Pertanika J. Trop. Agric. Sc. 42 (4): 1361 - 1373 (2019)

PERTANIKA JOURNALS

TROPICAL AGRICULTURAL SCIENCE

Journal homepage: http://www.pertanika.upm.edu.my/

Spider Assemblage (Arachnida: Araneae) in A Riparian Firefly Sanctuary of Sungai Chukai, Terengganu, Malaysia

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ABSTRACT

Sungai Chukai is a riparian sanctuary for synchronize firefly population. In riparian ecosystem, spider acts as top-invertebrate predator influencing the food-web. A survey of spider was conducted in Sungai Chukai, Terengganu, Malaysia. The objective of this study was to identify the assemblage of spider in the riparian area. Samples were collected in six sampling occasions from December 2017 to May 2018 using sweep net at both day and night. Collection of samples was done at 20 sampling points along the riverbanks with an averaged interval of 200 meter between each point. A total of 149 spider individuals from seven families (Araneidae, Clubionidae, Oxyopidae, Salticidae, Sparassidae, Tetragnathidae and Thomisidae) and 26 morphospecies were successfully collected. The most abundant family was Thomisidae (50 individuals; 33.56%) followed by Sparassidae (49 individuals; 30.87%) and Salticidae (24 individuals; 16.11%). There is no significant difference ($p>0.05$) for spider population between night and day. Three spider guilds had been identified according to its foraging pattern which are the orb-weaver, running hunter and ambush hunter. There is strong positive correlation between Araneidae and Dysderidae, Oxyopidae and Salticidae while Dysderidae is negatively correlated

ARTICLE INFO

Article history:
Received: 17 June 2019
Accepted: 03 September 2019
Published: 13 November 2019

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ISSN: 1511-3701
e-ISSN: 2231-8542

with Thomisidae and Sparassidae. This study adds to the inventories of spiders in Peninsular Malaysia.

Keywords: Firefly sanctuary, Peninsular Malaysia, riparian, spider

INTRODUCTION

Spiders are an important trophic group in ecosystems as they prey on smaller insects and directly stabilise ecological food webs (Sharma et al., 2010). This group of invertebrates feeds on smaller insects and becomes the food of larger vertebrates, such as birds and bats. Currently, there are 48,127 described spider species worldwide, from 117 families and 4150 genera (World Spider Catalog, 2019). Although the spider fauna of South East Asia has been recorded extensively, records are scarce for spiders in Peninsular Malaysia. The checklist of spiders in Peninsular Malaysia done by Norma-Rashid and Li (2009) includes 425 species from 42 families and 238 genera. The effort to inventory the spider fauna has included different habitats, such as mangroves (Norma-Rashid et al., 2009), forests, and agricultural plantations (Nasir et al., 2014).

While inventory of spiders in different habitats of Peninsular Malaysia is ongoing, records of the spider fauna in riparian habitats are limited. The riparian zone is an ecotone or interface between terrestrial and aquatic zones in ecosystems (Gregory et al., 1991). Riparian areas are constantly challenged by land-use change; human activity takes place immediately adjacent to the river edge, and there are multiple uses of the land in the riparian buffer. Agricultural practices such as oil palm growing and livestock farming often disregard the need for an appropriate distance from the riverbank (Lokman, 2016; Yunus et al., 2004).

The riparian area of Sungai Chukai is an important habitat for the synchronously flashing firefly, *Pteroptyx tener*. Fireflies are well known for their bioluminescent signalling, which is used for species recognition and mate choice (Lewis & Cratsley, 2008). Signalling is also likely to influence firefly interactions with potential predators such as spiders. In our ongoing study of fireflies at Sungai Chukai, we have observed spiders in our samples. According to Long et al. (2012), jumping spiders are highly likely to interact with fireflies, with bioluminescent signalling increasing the risk of predation of fireflies by the spiders. A predator–prey relationship between spiders and fireflies has never been recorded in Malaysia. In addition, spider assemblages, particularly those in riparian habitats that act as firefly sanctuaries, have never been documented before.

The restoration of riparian ecosystems is crucial because they can be refuges for wildlife. It is important to have baseline ecological data for comprehensive assessment and area management for restoring riparian habitats. Therefore, the aim of this study was to record preliminary data on the spider assemblage in a firefly sanctuary area, Sungai Chukai, and to provide a checklist of spiders in the riparian area. Quantification of spider functional

diversity will serve as a basis for uncovering the relationships between spiders and fireflies in Malaysia. The results of this study will provide background knowledge for management of the Sungai Chukai riparian firefly sanctuary, as well as contribute to the inventory of spiders in Malaysia.

MATERIALS AND METHOD

Sample Collection

Samplings were conducted in 20 sampling points along riverbank of Sungai Chukai, Kemaman, Terengganu (4° 18' 27.36'' N, 103° 22' 21'' E) (Figure 1). Sungai Chukai located at east coast of Peninsular Malaysia. This riparian area is noted as habitat for congregating firefly, *Pteroptyx tener* as the display tree of firefly, *Sonneratia caseolaris* can be found at the riverbanks (Cheng et al., 2019; Muhammad Mahmod et al., 2018). Twenty riparian trees along the river with an averaged distance of 200 m were selected as sampling points. The sampling points were assembled at both sides of the riverbanks from downstream towards upstream (Figure 2). Samples of spider were collected in six occasions for six consecutive months starting from December 2017 to May 2018 using sweep net for one minute at each of the sampling points. Sampling was conducted at daytime and nightime. At night, sampling was conducted from 8 p.m. until 10 p.m. while during the day, the sampling was conducted from 9 a.m. to 11 a.m. During each occasion, net was swept randomly on the riparian trees at a height of

Figure 1. Location of study site in Peninsular Malaysia

approximately three to four meters from the ground. The total sampling effort was total up to 240 (6 months x 20 sampling points x 2 times). Spider samples were placed in bottles containing ethyl acetate which then brought to laboratory for identification. Samples were identified using the morphospecies approach to the lowest taxa level wherever possible using the identification keys with the aid of illustrations notably by Dippenaar-Schoeman and Jocque (1997), Koh (1989), and Murphy and Murphy (2000). Classification of spiders into guild was done by referring to Rodrigues and Mendonça (2012) and Uetz et al. (1999). Voucher specimens were stored in Center of Insect Systematics, Universiti Kebangsaan Malaysia. The riparian host tree of spider were collected and identified.

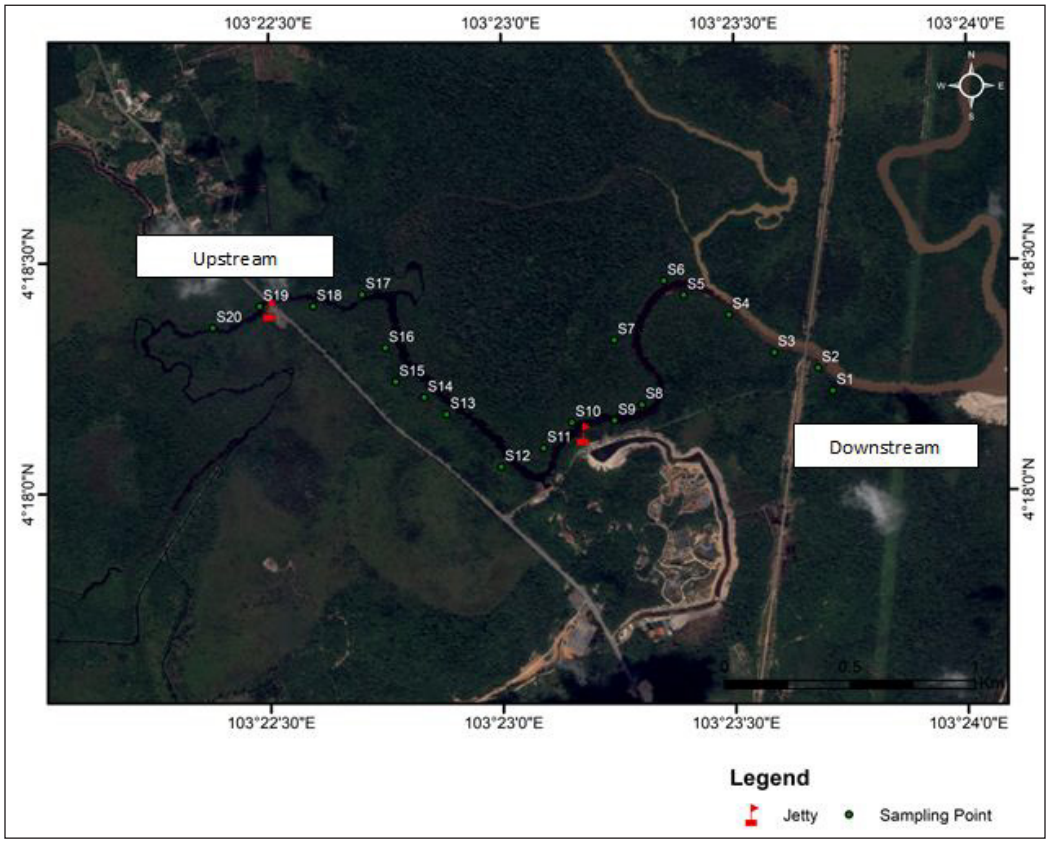

Figure 2. Sampling points in Sungai Chukai, Terengganu, Malaysia

Data Analysis

Spider diversity and riparian vegetation diversity were expressed by the Shannon-Wiener diversity index (H'). The Shannon-Wiener diversity index incorporates species richness as well as relative abundances of species. The indices were generated using PAST software version 2.17 (Hammer et al. 2001). In order to test for any significant difference between

populations of spider at different time of the day (day and night), Mann-Whitney test was conducted using Minitab software version 17.1. The adequacy of sampling effort within an area may be indicated by species accumulation curve (Chao et al., 2009). The species accumulation curve was generated after 100 randomization of sample order with nonparametric estimator, Chao 1 and Jackknife using EstimateS software version 9.1 (Colwell, 2009). Chao 2 and Jacknife was selected as the normality assumption was not satisfied. Cluster analysis was conducted to find structure of spider community in the riparian area with software PCORD 5.0 using Euclidean and Ward's distance matrices. Correlation network plot was analyzed and generated using package 'spaa' in R software version 3.5.3. The correlation network plot helps to determine the interaction between taxon (Zhang, 2011).

RESULTS AND DISCUSSION

A total of 149 spider individuals representing 26 species in seven families (Araneidae, Clubionidae, Oxyopidae, Salticidae, Sparassidae, Tetragnathidae and Thomisidae) (Table 1). The most abundant family was the Thomisidae (50 individuals; 33.56%) followed by the Sparassidae (49 individuals; 32.89%) and Salticidae (24 individuals; 16.11%) (Figure 3). The species accumulation curve generated using Chao 1 and Jacknife estimator shows an ascending trend, indicating that more spider species are yet to be discovered (Figure 4).

The Mann–Whitney *U* test showed no significant differences ($p>0.05$) between daytime and night-time spider populations, suggesting that resource partitioning occurred spatially rather than temporally. Nevertheless, results showed that spider abundance was higher at night than during the day (Table 1). It is important to note that the diel activity of spiders is highly influenced by the circadian rhythms of their prey (Krol et al., 2018). The higher abundance of spiders at night suggests that most of their invertebrate prey in Sungai Chukai were active at night-time. In addition, larger-bodied spiders tend to be more active at night to avoid diurnal predators such as birds (Krumpalova & Turf, 2013; van Berkum, 1982). This explains the higher abundance of the larger Sparassidae at night than during the day. The genus *Heteropoda* from this family was also nocturnal, as it was found to hunt actively at night (Zhang et al., 2015, 2018). On the other hand, we found that small-bodied spiders such as the Salticidae tended to be more active during the day. The Salticidae use visual cues to hunt for their prey and being active during daytime allow these spiders to make full use of their ability to see in fine detail (Jackson & Cross, 2011).

The spiders collected in this study are common in Malaysia. Since records of spiders are scarce for Peninsular Malaysia, we could compare our results only to those of Nasir et al. (2014), Norma-Rashid and Li (2009), and Norma-Rashid et al. (2009). Orb-weaver spiders such as the Tetragnathidae (*Tegranatha* sp.) and Araneidae (*Neoscona*

Table 1
Checklist of spider in Sungai Chukai, Terengganu, Malaysia

Family	Morphospecies	No. of Individuals		Total
		Day	Night	
Araneidae (A)	*Neoscona* sp.	1	1	2
Clubionidae (C)	*Araneus* sp.	0	4	4
	Clubiona sp. 1	0	2	2
	Clubiona sp. 2	0	1	1
	Clubionidae sp. 1	5	0	5
Oxyopidae (O)	*Oxyopes* sp. 1	0	1	1
	Oxyopes sp. 2	3	1	4
Salticidae (SA)	*Icius* sp. 1	4	0	4
	Icius sp. 2	3	1	4
	Myrmarachne sp.	1	0	1
	Salticidae sp. 1	3	1	4
	Spartaeus sp. 1	4	5	9
	Spartaeus sp. 2	2	0	2
Sparassidae (SP)	*Heteropoda* sp. 1	8	37	45
	Heteropoda sp. 2	0	1	1
	Heteropoda sp. 3	1	2	3
Tetragnathidae (TE)	*Tetragnatha* sp.	2	1	3
	Tetragnathidae sp. 1	0	4	4
Thomisidae (TH)	*Ebrechtella* sp.	0	5	5
	Mastira sp. 1	4	5	9
	Mastira sp. 2	1	0	1
	Mechapesa sp.	0	4	4
	Thomisidae sp. 1	2	0	2
	Thomisidae sp. 2	0	1	1
	Thomisidae sp. 3	1	2	3
	Thomisidae sp. 4	11	14	25
	TOTAL	**56**	**93**	**149**

sp.) have been recorded in the west coast of Peninsular Malaysia by Nasir et al. (2014). Long-jawed orb weavers, *Tegranatha* sp. have been found in mangrove areas of Morib and Tioman (Norma-Rasyid et al., 2009) while sac spider, Clubionidae (*Clubiona* sp.) has been found before in Tioman (Norma-Rasyid et al., 2009). These genera have been confirmed to be non-endemic to Peninsular Malaysia as they have also been recorded in Sarawak (Koh et al., 2013) and Sabah (Dzulhelmi et al., 2014), the Malaysian states in the island of Borneo. The lynx spider, Oxyopidae (*Oxyopes* sp.) was also recorded in Sarawak, but not in Sabah, while in Peninsular Malaysia it had

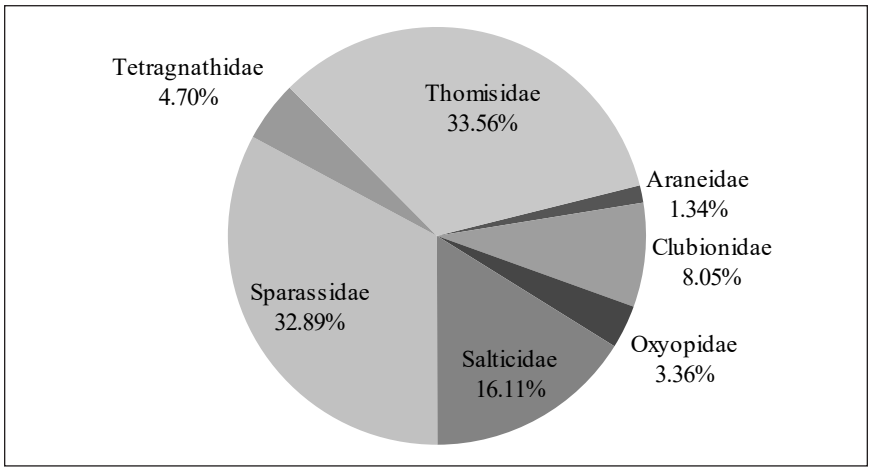

Figure 3. Assemblages of spider in Sungai Chukai, Terengganu, Malaysia

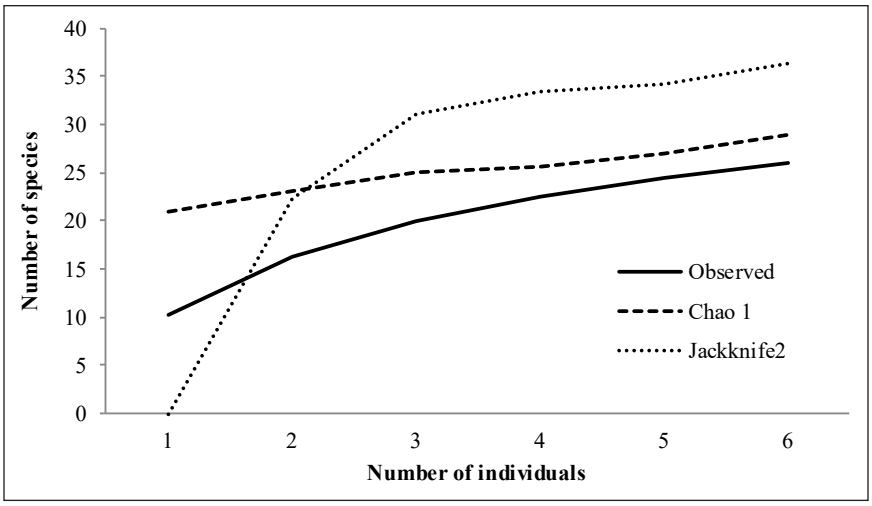

Figure 4. Species accumulation curve using Chao and Jackknife Estimator for spider species found in Sungai Chukai, Terengganu, Malaysia

been found in Penang, Tioman and Morib (Norma-Rayid et al., 2009; Norma-Rasyid & Li, 2009). Both genera of Salticidae, *Icius* and *Myrmarachne*, collected in this study had been recorded in Peninsular Malaysia (Norma-Rasyid & Li, 2009). However, *Icius* has never been recorded from Sabah and Sarawak. The huntsman spider, Sparassidae (*Heteropoda* sp.) and crab spider, Thomisidae (*Mastira* sp.) are widespread in Peninsular Malaysia, Sabah and Sarawak (Koh et al., 2013; Nasir et al., 2014; Norma-Rasyid & Li, 2009). On the other hand, *Ebrechtella* is a new record from Peninsular Malaysia, although it has been recorded in Sabah and neighbouring Thailand (Deeleman-Reinhold & Floren, 2008).

In this study, four riparian plant species i.e. *Barringtonia racemosa*, *Hibiscus tilaceus*, *Nypa fruticans* and *Sonneratia caseolaris* were observed to host spiders. Spider diversity was different between these species. The Shannon diversity index was the highest (*H*' = 1.782) for spiders on *Hibiscus tilaceus* and the lowest for spiders on *N. fruticans* (*H*' = 0.6315). The diversity index for spiders on *B. racemosa* and *S. caseolaris* was *H*' = 1.723 and *H*' = 1.563, respectively. The difference in spider diversity was hypothesised to be caused by differences in plant architecture. In comparison to the other three riparian genera, *H. tilaceus* has denser foliage, which may provide greater and more structurally complex support for web building, thereby resulting in the highest spider diversity. In contrast, the palm *N. fruticans* with its simple arrangement of pinnate leaves and linear leaflets, held the lowest spider diversity. These results are supported by a study by Hatley and Macmahon (1980) which found that spider diversity increased with shrub foliage volume and density. Highly dense foliage may hold a greater number of smaller invertebrates as prey options, as well providing substrates for web attachment. This demonstrates that vegetation composition and structure may play a significant role in controlling spider diversity in this area.

The assemblage of spiders in Sungai Chukai plays an important role as predators, although there are differences between different spider groups in their predatory behaviour. Based on cluster analysis, the spiders in Sungai Chukai can be divided into three foraging guilds (Figure 5). Group I consists of orb weavers, from the Araneidae and Tetragnathidae, that use sticky webs, while being stationary, to capture flying insects at all life stages. Orb weavers produce silk as soon as they hatch from the egg sac; as the spider lings grow, the amount of silk they produce increases, and the silk improves in quality, to support a larger body (Sensenig et al., 2011). This may also help the adult spider to capture larger prey. The webs produced by the Aranaidae and Tetragnathidae are bidimensional as opposed to the sheet-web spider's webs that are tridimensional (Ávila et al., 2017). Orb-weaver spiders depend strongly on the presence of structure for web support (Nasir et al., 2017). Riparian habitats in Sungai Chukai apparently provide the structure for web attachment by *Tegragnatha* and *Neoscona*. A complex habitat, particularly

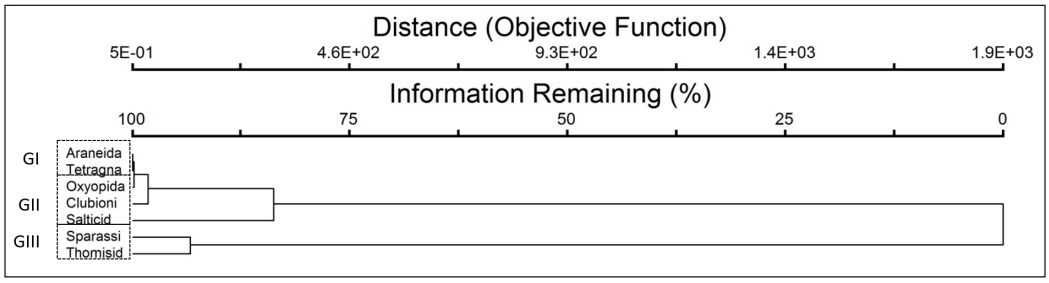

Figure 5. Dendogram for one-way cluster analysis of spider in Sungai Chukai, Terengganu, Malaysia

that with different types of vegetation, will provide more options for orb weavers to attach their webs, and will thus support diverse spider species.

Group II from the cluster analysis is represented by hunting spiders, and is dominated by ambush hunter. Similar to orb weavers, ambush spiders are sit-and-wait predators; however, the members of the Oxyopidae and Salticidae do not build webs (Ávila et al., 2017). They remain motionless until their movement is triggered by the movement of the prey. The Oxyopidae (*Oxyopes* sp.) may prey on calliphorid flies in oil palm plantations (Chin et al., 2008), the tea mosquito bug (*Helopeltis theivora*) in tea plantations (Basnet & Mukhopadhyay, 2014), and the white-backed planthopper (*Sogatella furcifera*) in rice fields (Butt & Xaaceph, 2015). The affinity of this spider for pests of economic importance shows that it has the potential to become a beneficial biocontrol organism. The ant-like salticid spiders (Salticidae, *Myrmarachne* sp.) also prey on various of arthropod prey, as well as being adept at cathing moth (Jackson & Willey, 1994).

Group III includes the families Thomisidae and Sparassidae and are mainly hunting spiders. The two families may be influenced by the same abiotic factors, our analysis consequently clustering them into one group. Therefore, we suggest that it is worthwhile to study how the abiotic factors in the riparian area affect these spider groups. However, the Thomisidae and Sparassidae have different modes of hunting; the former are ambush hunters, whereas the latter consists of both running and ambush hunters (Rodrigues & Mendonça, 2012). The Thomisidae frequently visit flowering plants, and may successfully attack butterflies, dragonflies, and stinging insects, such as bees and wasps (Lovell, 1915). The huntsman spider, Sparassidae, has been reported to be able to hunt on the water surface (Airamé & Sierwald, 2000), making riparian areas particularly suitable habitats for this spider family.

In our study, there is a strong positive correlation ($r>0.58$) between the presence of the Araneidae and the Oxyopidae. The Oxyopidae are also positively correlated ($r>0.58$) with the Salticidae. A strong negative correlation ($r<-0.41$) was exhibited between the Thomisidae and the Salticidae (Figure 6). According to Zhang (2011), a positive correlation may arise as a result of mutualistic or prey–predator interaction, while competition between species may yield a negative correlation. For example, the negative correlation between the presence of the Thomisidae and Salticidae may be evidence of competition for resources. Niche overlap between these two families may occur as both can be found at the same period of time during the day. The Thomisidae and Salticidae also exhibit similar foraging strategies; as ambush hunters, they may compete for the same prey. The positive correlation between the Araneidae and Oxyopidae may be the result of niche differentiation as the Araneidae are located in different niches within the habitat from those of the Oxyopidae. In addition, the types of prey consumed by the orb-

weaving Araneidae may be different from those consumed by the ambush-hunting Oxyopidae. The results for Spearman's correlation between each family are shown in Table 2.

It is also important to note that the spiders in this study coexisted with the congregating firefly populations in the same riparian habitat. The question is whether there is interaction between spiders and fireflies. There is the possibility that spiders' prey on *P. tener* in Sungai Chukai. Both nocturnal and diurnal spiders have been recorded as predators of fireflies (Lloyd, 1973). For example, wolf spiders (Lycosidae) are known to hunt for *Photuris* sp. in the US. A large number of prey items on the web of *Neoscona arabesca*, an orb-weaving spider, consisted of the congregating firefly, *Photinus carolinus* (Lewis et al., 2012). The genus *Neoscona* has also been recorded in our study, although no observation or record was made of its predator–prey relationships. Future research on predation of *P. tener* by spiders is recommended, as currently there are no studies on this subject.

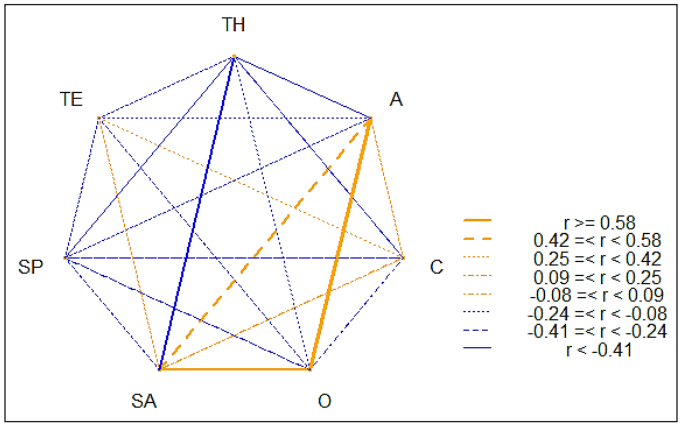

Figure 6. correlation network plot between Arachnids family in Sungai Chukai, Terengganu, Malaysia A=Araneidae, C=Clubionidae, O= Oxyopidae, SA= Salticidae, SP= Sparassidae, TE= Tetragnathidae, TH= Thomisidae

Table 2
Spearman's correlation value between family of Arachnids in Sungai Chukai, Terengganu, Malaysia

	A	C	O	SA	SP	TE	TH
A	1.000	0.333	0.885	0.670	0.000	-0.111	-0.299
C	0.333	1.000	0.156	0.287	0.258	0.333	-0.128
O	0.885	0.156	1.000	0.793	0.000	-0.156	-0.120
SA	0.670	0.287	0.793	1.000	0.124	0.351	-0.282
SP	0.000	0.258	0.000	0.124	1.000	0.000	0.248
TE	-0.111	0.333	-0.156	0.351	0.000	1.000	-0.085
TH	-0.299	-0.128	-0.120	-0.282	0.248	-0.085	1.000

Note. A=Araneidae, C= Clubionidae, O=Oxyopidae, SA= Salticidae, SP= Sparassidae, TE= Tetragnathidae, TH= Thomisidae

CONCLUSION

Malaysia is a tropical country with diverse and fascinating flora and fauna. It is highly feasible that there are more spiders awaiting to be discovered with additional sampling efforts and extension of study periods. The results from this study contribute to biodiversity knowledge of Sungai Chukai, which will help in the conservation of this area of high potential as an ecotourism attraction. A comprehensive inventory of Malaysian spiders is needed to expand our knowledge of spider taxa in the country. Continuing research will contribute to the conservation of both spiders and fireflies, as well as the Sungai Chukai riparian ecosystem as a whole, in the hope that it can be developed as an ecotourism centre and is maintained as an ecological corridor.

ACKNOWLEDGEMENT

We thank Dr. Dzulhelmi Muhammad Nasir, Dr. Nik Ahmad Irwan Izzauddin Nik Him and Juhaida Harun for their assistance in identification of specimen. We are also grateful to Mr. Muhammad Zabidi Yaacob and staff of Zoo Kemaman for their assistance in fieldwork. We thank Nor Shafikah Idris for the map generated in this article. This research was funded by grant from TNB Research Sdn. Bhd. (ST 2017-013).

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