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Arthropod Communities on *Sonneratia caseolaris* along Selangor River, Kampung Kuantan, Kuala Selangor, Malaysia

NURUL AINA ADNAN[1], MAMAT NUR-SYAHIRAH[2], DZULHELMI MUHAMMAD NASIR[3], NUR-ATHIRAH ABDULLAH[1], LAILATUL-NADHIRAH ASRI[1], MUHAMMAD FAIZ ZAKARIA[4], ADNAN AMIN-SAFWAN[5], SURZANNE MOHD AGOS[6], WAN JULIANA WAN AHMAD[1], MAIMON ABDULLAH[1], NORELA SULAIMAN[1] & FASZLY RAHIM*[1,7]

[1]Department of Earth Science and Environment, Faculty Science and Technology, Universiti Kebangsaan Malaysia, Bangi, 43600, Selangor, Malaysia; [2]International Institute of Aquaculture and Aquatic Sciences (I-AQUAS), Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia; [3]Biology and Sustainability Research Division, Malaysian Palm Oil Board, 6 Persiaran Institusi, Bandar Baru Bangi, 43000 Kajang, Selangor, Malaysia; [4]Faculty of Environment and Marine Science, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia; [5]Department of Applied Sciences and Agriculture, Tunku Abdul Rahman University College, Johor Branch Campus, Jalan Segamat/Labis, 85000 Segamat, Johor, Malaysia; [6]Higher Institution Centre of Excellence (HICoE), Institute of Tropical Aquaculture and Fisheries (AKUATROP), Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia; [7]PERMATA Insan College, Universiti Sains Islam Malaysia, 71800 Bandar Baru Nilai, Negeri Sembilan, Malaysia

*Corresponding author: faszly@usim.edu.my

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ABSTRACT

Sonneratia caseolaris commonly known as mangrove apple or Berembang in the Malay language, is a species of plant in the family Lythraceae. Area of *S. caseolaris* along Selangor River in Kampung Kuantan has become a natural habitat for a variety of arthropods. This study aimed to identify the species variations in arthropod communities at different selected stations along Selangor River at two different sampling times. Present study was conducted for six consecutive months (August 2010 until January 2011) at 19 selected stations along the Selangor River. Sampling was conducted once per day and night. Sweeping method by using sweep nets were used as the arthropod sampling method. Data analysis was done quantitatively to determine the composition of arthropod community. A total of 7,707 individual arthropods collected belonging to 10 different orders consisting of Coleoptera, Hymenoptera, Diptera, Neuroptera, Orthoptera, Odonata, Lepidoptera, Blattodea, Mantodea and Araneae. A total of 4,563 arthropod individuals were sampled at night, which was more than the daytime (3,144 individuals), with Station 17 recorded the highest arthropod individual out of the 19 sampling sites. During the night, the firefly, that belongs to the Lampyridae family showed the highest arthropod composition. The presence of arthropod biodiversity along the Selangor River reveals that the *S. caseolaris* area is important in maintaining a diverse community of fireflies and other arthropods for conservation purposes.

Keywords: Arthropod community, fireflies, mangrove, *Sonneratia caseolaris*

INTRODUCTION

Selangor River is known as greatest source of water (about 60%) in state of Selangor and Kuala Lumpur (Othman *et al*., 2014) that play a crucial role as a major source of protein through fisheries and aquaculture businesses, and an irrigation source for agriculture. Mangroves can be found in the Selangor River estuary up to 20 km along the coast. Despite the fact that Selangor River and its riverbanks have been designated as a protected zone under the Selangor Waters Management Authority Enactment 1999, the loss of firefly habitats along Selangor River has been recorded since 2007. According to Khoo *et al*. (2009), throughout the year 2008, there was a gradual increase in loss of firefly habitats.

The most dominant mangrove trees in this area are *Sonneratia caseolaris* species, known as Berembang in Malay. Berembang is classified under the order Myrtales and the family Lythraceae. Berembang are non-viviparous plants and an essential component of mangrove communities in the West-Indo Pacific (Chen *et al*., 2008). A high abundance of *S. caseolaris* or Berembang tress attracts fireflies, from the

species *Pteroptyx tener* as their natural habitats. *Pteroptyx tener* tends to make Berembang trees as their habitats compared to other mangroves species. In riparian habitat areas in Kuala Selangor, Berembang was observed to be the most dominant tree species followed by palms species, climbers, herbs and fern species (Wan Juliana *et al*., 2012). Most of the plant species discovered in this study area such as *S. caseolaris, Hibiscus tiliaceus, Nypa fruticans, Acrostichum aureum* and *Ficus* sp. were also present in the other riparian habitats of fireflies such as the Rembau-Linggi estuary of Negeri Sembilan and Sepetang estuary of Perak (Jusoh *et al*., 2010a, 2010b).

Arthropods are well known for their importance in forest ecosystems though they are not getting enough attention amongst the mangrove communities. However, the increased number of studies in mangrove herbivory recently has shown that arthropods research areas are crucial as they play a significant role in forest ecosystems (Cannicci *et al*., 2008). As such, Veenakumari and Prasanth (2009) have started to record the presence of herbivorous insect in mangrove area recording the true phytophagous insect to mangrove and mangrove associates. Leaf-eating arthropods and wood-boring arthropods are two groups of herbivorous arthropods that are often found in mangrove areas. The presence of these two arthropod groups gives a positive impact on the mangrove trees to improve the quality and quantity of mangrove leaf litter through loss of higher nutrient content leaves (Feller, 2002).

Until recently, there is a limited study done to understand the complex relationship between the other arthropod species and the firefly living in the mangrove area. While Abdullah *et al*. (2019) recorded the insect guild found in the mangrove firefly habitat, the interaction between firefly with other arthropod species found on the same mangrove tree species are yet to be explained. Studies on the ecology of arthropods and their relations to vegetation in a riparian area are important to identify its interaction with fireflies. Therefore, it is crucial to identify the interaction between the arthropod communities and mangrove vegetation, especially the *S. caseolaris* knowing that the *Pteroptyx* population are highly associated to this vegetation species. Hence, the present study aimed to identify the arthropod communities on *S. caseolaris* as baseline information in getting better insight for future conservation of *Pteroptyx* population and the whole biodiversity of Selangor River.

MATERIALS AND METHODS

Study Site

This study was conducted at Selangor River, in Kuala Selangor, West Coast of Peninsular Malaysia (3°20’57”N, 101°14’08”E). Selangor River is the longest river in the state of Selangor, Malaysia with 75 km long and 500 m wide at the downstream area. This river is about 2.4 m deep during the low tide; with the water depth can even reach to more than 10 m in the upstream area (Masni *et al*., 2009). The Selangor River flows in a south westerly direction traversing a total distance of about 110 km before discharging into the Straits of Malacca at the town of Kuala Selangor (Othman *et al*., 2014). The study focused on the Kampung Kuantan area which is a famous ecotourism spot for sightseeing the presence of fireflies at night (Figure 1).

Sampling

Sampling was conducted once per month for six consecutive months starting from August 2010 until January 2011. Fireflies and other arthropods were sampled by the sweeping method on the riparian vegetation and trees lining both banks of the Selangor River at 19 selected sampling stations in the study area. A total of 19 sampling stations was established (SR 1-SR 19, SL 1-SL 19) based on the observation of areas with high abundance of firefly populations. The stations were located along the left and right sides of the river, and the distance between each station was about 1 km. Sampling was conducted at all stations during day (10.00 a.m-12.00 p.m) and night (8.00 p.m to 10.00 p.m) to account for both diurnal and nocturnal activities of the arthropod (Abdullah *et al*., 2019). Night samplings are during moonless night to maximize catch and minimizing the sampling bias. The method used was sweeping by using a 50 cm diameter sweep net. The sweep net was used to trap arthropods found on the Berembang trees at each sampling station. The net was swept four times within 20 frequencies. The time intervals between frequencies were 3 minutes. The sampling was replicated two times for every sampling stations.

Figure 1. Location of sampling station at Selangor River (Google Maps)

Arthropods trapped in the net were transferred into a plastic bag and tissues damped with ethyl acetate were inserted before the plastic bag was tied with a rubber band. Each plastic bag was labelled with information on the date, location and sampling time. All samples were brought back to the laboratory for preservation and identification. Later in the laboratory, the arthropods were sorted out into plastic containers (60 ml) that contained 70% ethanol for preservation. Each container was labelled with the station name, date, time and collector's name.

In the laboratory, the collected insects were sorted and identified based on morphospecies. The identification of insects was carried out using an identification source in the form of an insectarium and identification guidebooks. A Field Guide to Insects of North America North of Mexico (Borror & White, 1970); An Introduction to the Study of Insects (Borror *et al.*, 1989); and Hymenoptera of the World: An Identification Guide to Families (Goulet & Huber, 1993).

Statistical Analysis

Species diversity was determined by using Shannon Diversity Index. All analyses were calculated by PC-ORD programme (McCune & Mefford, 2011). Two-way cluster analysis was carried out by using PC-ORD programme to observe the family overlap between sampling stations. Sorensen distance coefficient was used in this analysis. The differences in arthropod compositions among sampling stations with different sampling times were identified. The matrix of shaded squares represents the sample unit × species matrix, while the dendrograms show the clustering. The intensity of the shading is proportional to the abundance of the species. The axes show information remaining for sample unit (left) and species (top) clustering.

RESULTS

Taxonomic Composition

A total of 7,707 arthropods individual were recorded after six months of sampling (August 2010 until January 2011) at 19 stations along Selangor River. Ten orders were recorded as follows; Coleoptera, Hymenoptera, Diptera, Neuroptera, Orthoptera, Odonata, Lepidoptera, Blattodea, Mantodea and Araneae. There were 55 arthropod families among the 10 orders that have been identified. Lampyridae (4,053 individuals; 52.59%), Cantharidae (815 individuals; 10.57%) and Chrysomelidae (595 individuals; 7.72%) were the three families with the highest abundance (Table 1). Coleoptera recorded the highest number of arthropod individuals (6,351 individuals; 82.41%) followed by Diptera (475 individuals; 6.42%) and Araneae (370 individuals; 4.80%) (Figure 2). The complete checklist of insect families sampled in the Selangor River is shown in Table 1.

Table 1. List of order, family with number of individuals and percentage of insect families sampled on *Sonneratia caseolaris* in the Selangor River

Order	Family	Code	Day	Night	No. of individuals	Percent of individuals
Coleoptera	Buprestidae	COLBupre	4	1	5	0.06%
	Cantharidae	COLCantha	319	496	815	10.57%
	Carabidae	COLCarab	4	8	12	0.16%
	Chrysomelidae	COLChrys	197	398	595	7.72%
	Coccinelidae	COLCocci	34	18	52	0.67%
	Curculidae	COLCurcu	3	5	8	0.10%
	Elateridae	COLElate	0	2	2	0.03%
	Lampyridae	COLLamp	1745	2308	4053	52.59%
	Pentatomidae	COLPenta	2	4	6	0.08%
	Phalacridae	COLPhala	119	158	277	3.59%
	Scarabidae	COLScara	7	12	19	0.25%
	Staphylinidae	COLStaphy	2	0	2	0.03%
	Tenebrionidae	COLTene	161	344	505	6.55%
Hymenoptera	Bethylidae	HYMBethy	9	0	9	0.12%
	Braconidae	HYMBraco	22	32	54	0.70%
	Chalcididae	HYMChalc	5	0	5	0.06%
	Eucharitidae	HYMEucha	1	0	1	0.01%
	Formicidae	HYMFormi	59	97	156	2.02%
	Ichneumonidae	HYMIchneu	1	7	8	0.10%
	Proctotrupidae	HYMProcto	1	0	1	0.01%
	Sphecidae	HYMSpheci	5	0	5	0.06%
	Vespidae	HYMVespi	59	8	67	0.87%
Diptera	Asiliidae	DIPAsili	0	1	1	0.01%
	Calliphoridae	DIPCalli	5	2	7	0.09%
	Culicidae	DIPCuli	0	31	31	0.40%
	Dolichopodidae	DIPDoli	47	19	66	0.86%
	Drosophilidae	DIPDroso	18	69	87	1.13%
	Lonchaedae	DIPLonch	3	24	27	0.35%
	Muscidae	DIPMusci	32	184	216	2.80%
	Sciaridae	DIPSciar	0	2	2	0.03%
	Stratiomyidae	DIPStrat	1	2	3	0.04%
	Syrphidae	DIPSyrphi	3	2	5	0.06%
	Tachidae	DIPTachi	7	6	13	0.17%
	Tephritidae	HYMTephr	3	1	4	0.05%
	Tipulidae	DIPTipu	0	7	7	0.09%
	Ulididiidae	DIPUlidi	2	1	3	0.04%
	Pipunculidae	DIPPipun	3	0	3	0.04%
Neuroptera	Chrysopidae	NEUChrys	28	86	114	1.48%
	Mantispidae	NEUManti	2	17	19	0.25%
Araneae	Araneae	Araneae	178	192	370	4.80%
Hemiptera	Lygaeidae	HEMILyga	1	0	1	0.01%
	Miridae	HEMIMiri	19	4	23	0.30%
	Nabidae	HEMINabi	5	2	7	0.09%
	Cicandellidae	HEMICican	1	0	1	0.01%
	Dictyopharidae	HEMIDicty	2	1	3	0.04%
	Flattidae	HEMIFlat	1	0	1	0.01%
	Membracidae	HEMIMembr	8	3	11	0.14%
Orthoptera	Acrididae	ORTAcri	8	1	9	0.12%
	Gryllidae	ORTGryll	0	1	1	0.01%
	Tettigonidae	ORTTetti	1	0	1	0.01%
Odonata	Coenogrionidae	ODOCoeno	1	0	1	0.01%
	Libellulidae	ODOLibellu	3	0	3	0.04%
Mantodea	Mantidae	MANManti	3	0	3	0.04%
Lepidoptera	Lepi 1	LEPILepi	0	6	6	0.08%
Blattodea	Blattaria	BLATTBlatt	0	1	1	0.01%
Total			3144	4563	7707	100.00%

Notes: Name code were coding used in family overlapping analysis. Code used in dendogram generated through clustering analysis.

Comparison of Arthropod Compositions with Sampling Time

The number of arthropods sampled during nighttime (4,563 individuals) was higher compared to the daytime (3,144 individuals). Table 1 shows the arthropod individuals according to sampling time. Firefly (Family: Lampyridae), which is a nocturnal arthropod, contributes to the highest arthropod compositions at nighttime. Chi-squared analysis indicated that there were significant differences in abundance among arthropod families at the 19 sampling stations (χ^2= 333.283, df =18, P<0.05). It was proven that the arthropod diversity among stations was significant and the highest Shannon diversity index value was recorded at Station 17 (H'=2.361).

Community Similarity

Two distinct groups were formed which are Group A and Group B from the 25% of families overlap. Group A consisted of Stations 1, 11, 12, 13, 14, 15, 16, 18 and 19 which were night sampling time, while Group B consisted of other stations for sampling during both daytime and nighttime (Figure 3). Group A was different from Group B due to the presence of a unique family of arthropods consisting of Mantidae, Pentatomidae, Syrphidae, Coenogrionidae, Eucharititdae, Tettigonidae, Pipunculidae, Elateridae, Proctotrupidae, Dictyopharidae, Libellulidae and Membracidae. The presence of arthropods from these families is very small in number because they were not commonly found in the mangrove areas. For example, arthropods from the family Libellulidae and Coenogranidae (Order: Odonata) live in areas with clean water and also well known as the biological indicator of water pollution (Kutcher & Bried, 2014).

The low number of Odonata recorded in this area might be due to the Selangor River being polluted and contaminated with domestic wastes. Group B was divided into two distinct groups, which were Group B1 and Group B2 with 44% overlapping (Figure 4). Group B1 was dominated by arthropods sampled in the daytime while Group B2 was dominated by arthropods sampled in the nighttime. Arthropods from the family Vespidae was found in Group B1 but not in Group B2.

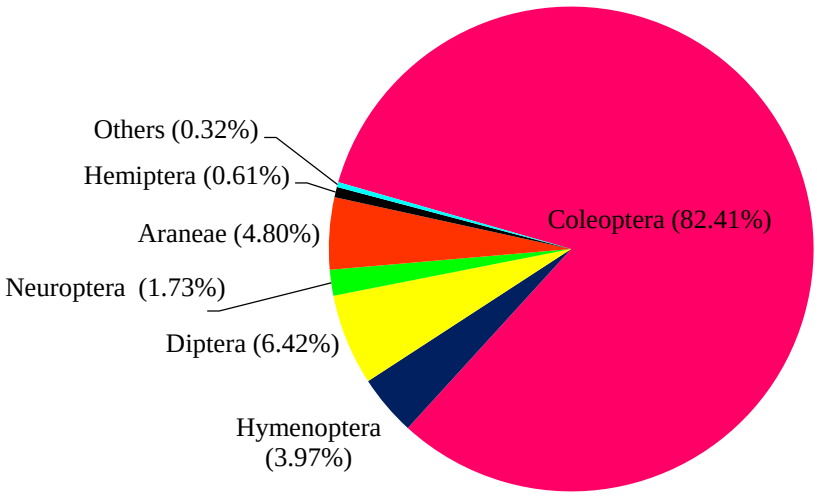

Figure 2. Arthropod compositions according to order in Selangor River, Kuala Selangor

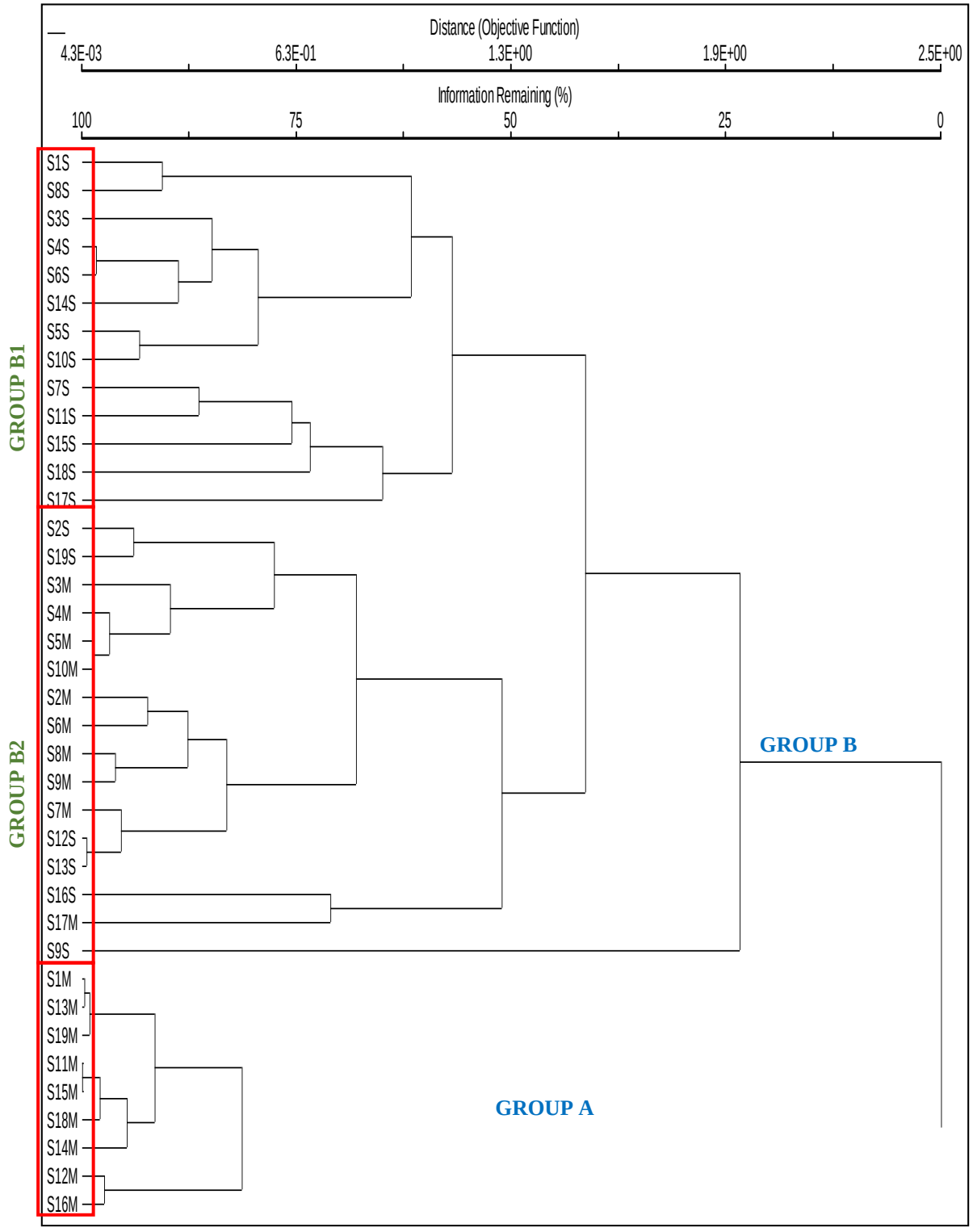

Figure 3. Arthropods similarities dendogram

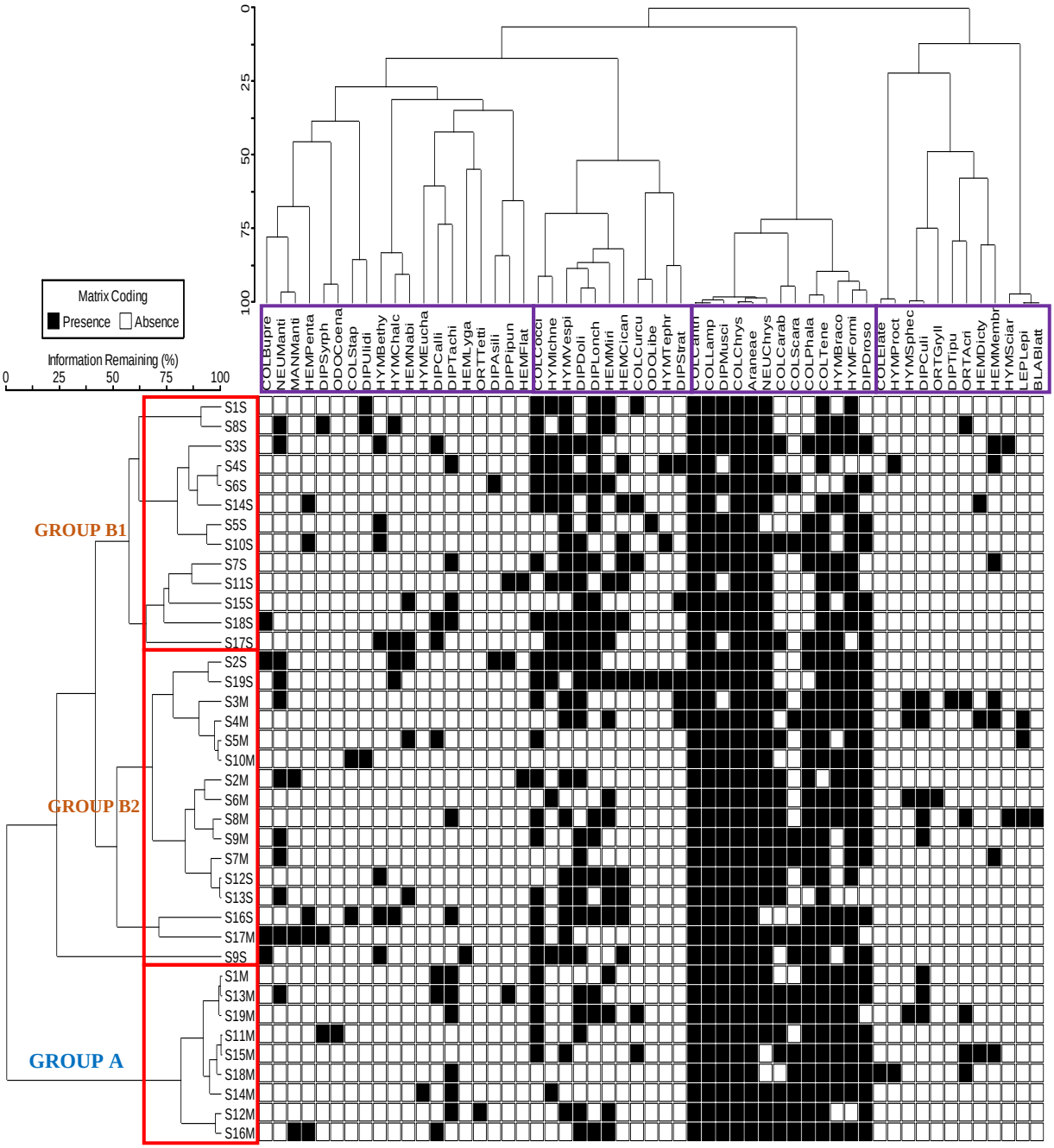

Figure 4. Family overlapping dendogram with different sampling time

DISCUSSION

Taxonomic Composition

Coleoptera recorded the highest arthropod individuals due to the presence of fireflies from *Pteroptyx tener* species (Family: Lampyridae) which dominated Berembang. Similar result was recorded by Abdullah *et al*. (2019) showing a large percentage of Coleoptera contributed by the high number of Lampyridae in the firefly riparian sanctuary. Coleoptera is the largest arthropod order and covers almost 40% of species identified in the class Hexapoda. The presence of abundant Coleoptera individuals was not surprising as it can be found almost anywhere in the world due to its adaptable ability to various situation and environment conditions (Triplehorn & Johnson, 2005). Berembang vegetation is the dominant mangrove vegetation along Selangor River which attracts the presence

of many fireflies (Family: Lampyridae). This firefly life commonly associated with Berembang. Kampung Kuantan is a well-known Malaysian eco-tourism spot and is also internationally known for the presence of fireflies on *S. caseolaris* (Kirton *et al*., 2006).

Arthropods Community Diversity

There are several factors that contribute to the low arthropod communities along the Selangor River (Othman *et al*., 2014). Based on GIS analysis of satellite image done by Kirton *et al*. (2006) in Kampung Kuantan, only 23% of the land are covered by forest while a larger portion (46%) constituted of plantations. The use of fertilisers, herbicides and pesticides in the plantation located nearby may flows into Selangor River causing contamination. Pollutants in the river water were shown to negatively influence the firefly population (Hazmi & Syed Sagaff, 2017; Abdullah *et al.*, 2021). The whole arthropods community will not be an exception and be subjected to the same environmental pressure.

Erosion along riverbanks also contributed to water pollution as there were palm trees that were uprooted and fell into the river. The local community also was lack of awareness regarding the river's cleanliness. Habits such as dumping of domestic wastes easily can be found here, thus affects the aquatic organisms and plants that live along the river. According to Wan Juliana *et al*. (2012), most natural vegetation along the riverbank of Selangor River was disturbed, as evident by the lower density of riparian plants, including *S. caseolaris*. This condition is alarming since firefly largely depends on this particular plant. However, Station 17 was located quite far from Kampung Kuantan jetty and the environment is not disturbed by human activities, such as farming, manufacturing and housing, therefore, recorded the highest abundance of arthropods collected. Based on our personal observations, Berembang at Station 17 has lived well without interference from the surroundings and anthropogenic activities.

Temporal Variation of Arthropod Composition

The composition of arthropods obtained at nighttime (4,563 individuals) for the six sampling months was higher than daytime (3,144 individuals). Table 1 shows the number of arthropod individuals according to sampling time. Firefly (Family: Lampyridae) is a nocturnal arthropod that contributes to the high composition of arthropods during nighttime. Their abundance equipped with light emission may have attracted some arthropod predator communities to hunt there. For instance, arthropods from the family Cantharidae were recorded as the second highest individuals at nighttime as compared to daytime. Cantharidae is predator arthropods that feed mainly on small and soft-bodied arthropods (Daly *et al*., 1998).

Based on the Chi-square test carried out, the differences of arthropod diversity among the families between nighttime and daytime sampling were highly significant (χ^2=333.283, df = 1, P<0.05). The results clearly showed that there were differences in arthropod communities along the river. The difference was due to the existence of different arthropod groups on Berembang at different sampling times (day and night). The differences were due to the presence of insects that are active at different times of the day. This study recorded both diurnal and nocturnal insects. Most diurnal insects consist of herbivores, predators, and parasitoids while the firefly and other scavenging insects were mostly active at night. Three other firefly habitats in Peninsular Malaysia such as the Rembau River (Negeri Sembilan), Sepetang River (Perak), and Chukai River (Terengganu) also recorded similar compositions with diurnally and nocturnally active insects found on the display trees of firefly (Abdullah *et al*., 2019).

Community Similarity

Group A and B were highly differentiated by sampling time. Group A consisted of insect families captured at night-time representing nocturnally active insects. Group B can be split into two where Group B1 are dominated by diurnally active family while Group B2 consisted of many generalists that can be captured at both time of the day. Group A was highly characterised by the presence of the phytophagous insect (Pentatomidae, Elateridae, Membracidae, Tettigonidae) and predator insect (Mantidae, Syrphidae, Mantispidae, Tachinidae). The Tettigonidae and Pentatomidae were recorded as phytophagous insect living on mangrove species in Andaman and Nicobar Island (Veenakumari *et al*., 1997).

The predator insect such as Mantidae, Syrphidae may have regulates the population of herbivorous insects living on the *S. caseolaris*, keeping it at a stable range so as not to cause damage to the mangrove vegetation. Hence, while the herbivorous insect guild is known to suck and chew on the leaf, there was no significant damage done on the *S. caseolaris* in Selangor River. The well-being of the *S. caseolaris* in Selangor River is crucial when the firefly population is highly dependent upon this tree species as its display tree in order to find a mating partner. It is important to highlight the low number of Odonata captured in this study.

The Odonata from the family Libellulidae and Coenogranidae live in areas with clean water and are also well known as the biological indicator of water pollution (Kutcher & Bried, 2014). The low number of Odonata recorded in this area might be due to the Selangor River being polluted and contaminated with domestic wastes. Several study in Peninsular Malaysia had reported a reduction in the firefly population due to low water quality (Hazmi & Syed Sagaff, 2017; Abdullah *et al*., 2021). Selangor River has an outstanding reputation as a huge firefly ecotourism site in Malaysia. Therefore, there is a vital need for the monitoring of its water quality from time to time, in making sure the firefly population continues to thrive in its habitat.

According to Figure 3, Group A and Group B are also different due to the presence of arthropods from the family Scarabaeidae (stool beetles) and Carabidae (ground beetles). Both families of Scarabaeidae and Carabidae are nocturnal arthropods. The larvae of Scarabaeidae live by burrowing into the food and feeding at night (Daly *et al*., 1998). Meanwhile, Carabidae is one of the largest beetle families where they live under rocks, leaves, trees, or crawling on the ground. Carabidae also can be found in moist areas and tend to be nocturnal arthropods, yet there are also diurnal Carabidae species (Daly *et al*., 1998). Many Carabidae species hide by day and forage for food at night, but some species are attracted to light (Triplehorn & Johnson, 2005). We postulated that the Carabidae species caught during night sampling might be due to attraction of light emitted by the fireflies, however further studies are required to prove the validity of this postulation.

Arthropods from the family Vespidae were present during the day because they are pollinator arthropods. Adult female Vespidae store pollen and nectar in the nest as food for its larvae (Daly *et al*., 1998). According to Shalini and Choudhury (2001), Berembang flowers bloom during daytime and nighttime. As navigation of pollinating insects also depends on visuals as most of them are attracted to the colour of fruits or flowers, which are easily seen under bright light during the day (Streinzer *et al*., 2009), the red color of Berembang attracts these Vespidae to visit, and therefore become their pollinating agent.

Group B1 differed from Group B2 due to the presence of arthropods from the order Lepidoptera (Figure 4). The moth is a nocturnal pollinator. Lepidoptera contributes to pollen transportation based on pollens found attached to its proboscis, antennae, legs and body (Ikenoue & Kanai, 2010). Flowers pollinated by Lepidoptera bloom in the day or night with a nice scent. Group B2 was also different from Group B1 due to the presence of the family Culicidae. This family consists of mosquitoes. Adult mosquitoes are usually active at dusk and night (Ikenoue & Kanai, 2010). Female mosquitoes (Culicidae) and other small biting flies (Ceratopogonidae, Simuliidae and Phlebotominae) that inhabit mangroves take a blood meal from vertebrate hosts before reproduction (Nagelkerken *et al*., 2008). These results clearly showed that there are differences in arthropod communities along the river and sampling time does affect the presence of different insect families gained from *S. caseolaris* communities.

It is shown in this study that arthropods of various functional groups were found living on the *S. caseolaris* along with the population of fireflies. There is a crucial need to understand the relationship of each group with the firefly population, especially to assist in the determination of appropriate management practices for the firefly mangrove sanctuary. The checklist provided in this study will be the basis for further effort in firefly conservation.

CONCLUSION

A total of 7,707 individual arthropods were collected consisting of Coleoptera, Hymenoptera, Diptera, Neuroptera, Orthoptera, Odonata, Lepidoptera, Blattodea, Mantodea and Araneae. Coleoptera recorded the highest arthropod individuals found at Selangor River due to the presence of fireflies from *P. tener* species that inhabit mangrove areas. For diversity community, statistical analysis showed that there were significant differences in abundance among arthropod families at the total of 19 sampling stations with the highest diversity of arthropods was found in Station 17. Among 10 orders of arthropods that were collected, the firefly (Family: Lampyridae) was the highest arthropod during nighttime. The unique and great arthropod biodiversity found in the Selangor River suggests that the area is supposed to be protected to maintain its biodiversity for future generation.

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