, cement road.

Result

Of the 181 adult specimens collected, six genera were identified (Table 2). These are *Artoria*, *Draposa*, *Hippasa*, *Pardosa*, *Venonia*, and *Wadicosa*. Genus *Hippasa* and Genus *Pardosa* were previously recorded and described by Barrion and Litsinger (1981a, 1981b, 1995). On the other hand, *Wadicosa*, *Venonia*, and *Draposa* were not mentioned or described in previous Philippine ecological or taxonomic publications hence they can be considered as new records from the Philippines. The genus *Artoria* was mentioned by Barrion and Litsinger (1995) however it was only recorded in Luzon Island. This is the first record of the genus *Artoria* in Mindanao Island. A pie chart was also generated to represent the sex ratio of the collected specimens (87.84 % and 12.15 % adult females and adult males respectively).

Table 2. List of the collected and identified lycosid genera and their respective individual counts per sampling site (S1-S9)

Genera	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**Total**
Genus *Artoria*Thorell, 1877	0	8	0	0	0	0	0	0	0	8
Genus *Draposa* Kronestedt, 2010	0	0	0	0	0	1	0	6	0	7
Genus *Hippasa* Simon, 1885	3	0	0	4	0	3	7	0	3	20
Genus *Pardosa* C. L. Koch, 1847	22	0	8	18	4	11	28	2	4	97
Genus *Venonia* Thorell, 1894	4	0	0	0	0	0	0	0	0	4
Genus *Wadicosa* Zyuzin, 1985	5	1	0	11	6	6	0	7	9	45
Total per site	34	9	8	33	10	21	35	15	16	181

Richness estimators

Nonparametric species estimators particularly Chao1, Chao2, Jackknife 1, Jackknife 2, and Bootstrap were utilized in this study to measure the richness of each genus from all sampling sites (Fig. 2). To visualize the estimated values, accumulation curves for each estimator were generated along with the accumulation curve of the observed richness, which was 6. The larger value for Chao2 was utilized in the results since the CV (Coefficient of Variation) of the abundance or incidence distribution of the provided data is equal to 0.534. EstimateS automatically suggest to the user to consider the larger Chao2 value if the estimated CV of the abundance or incidence distribution is greater than 0.5 (Colwell 2013). On the other hand, the results showed that the highest estimate of species richness is from Chao2 at 25.89 or 26 genera followed by Jackknife2 at 8.65, Jackknife1 at 7.78, bootstrap at 7.69 (14), and the lowest is Chao1 at 6. The generated accumulation curves failed to reach an asymptote and seem to be rising as well. However, Jackknife2 seems to approach asymptotic values.

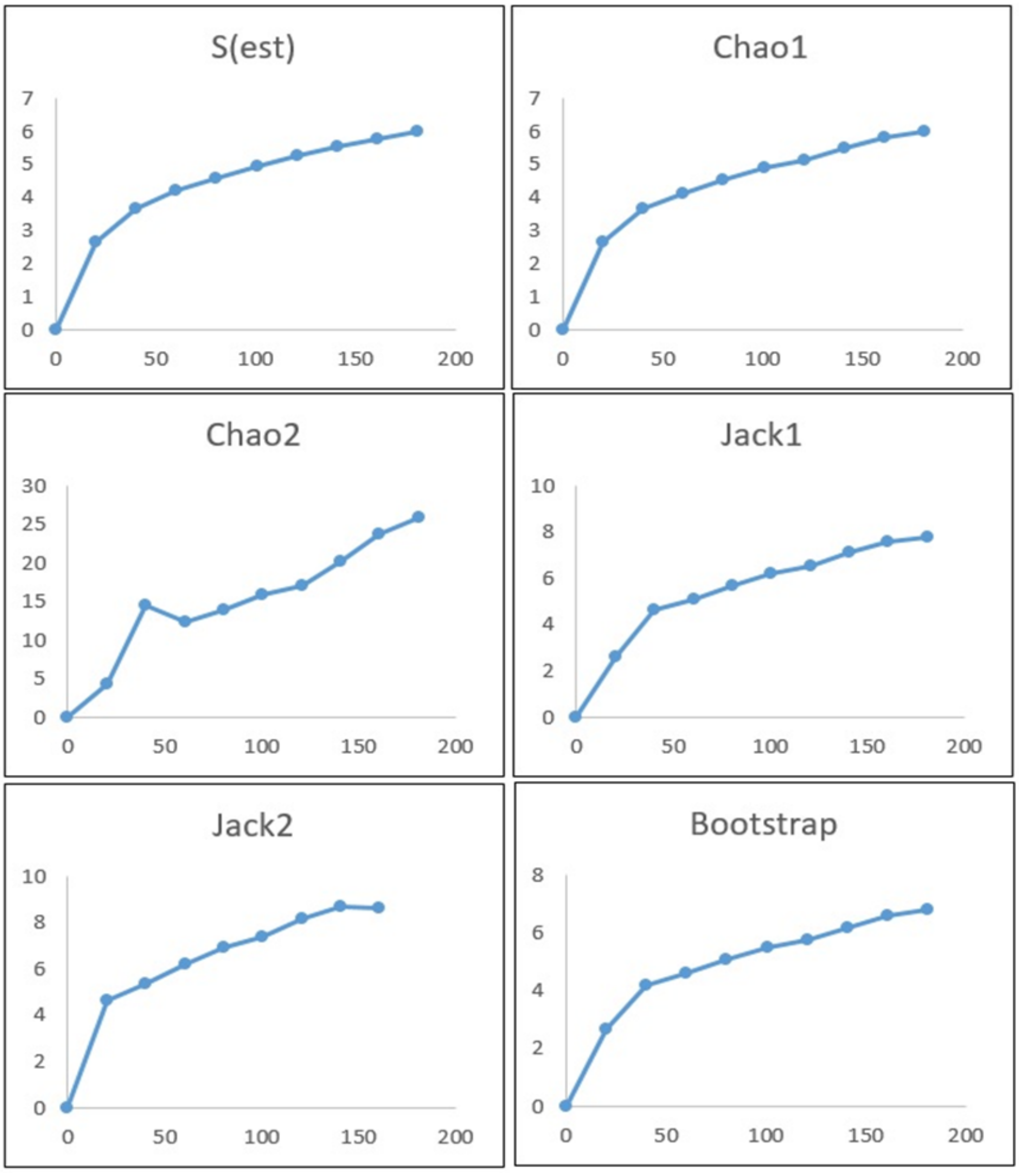

Figure 2. Accumulation curves for the observed richness [S(est)] and richness estimators (Chao1, Chao2,Jackknife 1, Jackknife 2, and Bootstrap).

Abundance

The abundance curve exhibited a steep gradient implying a low evenness between genera with higher-ranked genera such as *Pardosa* exhibiting a much larger abundance gap compared to lower-ranked genera. The genus *Pardosa* is the most abundant with a relative abundance of 53.59%. This is followed by *Wadicosa* and *Hippasa* at 24.86% and 11.04%, respectively. *Artoria* is at 4.41% and *Draposa* at 3.86%. The least abundant genus was *Venonia* at 2.20%.

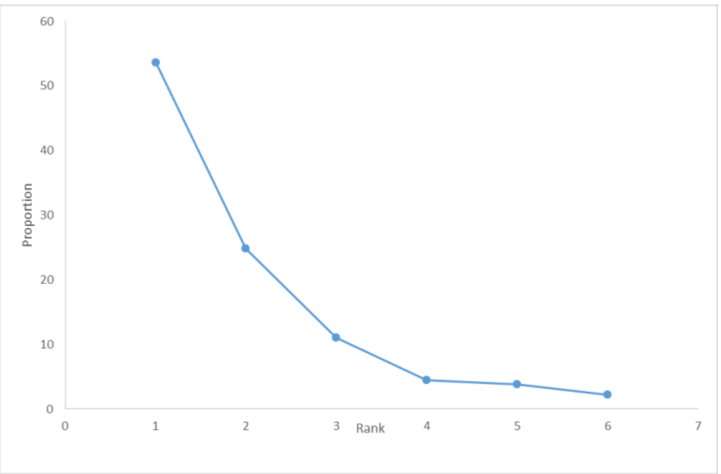

Figure 3. Rank-abundance curve of the observed *Lycosid* genera found in Western and Northern Mindanao. The steep gradient indicates a low evenness.

Distribution

Distribution maps based on the genus were generated through GIS mapping. The distribution map of Genus *Pardosa* (Fig. 5) indicates that the representative specimens of the said genus can be found in all sampling sites except in CEDAR (S2) and Baylao, Mambajao (S9). The distribution map of the said genus also suggests that the bulk of its sample population can be found in Sto. Domingo (S1), Mt. Kalatungan (S4), and Bobongan (S7). On the other hand, all specimens of the Genus *Hippasa* were observed to be distributed in agroecosystems as shown in Fig. 4. The bulk of the sample population of *Hippasa*can also is found in S7 which is a coconut plantation. The distribution of *Artoria* seems to be limited only to CEDAR. The sampled *Draposa* specimens, on the other hand, are distributed on habitats such as grasslands or rice fields situated near freshwater bodies. Genus *Wadicosa*in this study was found in Sites 1, 2, 5, 8, and 9 which are situated along or beside a stream. *Venonia* specimens were only collected in Site 1.

Species Diversity

Table 3 shows the observed richness and Shannon-Weiner Diversity values for each sampling site. Based on the Modified Fernando Biodiversity Scale, the Shannon-Weiner diversity indices of all sampling sites are very low (1.99 and below). The highest Shannon-Weiner value is from Site 6 with H’ = 1.29 followed by Site 1 with H’ = 1.23. The highest richness value (number of recorded genera per/site) can also be attributed to both sites at S = 4. The lowest Shannon- Weiner value is from Site 3 with H’ = 0. This is expected since only one genus was recorded in this site.

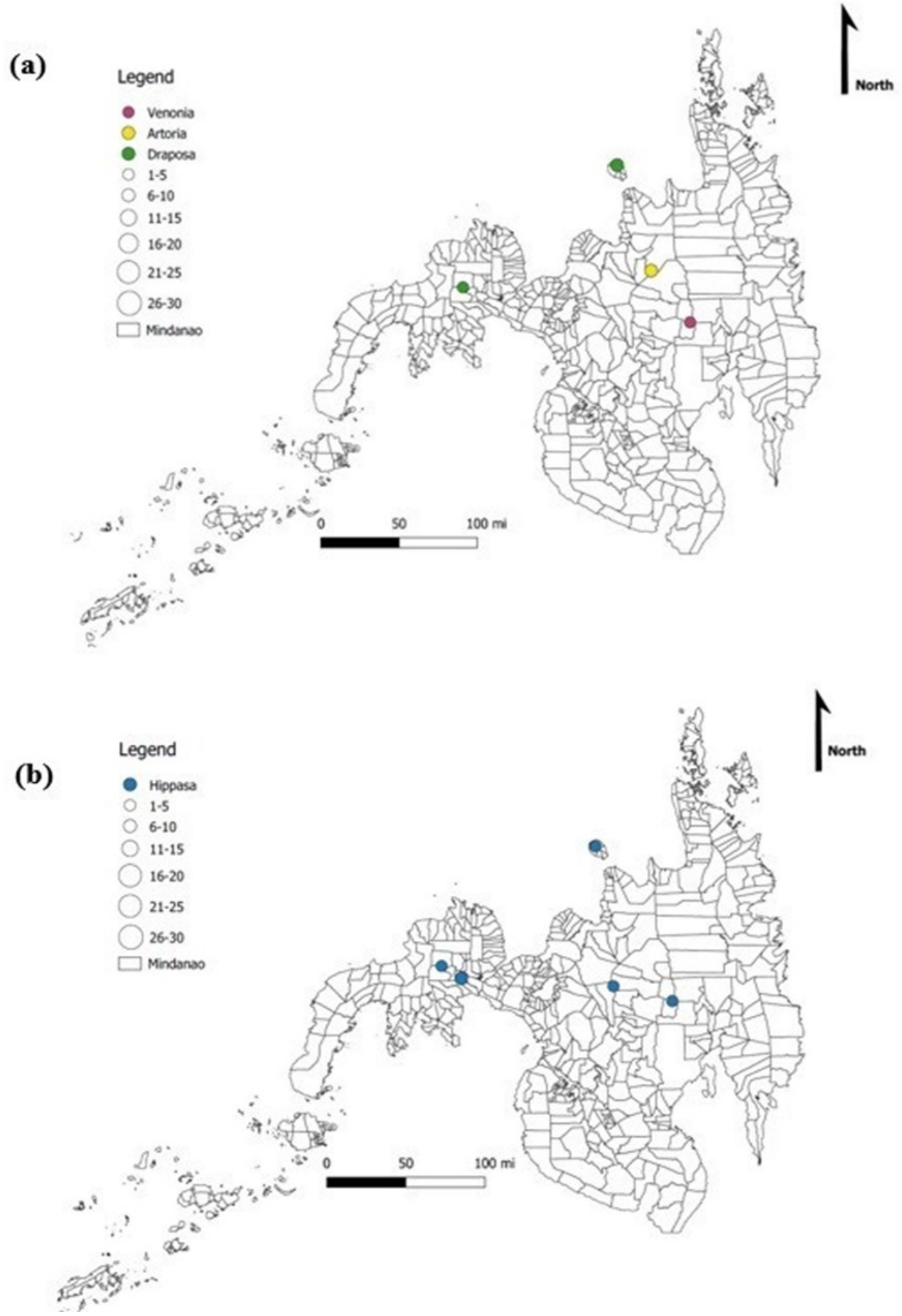

Figure 4. Distribution map of genus *Artoria*, *Draposa*, *Venonia*(a) and *Hippasa* (b).

Specimens are represented by color-coded dots. The size of the dots represents the abundance (in range) of the collected specimens in a specific site. The larger the marker, the greater the abundance range. The same set of legends are also used for Fig. 5.

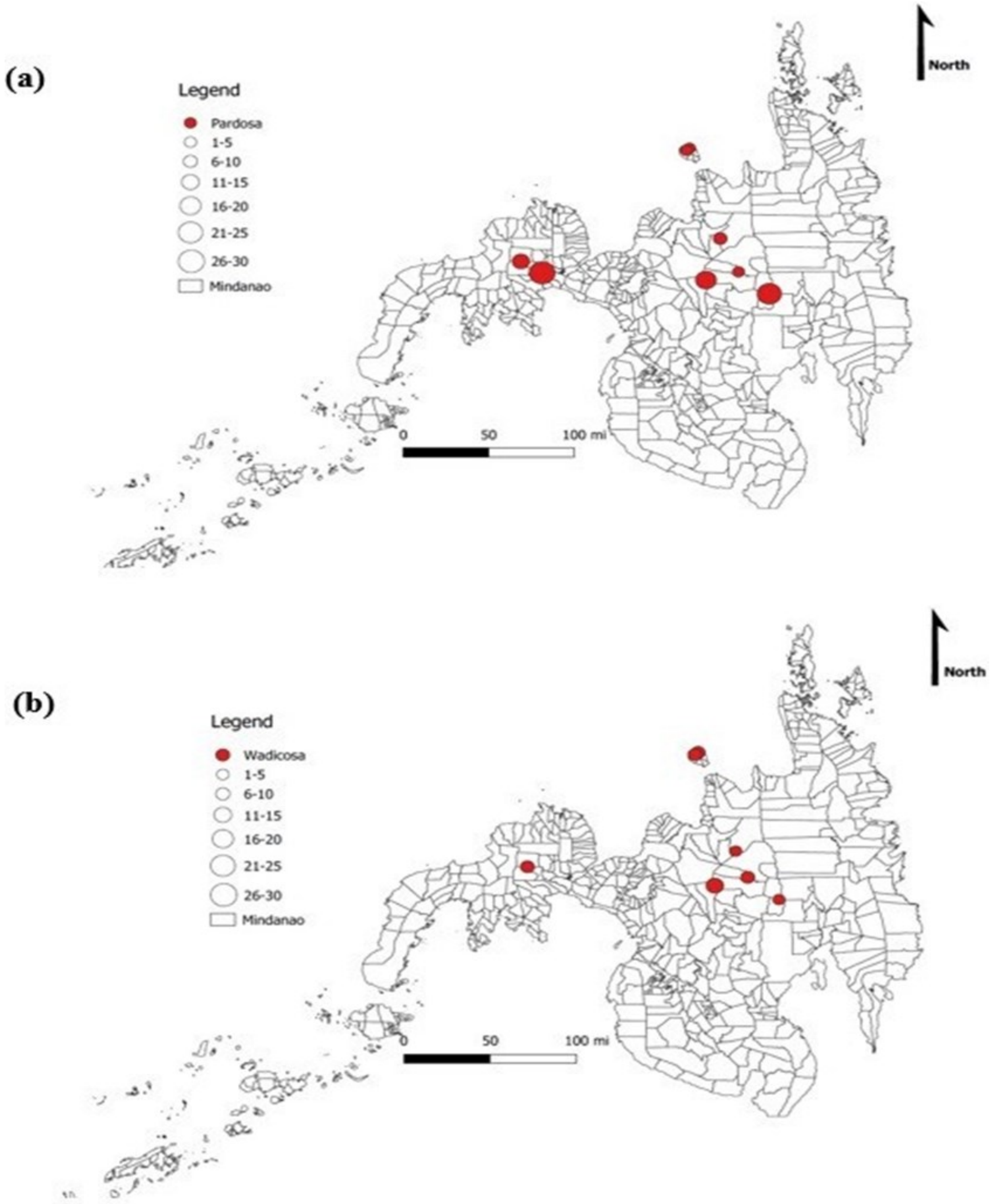

Figure 5. Distribution maps of Genus *Pardosa* (a) and *Wadicosa* (b)

Discussion

Richness

Results imply that the species/genus inventory is not yet complete and it is also probable that the richness of the sampling areas is much larger than the estimated richness generated in this study. Possible reasons for the occurrence of the above-mentioned estimator values include cryptic habitat, biased sex ratio, clumped distribution, and small size which is based on a study by Coddington*et al.* (2009) about singletons which can affect diversity indices and species richness. No singletons were recorded (in relation to genus) in this study but some results of this study are seemingly similar to the results of Coddington *et al.* (2009) particularly the presence of female-based sex- ratio bias. A study by Vollrath and Parker (1992) which was also mentioned in Coddington *et al*. (2009) stated that adult male spiders, particularly wandering males, exhibit higher mortality rates than females, hence the higher occurrence of females which is again, a plausible reason for the occurrence of the resulting estimator values. However, Coddington *et al.* (2009) also pointed out that the abovementioned reasons cannot affect the frequency of singletons and in effect the occurrence of the generated estimator values in this study. According to Coddington *et al.* (2009), the main culprit for negative richness bias is undersampling. The mentioned study along with other previous studies like Walther and Morand (1998) and Mao and Colwell (2005) showed that non-parametric species estimators can only properly measure the true species richness of a given data set if the observed species of the said data set reach 66.6% or 80% threshold. This means that the current study needs a fairly large amount of samples or a greater sampling intensity to generate realistic species/generic estimates. But one could still speculate for other possible reasons. Morphological conservatism can also be used to discuss the generated estimator values of this study. Morphological conservatism is a considerable deterrent in identifying spider assemblages particularly in lycosids (Bond *et al.* 2001, Vink 2002). Philippine species such as *Pardosa daniloi*, *P. asacayi*, and *Pardosahawakana* are previously described as separate species and were reclassified as synonyms of *P. magkasalubonga* (Barrion and Litsinger 1995). Framenau (2006) then transferred the same species to the genus *Venatrix*. A study about trapdoor spiders by Bond *et al*. (2001) suggests that using morphology-based species concepts to identify spiders can possibly affect our understanding of spider evolution and diversity. Habitat utilization could also be a factor but needs further information (Elias and Nuñeza 2015). Despite the conclusions of Coddington *et al.* (2009), factors like morphological conservatism and female based sex-ratio bias could possibly still affect species richness or diversity but further studies should be conducted to draw more accurate conclusions.

Table 3. Observed richness and Shannon-Weiner Diversity (H’) values in the nine sampling sites of Western and Northern Mindanao

Sampling Site	Observed Richness	Shannon-Weiner (H’)
1	4	1.23
2	2	0.63
3	1	0
4	3	1.06
5	2	0.69
6	4	1.29
7	2	0.64
8	3	1.08
9	3	1.09

Distribution and Abundance

Except for CEDAR, all sampling sites are considered as agroecosystems or buffer zones. Genus *Pardosa*, particularly *P. asumatrana*, are known to dominate (in terms of abundance) agroecosystems when compared to other species as confirmed by similar studies like the assessment of spider fauna in Punjab, Pakistan by Mukhtar *et al*. (2012). The seemingly high abundance of *Pardosa* in agroecosystems can be probably attributed to its resistance to some pesticides. A study by Tahir *et al.* (2016) suggested that when compared to susceptible (control) groups, resistant groups of *P. sumatrana* contained higher levels of non-specific esterases and monooxygenases in which both enzymes play a role in metabolic resistance. However, the *Pardosa* specimens from Sto. Dominggo seems to be different from the rest. Specimens from Sto. Dominggo was collected from a stream within a Secondary forest patch and the morphology of the said specimens seems to be different from specimens found in grasslands and fields. However, further taxonomic and molecular analyses are required to confirm this. Results indicate that *Hippasa* specimens are heavily distributed in agroecosystems. A web-building genus, *Hippasa* is considered being commonly found in agroecosystems as stated by Barrion and Litsinger (1995). A representative species, *Hippasa holmerae*, was also considered as a predator of leafhoppers in rice agroecosystems (Barrion and Litsinger 1981b). As shown in the results, genus *Artoria* and genus *Venonia* were only collected in a single site. Since the species/genus inventory of this particular study is considered to be incomplete, the abovementioned genera could probably be found in other sites. Compiled results from a review by Framenau (2002) suggested that members of the genus *Artoria* are usually found in river banks and forest. CEDAR is an ecological preserve and the *Artoria* specimens were collected beside a stream situated along a forest. It is probable that streams located in primary forest or forest patches are the habitat preference of *Artoria*. More studies focused on microhabitat preferences and utilization are again required for further confirmation. On the other hand, the distribution of *Draposa* documented in this study is fairly similar to a study on spider faunal diversity conducted by Dhali*et al*. (2017) at West Bengal, India in which the majority of *Draposa* specimens were found in grasslands. Not much is known about the habitat preferences of Genus *Wadicosa* but most taxonomic studies particularly Ahmed *et al.* (2014) and Kronestedt (2015) suggest that Genus *Wadicosa* is usually found in water bodies like lakes, streams, or even in irrigated rice fields. This can explain why most of the members of the Genus *Wadicosa* that were collected in this study were found in Sites 1, 2, 5, 8, and 9. Generally, the results from the generated species distribution maps suggest that only a handful of the sampled lycosid species were found in forested sites like CEDAR. Most of the sampled species seem were found to prefer open areas and buffer zones situated near bodies of freshwater such as streams and rivers.

Diversity

The very low diversity values can also be attributed to the low richness since it can affect diversity indices (Stirling and Wilsey 2001). Another possible reason is that most of the sampling sites are agro-ecosystems. Due to high anthropogenic disturbance, agro-ecosystems tend to yield low diversity values when compared to undisturbed forest ecosystems (Bos *et al*. 2007). On the other hand, Sites 1 and 6 exhibited the highest H' values since they can be both considered as field margins or ecotones based on their site descriptions. Field margins are least productive compared to the central field area but are particularly considered as a key factor for promoting wildlife in agro-ecosystems (Marshall and Moonen 2002). A study by Gallé and Fehér (2006) also stated that spider diversity is high in ecotones. In Sites 1 and 6, the ecotones are characterized as streams and forest patches that are favorable to some lycosid species like *Pardosa sumatrana* and *Wadicosa fidelis* due to the mix vegetation and the presence of a nearby water source. This was also confirmed by Mukhtar *et al*. (2012) in which spider abundance was significantly higher in margins than in central field areas.

Conclusion

Of the 6 genera that were observed and identified, *Wadicosa*, *Venonia*, and *Draposa* are considered as new Philippine records. Non-parametric species estimator values suggest that the true estimate of the species richness in this study is much higher than the generated estimates. The notion that female based sex-ratio bias and morphological conservatism as possible factors that can affect species richness in given samples should be investigated further. Overall results for distribution suggest that most of the sampled specimens are found in agroecosystems situated near freshwater bodies. In general, the Shannon-Weiner Diversity value of this study is considered to be very low but is supported by the fact that most of the sampling sites are agroecosystems that tend to exhibit lower diversity values. Diversity tends to be higher in sites such as ecotones that are dotted with streams or forest patches. Information on microhabitat preferences of lycosid spiders is limited which means that the collection of quantitative microhabitat data and GIS mapping, with emphasis on microhabitats, is highly recommended for future studies.

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References

Ahmed M., Anam J., Saikia M.K., Manthan S.V., Saikia P.K. 2014. New records spider species under the Wadicosa genus (Sub-order: Araneae; Family: Lycosidae) from the agricultural field of Sonitpur District, Assam, India. Journal on New Biological Reports 3(1): 60-65.

Barrion A.T. 2001. Spiders: natural biological control agents against insect pests in Philippine rice fields. Transactions of the National Academy of Science & Technology, Philippines (23): 121-130.

Barrion A.T., Litsinger J.A. 1981a. HippasaholmeraeThorell (Araneae: Lycosidae): a new predator of rice leafhoppers and planthoppers. International Rice Research Newsletter 6(4): 15.

Barrion A.T., Litsinger J.A. 1981b. The spider fauna of Philippine rice agroecosystems I. Dryland.The Philippine Entomologist 5: 139-166.

Barrion A.T., Litsinger J.A. 1995. Riceland Spiders of South and Southeast Asia.Entomology Division International Rice Research Institue. UK, Philippines, pp. 700

Bond J.E., Hedin M.C., Ramirez M.G., Opell B.D., 2001. Deep molecular divergence in the absence of morphological and ecological change in the Californian coastal dune endemic trapdoor spider Aptostichussimus. Molecular Ecology(10): 899–910.

Bos M.M., Tscharntke T., Leuschner C., Zeller M., Guhardja E., Bidin A.2007. Insect diversity responses to forest conversion and agroforestry management. Stability of Tropical Rainforest Margins 277-294.

Cardoso P., Scharff N., Gaspar C., Henriques S.S., Carvalho R., Castro P.H., Schmidt J.B., Silva L., Szüts T., de Castro A., Crespo L.C. 2008. Rapid biodiversity assessment of spiders (Araneae) using semi-quantitative sampling: a case study in a Mediterranean forest.Insect Conservation and Diversity1:71–84.

Castanheira P., Pérez-González A., Baptista R., 2016. Spider diversity (Arachnida: Araneae) in Atlantic Forest areas at PedraBranca State Park, Rio de Janeiro, Brazil. Biodiversity Data Journal (4): 4e7055.

Coddington J.A., Griswold C.E., Da´vila D.S., Penaranda E., Larcher S.F.1991. Designing and testing sampling protocols to estimate biodiversity in tropical ecosystems. In E. C. Dudley (ed.), The Unity of Evolutionary Biology: Proceedings of the Fourth International Congress of Systematic and

Evolutionary Biology. Dioscorides Press, Portland, Oregon, USA, pp. 44-60.

Coddington JA, Agnarsson I, Miller JA, Kuntner MZ, Hormiga G. 2009. Undersampling bias: the null hypothesis for singleton species in tropical arthropod surveys. Journal of Animal Ecology 78(3):573–584.

Colwell R. K., 1999. EstimateS: Statistical Estimation of Species Richness and Shared Species from Samples (Software and User's Guide) http://viceroy.eeb.uconn.edu/estimates. 8.2. Downloaded December 18, 2018.

Colwell R.K. 2013. Estimates, Version 9.1: Statistical Estimation of Species Richness and Shared Species from Samples (Software and User's Guide). Downloaded December 18, 2018.

Crawford R.L., Sugg P.M., Edwards J.S. 1995. Spider arrival and primary establishment on terrain depopulated by a volcanic eruption at Mount St. Helens Washington.The American Midland Naturalist 133(1): 60–75.

Dacar M.R.B., Nuñeza O.M. 2016. Microhabitat of leaf-dwelling pholcid spiders (Araneae:Pholcidae) in Rajah Sikatuna Protected Landscape (RSPL), Bohol, Philippines. ELBA Bioflux 8(1):1-6.

Dhali D.C., Saha S., Raychaudhuri D. 2017. Litter and ground-dwelling spiders (Araneae: Arachnida) of reserve forests of Dooars, West Bengal. World Scientific News63(2017): 1-242.

Dondale CD. 1986. The subfamilies of wolf spiders (Araneae: Lycosidae). Actas X CongresoInternacional de Aracnologia. Jaca, Espana 1: 327–332.

Edwards J.S., Thornton W.B. 2001. Colonization of an island volcano, Long Island, Papua New Guinea, and an emergent island, Motmot, in its caldera lake. VI. The pioneer arthropod community of Motmot. Journal of Biogeography 28: 1379–1388.

Elias N., Nuñeza O.M. 2015. Microhabitat utilization of leaf-dwelling pholcids (Araneae: Pholcidae) in Mount Baya, Camp Abubacar, and DimapatoyWatershed in Mindanao, Philippines. Asian Journal of Biological and Life Sciences4(3):189-193.

Fernando ES. 1998. Forest formations and flora of the Philippines: Handout in FBS 21. (Unpublished).

Framenau V.W. 2006. The wolf spider genus VenatrixRoewer: new species, synonymies and generic transfers (Araneae, Lycosidae). Records of the Western Australian Museum 23: 145-166.

Framenau VW, Manderbach R, Baehr M. 2002. Riparian gravel banks of upland and lowland rivers in Victoria (south-east Australia): arthropod community structure and life history patterns along a longitudinal gradient. Australian Journal of Zoology50: 102–123.

Gallé R, Fehér B. 2006: Edge effect on spider assemblages. Tiscia 35: 37-40.

Garciano D., Nuňeza O.M., Barrion-Dupo A. 2014. Species richness of spiders in Mt. Matutum, South Cotabato, Philippines.Journal of Biodiversity and Environmental Sciences 4(6): 214-224.

Greenstone M.H. 1982. Ballooning frequency and habitat predictability in two wolf spider species (Lycosidae: Pardosa). Florida Entomologist. 65(1): 83–89.

Greenstone M.H., Morgan C.E., Hultsch A-L., Farrow R.A., Dowse J.E. 1987: Ballooning spiders in Missouri, USA, and New South Wales, Australia: family and mass distributions. Journal of Arachnology (15): 163-170.

Griswold CE. 1993. Investigations into the phylogeny of the lycosid spiders and their kin (Arachnida: Araneae: Lycosoidea). Smithsonian Contributions to Zoology539: 1-39.

Hammer Ø., Harper D.A.T.,Ryan P.D. 2001. PAST: Paleontological Statistics software package for education and data analysis. Palaeontologia Electronica 4(1):1-9.

Hodge S., Vink C.J. 2000: An evaluation of Lycosahilaris as a bioindicator of organophosphate insecticide contamination. New Zealand Plant Protection 53: 226-229.

Krebs C.J. 1989. Ecological Methodology.NY Harperand Row Publishers Inc.,New York, pp. 654

Kronestedt T. 2015. Species of Wadicosa (Araneae, Lycosidae): transfer of two species from Pardosa and description of three new species from Africa. European Journal of Taxonomy132(132): 1-19.

Kronk A.E., Riechert S.E. 1979. Parameters affecting habitat choice of a desert wolf spider, Lycosasantrita Chamberlin and Ivie. Journal of Arachnology (7): 155-166.

Liu Z.H., Qian W., Li J., Zhang Y., Liang S. 2009. Biochemical and pharmacological study of venom of the wolf spider *Lycosa singoriensis.* Journal of Venomous Animals and Toxins including Tropical Diseases 15(1): 79-92.

Maandig R., Nuñeza O.M., Dupo A.B. 2017. Species richness and microhabitats of spiders in caves of Agusan del Sur, Philippines.Uttar Pradesh Journal of Zoology 37(1, 2):10-21.

Manderbach R., Framenau V.W. 2001. Spider (Arachnida: Araneae) communities of riparian gravel banks in the northern parts of the European Alps. Bulletin - British Arachnological Society12(1): 1–9.

Mao C.X., Colwell R.K. 2005. Estimation of species richness: mixture models, the role of rare species, and inferential challenges. Ecology 86(5):1143–1153.

Marshall E.J.P., Moonen A.C. 2002. Field margins in northern Europe: Their functions and interactions with agriculture. Agriculture, Ecosystems and Environment 89(1):5-21.

McKay RJ. 1974. The wolf spiders of Australia (Araneae: Lycosidae): A coral shingle inhabiting species from Western Australia. Memoirs of the Queensland Museum 17:21–26.

Morse D.H. 2002. Orientation and movement of wolf spiders Pardosalapidicina (Araneae, Lycosidae) in the intertidal zone. Journal of Arachnology (30): 601–609.

Mukhtar M.K., Khan Y., Jabeen S., Tahir H.M., Qadir A., Ahmad K.R., Butt A., Arshad M. 2012. A preliminary checklist of the spider fauna of Sargodha (Punjab), Pakistan.Pakistan Journal of Zoology44(5): 1245-1254.

Murphy N.P., Framenau V.W., Donnellan S.C., Harvey M.S., Park Y-C, Austin A.D. 2006. Phylogenetic reconstruction of the wolf spiders (Araneae: Lycosidae) using sequences from the 12S rRNA, 28S rRNA, and NADH1 genes: implications for classification, biogeography, and the evolution of web building behavior. Molecular Phylogenetics and Evolution 38(3):583–602.

Patiño S.C., Dupo A.B., Nuñeza O.M. 2016.Rapid assessment of spider fauna in Marilog District, Davao City, Philippines. 8(1):95-109.

Platnick NI. 2005. The World Spider Catalog, Version 6.0. Available at:<http://research.amnh.org/entomology/spiders/catalog/INTRO1.html>.American Museum of Natural History.

Quiñones L., Dupo A., Nuñeza O.M. 2016. Salticidae species richness in Rajah Sikatuna Protected Landscape (RSPL), Bohol, Philippines.ELBA Bioflux. 8(1):18-26.

Responte M., Nuñeza O.M. 2016. Microhabitats of pholcid spiders Araneae:Pholcidae) in Marilog District and Mount Hamiguitan, Davao, Philippines.Journal of Biodiversity and Environmental Sciences8(5):36-44.

Richter C.J.J. 1970. Aerial dispersal in relation to habitat in eight wolf spiders (Pardosa, Araneae, Lycosidae).Oecologia5(3): 200–214.

Sørensen L.L., Coddington J.A., Scharff N. 2002. Inventorying and estimating subcanopy spider diversity using semiquantitative sampling methods in an afromontane forest. Environmental Entomology 31(2):319–330.

Stirling G., Wilsey B. 2001.Empirical relationships between species richness, evenness, and proportional diversity.The American Naturalist 158(3): 286 299.

Tahir H.M., Khizar F., Naseem S., Yaqoob R., Samiullah K. 2016. Insecticide resistance in the ground spider, Pardosasumatrana (Thorell, 1890; Araneae: Lycosidae).Archives of Insect Biochemistry and Physiology93(1): 55-64.

Van Erp S., Booth L.R., Gooneratne R., O'Ralloran K. 2000: Organophosphate toxicity in wolf spiders (Lycosidae): An evaluation of sublethal responses. NewZealand Plant Protection (53): 447-447.

Vink C.J. 2002. Lycosidae (Arachnida: Araneae). Fauna New Zeal44: 1–94.

Vollrath F., Parker G.A. 1992. Sexual dimorphism and distorted sex ratios in spiders.Nature 360(6400): 156–159.

Walther B.A., Morand S. 1998. Comparative performance of species richness estimation methods.Parasitology 116(4):395–405.