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Role of Ephemeroptera, Plecoptera and Trichoptera (Insecta) functional feeding groups in leaf decomposition in Tropical River

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Key words: Leaf packs, Decompose, Functional feeding groups, EPT, Tropical river, Dipterocarp forest.

Abstract

The riparian vegetation along the riverbanks had an influence on Ephemeroptera, Plecoptera and Trichoptera (EPT) functional feeding groups' composition (FFG). This is because FFG from these three orders play a major role in leaf decomposition. A study of EPT FFG on leaf breakdown was carried out on two types of leaf packs, single leaf species (*Pometia pinnata*) and two leaf species (*Pometia pinnata* and *Dolichandrone spathacea*) in Tupah River, Kedah, Malaysia. In single species leaf pack, the collector-gatherers were most abundant but in two species leaf pack, the collector-filterers were more abundant. Shredders were well represented in the two species leaf pack while predator abundance was higher in the single species leaf pack. On the first 14 days of leaf immersion, the shredders were found to be the most highest in abundance. Meanwhile, high abundance of collector-filterers and collector-gatherers were observed at the later stage of decomposition (14-21 days) in both leaf types. However, higher predator populations were recorded on day 14 until day 28 corresponded to high availability of prey species (collectors) within the leaf packs.

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Introduction

Tropical streams differ from those in temperate region in various aspects including topography, ecology, physical environment such as water temperature regime and riparian canopy (Dudgeon, 2008). Leaf of trees in the tropical forests fall throughout the year (Wantzen and Wagner, 2006), thus stock of leaf litter is always available to stream fauna (Pearson *et al.*, 1989). However, previous studies have shown that breakdown of leaf litter is more rapid in low-order tropical rivers compared to similar order rivers in temperate areas (Dudgeon, 1982; Benstead, 1996) although tropical leaves generally are more recalcitrant and have higher levels of secondary compounds than leaves from temperate deciduous trees (Li and Dudgeon, 2009). Several recent studies on leaf litter processing in tropical streams (Mathuriau and Chauvet, 2002; Parnrong *et al*, 2002; Cheshire *et al.*, 2005; Goncalves *et al.*, 2006; Wantzen and Wagner, 2006; Shieh *et al*, 2007) have provided valuable insight regarding this process in the tropical rivers, however more field studies concerning leaf species preferences by aquatic insects especially among the EPT taxa are desirable. The interaction of river retentiveness and leaf decay can guide the riparian management to recommend more tree plantings to increase river supply of terrestrial organic carbon because in-stream nutrient dynamics are influenced by the litter inputs from riparian vegetation (Quinn *et al.*, 2000).

Aquatic insects from orders Ephemeroptera, Plecoptera and Trichoptera (EPT) play essential role in litter decomposition process (Voshell and Reese, 2002). Previous studies in temperate region have shown biological breakdown of leaf litter occurs through the activities of detritivorous insects (Anderson and Sedell, 1979; Webster and Benfield, 1986). Subsequently, EPT feeding on CPOM leads to significant changes in the organic materials quantitatively and qualitatively as well as production of fine particulate organic matter (FPOM). The FPOM was utilized by various insect groups such as collector-gatherers and collector-filterers (Wallace and Merritt, 1980).

Meanwhile, the leaf shredders of the EPT mainly Plecoptera and Trichoptera in low order streams feed directly on CPOM and their feeding activity is a necessary mechanism in conversion of organic particles from CPOM to FPOM. Different insect groups vary in their effect on removing the FPOM. For instance, filter-feeding aquatic insects were reported to have a slight effect in removing FPOM from the water column in most streams and rivers (Resh and Rosenberg, 1984). For higher efficiency in utilization of particulate substrates in the streams, filter-feeding insects are adapted to consume different materials varying in particle sizes (Wallace and Merritt, 1980).

Specifically, this study was designed to investigate the role of EPT FFG on leaf breakdown. The aims of our study were to quantify the EPT FFG abundance and relate the FFG composition to types of leaf packs in tropical upstream river because we hypothesized that many leaf species would encourage higher EPT immigration.

Materials and method

Description of study area

This study was carried out in a tropical river, Tupah River situated between latitudes 5°45.008’ N and longitudes 100°26.526’E. The river lies within the catchment area of Gunung Jerai Forest Reserve, Kedah, northern peninsular Malaysia. The river located at 200 meter above sea level composes of low land dipterocarp forest such as *Shorea leprosula*, *Shorea ovata*, *Dipterocarpus* sp., *Dillenia* sp., *Pometia pinnata, Pongamia pinnata, Dolichandrone spathacea* and *Sindora* sp. In Tupah River, the substrates are predominantly cobble and gravel (55%) and the other 45% of river sediment is made up of boulder. Mean annual rainfall for the year 2008 in this area was 2301.3 mm. The yearly mean water temperatures ranged from 22.8 to 25.7°C while the water pH ranging from 5.03 to 6.66.

In situ leaf decomposition

Two leaf species, *Pometia pinnata* (Family: Sapindaceae) and *Dolichandrone spathacea* (Family: Bignoniaceae) were used in this study as they are commonly found in the area.

The leaves of these two tree species were made into leaf packs by placing them in wire cages (10 mm mesh) each measuring 15 cm x 10 cm x 5 cm as proposed by Mathuriau and Chauvet (2002). Two types of leaf packs were prepared; single species leaf using *Pometia pinnata* and two species leaf by mixing *Pometia pinnata* and *Dolichandrone spathacea* at a weight ratio of 1:1.

All leaf packs (experimental and control) were placed randomly in the river at suitable locations completely submerged in the water. The mean depth of this river was 0.32 ± 0.045 meter. The cages were secured to the river bottom by fastening each of them to a meter long metal pole erected on the river bank. Based on a preliminary investigation, all leaves decomposed after 6 weeks. The leaves were assumed to decompose completely when the entire leaf fragments were broken to smaller than 20 mm in diameter. Therefore at the beginning of the experiment, 36 cages of experimental were placed randomly in the river. All 36 cages of each leaf pack would be collected within 6 weeks when 3 cages of each single leaf and two leaf species were collected weekly.

Sample collection and laboratory procedures

Six cages of both control and experimental leaf packs (3 cages of single leaf and 3 cages of two leaf species of each pack) were collected weekly. Each experimental cage was placed into a plastic bag containing little amount of river water. In the laboratory, leaf pieces in the cages were removed, rinsed and EPTs found on the leaves were sorted and preserved in a universal bottle containing 75% ETOH for subsequent identification and enumeration. All insects were identified to genera using keys provided by Kenneth and Bill (1993), Morse *et al.* (1994), Wiggins (1996), Dudgeon (1999) and Yule and Yong (2004). Each EPT taxon was further assigned to a functional feeding group as proposed by Cummins and Klug (1979) Merritt and Cummins (1996) and Yule *et al.* (2009) based on their mouthparts and feeding habits. Four tropic functional categories were identified; collector-gatherers, collector-filterers, shredders and predators.

Statistical analysis

Variations of FFG in single species and two species leaf packs were compared using the T-test analysis. All statistical tests were carried out using the SPSS 14.0®. The functional feeding group of EPT immatures was expressed as the proportion ± standard error (SE) of the total immature collected. SEs were calculated according to the binomial theorem, i.e., $SE = (pq/k)^{1/2}$, where p is the proportion of x functional feeding groups, q is the proportion of groups other than x and k is the sample size (Hudson and Ciborowski, 1996).

Results

Twenty three genera of EPT were found colonizing both single species leaf and two species leaf packs. Higher diversity of all EPT orders were observed in two species leaf pack compared to single species leaf pack (Table 1). The proportion of each functional feeding group (FFG) is presented in Fig. 1. In this study, the structures of resident EPT FFG differed between single species and two species leaf packs. Collector-gatherers were dominant in single species (49.1%) but collector–filterers were dominant (42.1%) in two species leaf packs. In single species leaf pack, there were 25.2%, collector-filterers followed by predators (21.4%) and shredders (1.9%). In two species leaf pack, collector–filterers were more dominant, followed by collector-gatherers (25.7%), predators (19%) and shredders (3.2%). The functional feeding groups had a homogenous distribution and their proportions varied over time during the course of the study. Highest percentage of collector-gatherers occurred in the single species leaf packs in November 2015 with 83.6% while in two species leaf, 56.7% of collector-gatherers was recorded in June 2015 (Fig. 2 and 3). More shredders were found in single species leaf pack (13.2%) in June 2015 but for two species leaf pack, 17.4% shredders was recorded in May 2015. Collector–filterers were more dominant in two species leaf pack and it peaked (85.2%) in December 2015 while in single species leaf 41.7% were recorded in August 2015.

Table 1. Total abundance (in percentage) of EPT in single species leaf pack and two species leaf packs in Tupah River.

Order	Family	Genera	Functional Feeding group	*P. pinnata* (%)	*P. pinnata* + *D. spataceae* (%)	*D. spataceae* (%)
Ephemeroptera	Heptageniidae	*Thalerosphyrus*	Collector-gatherers	3.9	1.3	0
	Baetidae	*Baetis*	Collector-gatherers	26.7	13.2	8.6
	Baetidae	*Platybaetis*	Collector-gatherers	1.2	0.5	1.0
	Tricorythidae	*Tricorythus*	Collector-gatherers	3.9	2.1	0
	Caenidae	*Caenis*	Collector-gatherers	8.8	3.6	71.7
	Heptageniidae	*Campsoneuria*	Collector-gatherers	3.9	4.7	0
	Leptophlebiidae	*Habrophlebiodes*	Scrapers	2.2	2.9	1.8
		Choroterpes	Scrapers	0	0	0.6
	Ephemerellidae	*Crinitella*	Collector-gatherers	0	0.3	0
Plecoptera	Nemouridae	*Indonemoura*	Shredders	0.2	0	0
	Perlidae	*Kamimuria*	Predators	1.2	0.3	0
	Perlidae	*Neoperla*	Predators	18.8	17.9	0
	Perlidae	*Phanoperla*	Predators	1.2	0.3	2.4
	Peltoperlidae	*Cryptoperla*	Shredders	0	0.3	0
Trichoptera	Ecnomidae	*Ecnomus*	Collector-filterers	1.5	0.3	0
	Hydropsychidae	*Cheumatopsyche*	Collector-filterers	13	27	0
	Hydropsychidae	*Hydropsyche*	Collector-filterers	10.5	18.4	0
	Hydropsychidae	*Macrostemum*	Collector-filterers	0.2	0.5	0
		Diplectrona	Collector-filterers	0	0	0.6
	Calamoceratidae	*Ganonema*	Shredders	1.5	0.5	0
	Rhyacophilidae	*Rhyacophila*	Predators	0.2	0.5	1.8
	Philopotamidae	*Chimarra .*	Collector-filterers	0	2.9	0
	Lepidostomatidae	*Lepidostoma*	Shredders	0	1.8	0
	Leptoceridae	*Setodes*	Collector-gatherers	0.7	0.3	0
		Oecetis	Predators	0	0	1.2
	Odontoceridae	*Marilia*	Shredders	0.2	0.6	0
	Seriscostomatidae	*Gumaga*	Shredders	0	0	4.8
	Molannidae	*Molanodes*	Collector-gatherers	0	0	5.4

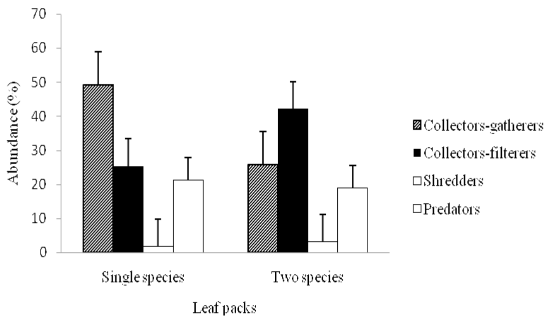

Fig. 1. Percentage of mean abundance of Ephemeroptera, Plecoptera and Trichoptera for each guild between single and two species leaf packs in Tupah River. Vertical bars indicate 1 standard error.

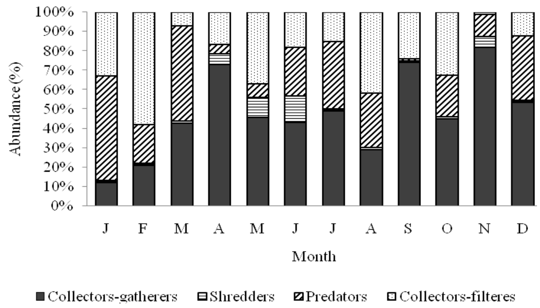

Fig. 2. Compositions of mean abundance of functional feeding groups (FFG) (percentage) during leaf breakdown in single species leaf packs in Tupah River.

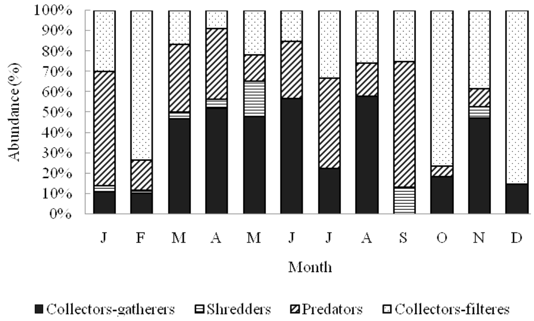

Fig. 3. Compositions of mean abundance of functional feeding groups (FFG) (percentage) during leaf breakdown in two species leaf packs in Tupah River.

Changes in individual numbers of FFG during the course of the study are shown in Fig. 4. In general, the number of shredders (SH) increased in the first 7 days of immersion in the river (1.3 individuals per cage in two species leaf and 1.1 individuals per cage in single species leaf) but the number decreased thereafter in single species leaf pack. No SH was found in two species leaf pack after day 21. There was no significant difference in SH abundance between the single species leaf and two species leaf packs (t=1.58, *P*=0.194).

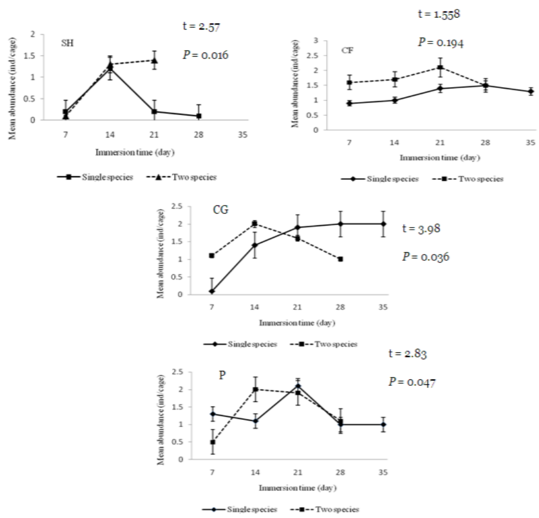

Fig. 4. Mean abundance of FFG colonizing single and two species leaf during their immersion in Tupah River. Vertical lines indicate standard error. SH-shredders, CF-collector-filterers, CG-collector-gatherers and P-predators.

The collector-filterers (CF) colonized the two species leaf pack very rapidly until day 21 (2.1 individuals per cage) but decreased thereafter. However, CF in single species leaf increased in number after day 21 and reached 1.5 individuals per cage on day 28. There was a significant difference in CF abundance between the single species leaf and two species leaf packs (t=2.57, *P*=0.016).

The number of collector-gatherers (CG) reached a maximum on day 14 (2 individuals per cage in two species leaf and 1.4 individuals per cage in single species leaf packs) and then increased thereafter for single species leaf pack. For two species leaf pack, the CG abundance decreased from day 14 until the leaves fully decomposed. There was a significant difference in CG abundance between the single species leaf and two species leaf packs (t=3.98, *P*=0.036).

The number of predators peaked on day 21 for single species leaf (2.5 individuals per cage) but the predators increased in number on day 14 (2.3 individuals per cage) in two species leaf packs. There was a significant difference in predators abundance between the single species leaf and two species leaf packs (t=2.83, *P*=0.047).

Discussion

Among all FFGs, shredders are more important in leaf breakdown (Benfield, 1996, Lopez *et al.*, 1997). In this study, shredder abundance was extremely low in both single species and two species leaf packs. Shredder abundance was found to be lower in the single species leaf packs presumably because of tougher structure of *P. pinnata* leaves compared to *D. spathacea* leaves. Leaf toughness which affects the food quality of CPOM (Mathuriau and Chauvet, 2002), presumably reduce the shredder abundance and thus slower the decomposition rate (Stout, 1989). It has been proven by Friberg and Jacobsen (1994) that leaves with high carbon and low nitrogen contents serve as low quality foods that are less preferred by the shredding macroinvertebrates.

The abundance of shredders in a river is affected by the amount of canopy cover on the water surface. Open rivers have less contribution of allocthonous organic matter that serves as food for most aquatic insects. In this case, Tupah River had very poor canopy hence fewer leaves were available in this river coinciding with lower CPOM stocks and shredders in unshaded (Li and Dudgeon 2009; Touma *et al.*, 2009) than in shaded streams.

Shredder richness is low in several rivers in Malaysia (Sivec and Yule, 2004; Yule *et al.*, 2009). In this study, only five EPT shredder genera were reported compared to more than 10 shredder genera in temperate rivers (Graca, 2001; Merritt *et al.*, 2008). Generally, shredders are fewer or even absent from tropical streams (Goncalves *et al.,* 2006; Mathuriau *et al.*, 2008). In addition, some family such as Pteronarcyidae and Leuctridae (Plecoptera) were not present in Tupah River or in most of areas in northern peninsular Malaysia. In Hong Kong, similar findings was reported as the shredder species richness was low (8 taxa) in 10 streams studied by Li and Dudgeon (2009) and no Pteronarcyidae and Peltoperlidae were recorded. In many tropical streams, patterns of low shredders abundances were also reported by Benstead (1996), Pringle and Ramirez (1998), Rosemond *et al.* (1998) and Dudgeon and Wu (1999).

Despite their low abundance and diversity, shredders play an important role in leaf breakdown in tropical streams (Cheshire *et al.* 2005; Crowl *et al.* 2006). In this study, shredders were dominated by few nemourid, peltoperlid plecopterans with calamoceratid, lepidostomatid and odontocerid trichopterans (Shieh *et al.*, 2007; Yule *et al.,* 2009; Li and Dudgeon, 2009). The ability of shredders to consume a variety of food resources has been demonstrated in numerous studies such as Friberg and Jacobsen, (1994) and Tuchman and King (1993). According to Petersen and Cummins (1974), shredders feeding have attributed 30% of the conversion of CPOM leaf litter to FPOM in Michigan, USA.

This increase of FPOM affects the collectors' growth. Like other shredders, EPT leaf shredders feed directly on CPOM and their feeding activities are important mechanism for conversion of CPOM to FPOM (Dudgeon and Brestchko, 1996). In return, other groups of collector-filterers and collector-gatherers can have their primary food generated by the shredders (Dudgeon and Wu, 1999). Vannote *et al.* (1980) suggested the FPOM generated by shredders were exported as seston to support food webs in downstream ecosystem.

In this study, collector-filterers and collector-gatherers numerically dominated each leaf packs compared to other functional feeding guilds. According to Mathuriau and Chauvet (2002), the collectors use leaf litter as substratum and feed on FPOM. The pattern was similarly observed in previous studies in other tropical streams (Ramirez and Pringle, 2001; Wantzen *et al.,* 2008; Goncalves *et al.*, 2006; Wantzen and Wagner, 2006; Colon-Gaud *et al.*, 2008; Mathuriau *et al.,* 2008). The collectors were probably more important towards the later phase of decomposition when the organic matter have been reduced to FPOM.

At later stage of decomposition, accumulating FPOM in the leaf packs may have attracted other feeding guilds especially collector-gatherer and collector-filterer. Mathuriau and Chauvet (2002) and Shieh *et al.* (2007) suggested that since collectors feed on FPOM, therefore this group may not participate in the leaf breakdown directly but probably contribute to the leaf litter dynamics in streams. The abundance of collector-filterers was recorded highest in the two species leaf pack in this study. The colonization of collector-filterers in the two species leaf packs may be a function of the amount of FPOM present. According to Richardson (1992) and Dudgeon and Wu (1999), collectors use leaf litter as a food source when the organic matter was in the form of FPOM. This was supported by Wantzen and Wagner (2006) and Shieh *et al.* (2007) as they found collectors (collector–filterers and collector–gatherers) feed on the FPOM.

However, collector-gatherers were observed in their highest abundance in single species leaf. The collector-gatherers preferred the single species leaf (*P. pinnata*) probably because they used these leaves as a substratum to trap drifting FPOM (Mathuriau and Chauvet 2002) but not as a food source. Moreover, some ephemeropteran such as *Americabaetis* and trichopteran *Leptonema* used leaf litter in the stream as a temporary (short-live) habitat (Dudgeon and Wu, 1999; Mathuriau and Chauvet, 2002).

Another FFG was the predators. Predators such as plecopterans *Kamimuria*, *Neoperla*, *Phanoperla*, and trichopteran *Rhyacophilia* may have slowed down the leaf breakdown by eating the shredders and collectors (Oberndorfer *et al*., 1984; Malmqvist, 1993; Mathuriau and Chauvet, 2002). The population of predators was high and peaked on day 14 and 21 in two species leaf and single species leaf, respectively. Oberndorfer *et al*. (1984) had proven that fast decomposition rate was obtained not by manipulating shredders but rather by exclusion of predators within the leaf packs.

Conclusion

Collector-gatherers were abundant in single species leaf pack but collector-filterers were more abundant in two species leaf pack. More shredders were found in the two species leaf pack while predator abundance was higher in the single species leaf pack. The shredders were found in high abundance on the first 14 days of leaf immersion. High abundance of collector-filterers and collector-gatherers were observed at the later stage of decomposition (14-21 days) in both leaf types. Meanwhile, higher predator population corresponded to high availability of prey species (collectors) within the leaf packs on day 14 until day 28.

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