A preliminary study of the macroinvertebrate fauna of freshwater habitats in Maludam National Park, Sarawak

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SUMMARY

Macroinvertebrates are diverse and widespread, and they play important ecological roles in aquatic ecosystems; yet little is known about the macroinvertebrate fauna of the peat swamp forests of Borneo. In light of this knowledge gap, we present a preliminary species list of macroinvertebrates in the peat swamp forest of Maludam National Park, Sarawak, Malaysia. Macroinvertebrates were sampled between April 2011 and November 2014 from three stations on the Maludam River, which flows through the National Park. In total, 3,257 individual macroinvertebrates were examined, representing 37 morpho-species from 20 families and eight orders. Of the total number of individuals captured, 51 % were aquatic beetles (Order Coleoptera), 26 % were aquatic bugs (Hemiptera), 10 % were dragonflies (Odonata), 5 % were flies (Diptera) and 4 % were mayflies (Ephemeroptera). Other orders contributed less than 5 % of the total. The dominant species was the whirligig beetle *Dineutus unidentatus* (36 % of all individuals caught) which may, thus, be a stenotopic habitat specialist. Despite the harsh environmental conditions of Maludam, where aquatic habitats are acidic and low in dissolved oxygen, the area was found to be inhabited by a diverse macroinvertebrate fauna which is likely to contribute to maintaining the important ecosystem services that the peat swamp forest provides.

KEY WORDS: aquatic ecosystem, biodiversity, macroinvertebrates, tropical peat swamp forest

INTRODUCTION

Freshwater peat swamp forest is a waterlogged habitat which is characterised by low nutrient availability and highly acidic water with low dissolved oxygen content (UNDP 2006). It is regarded as a unique ecosystem that is home to many rare and endemic species (Posa *et al.* 2011). Whereas the flora and vertebrate fauna of freshwater peatlands in Borneo have been substantially studied, little is known about the diversity and distribution of macroinvertebrates in this unique environment (Yule 2010, Posa *et al.* 2011).

Macroinvertebrates are important components of freshwater peat swamp ecosystems, with roles in predator-prey relationships and as processors of organic materials (Yule & Yong 2004). They are often used to assess stream quality because of their sensitivity to environmental changes (Karr & Chu 1999, Che Salmah *et al.* 2007). Tropical freshwater habitats host numerous endemic macroinvertebrates, of which many taxa remained undescribed (Mattson *et al.* 1999, Jacobsen *et al.* 2008). The macroinvertebrates of Malaysia are still poorly known and few new species have been described in the last few decades, especially from peat swamp habitats (Morse *et al.* 2007). According to Yule (2010), many aquatic invertebrate species that are restricted to freshwater peat swamps are at risk of extinction because these habitats are vanishing rapidly due to drainage, logging and conversion to agriculture.

In light of this importance and vulnerability, plus the limited published information on freshwater peat swamp macroinvertebrates within the Southeast Asia region, we provide here preliminary documentation on the species composition of the macroinvertebrate community found in the protected freshwater peat swamp forest in Maludam National Park (Sarawak, Malaysia). Our data build on previous Odonata surveys conducted in the area by Dow *et al.* (2015). Thus, we aim to enhance knowledge about the faunal diversity of this habitat and help stimulate further in-depth studies of peat swamp macroinvertebrates in the region.

METHODS

Study area

Maludam National Park is located in the Betong Division of Sarawak. It covers an area of 43,147 ha

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and is the largest peat dome in northern Borneo (Whitmore 1990, Melling 2016). The study sites are located along the middle part of the Maludam River (Figure 1), a major river system that drains Maludam National Park. Sampling was conducted at three sites, namely: Station A (01° 34.894′ N, 111° 05.086′ E), Station B (01° 35.799′ N, 111° 04.415′ E) and Station C (01° 37.043′ N, 111° 03.746′ E). The forest surrounding these stations is mixed peat swamp forest, of which some parts have been disturbed by logging in the last few decades. *Pandanus* species frequently dominate the plant communities around streams. The water of the Maludam River is almost stagnant in some sections, and black in appearance due to its high tannin content. The bottom sediments consist mainly of semi-decomposed peat, logs, leaves and branches, and submerged vegetation is common in the shallow parts of stream channels. The general condition and main channel of the Maludam River are shown in Figure 2. Its mean water depth varies from 1.1 m in dry seasons to 6.2 m in wet seasons.

Macroinvertebrate sampling

The sampling programme covered both wet (October–March) and dry (April–September) seasons, and involved 14 sampling visits between April 2011 and November 2014. Macroinvertebrates were collected using a 'kick-net' (frame 40 × 32 cm, mesh size 0.4 mm). To obtain each sample, the net was forced through the vegetation or surface layers of sediment across an area of approximately 1 m^2 for two minutes. Three replicate samples were collected from each of the three sampling stations. Sampling points included the banks of the main channel and its tributaries, particularly shallows. Floodplains near the riverbank were also sampled, but sampling did not extend into the forest. Habitat types at the three sampling stations were quite similar and included extensive strips of *Pandanus* in some sections along waterways together with nearby forest trees. Samples were also taken from the roots of floating vegetation. Large debris entering the net, such as leaves and branches, was rinsed to dislodge macroinvertebrates.

Net contents were placed in a white tray (for easy visibility) to sort the macroinvertebrates from the debris. The samples were then preserved in plastic bottles containing 85 % ethanol, labelled and brought back to the Ecology and Systematics Laboratory at Universiti Malaysia Sarawak for final sorting and identification. In the laboratory, macroinvertebrates were sorted according to their morphological characteristics and identified under a binocular

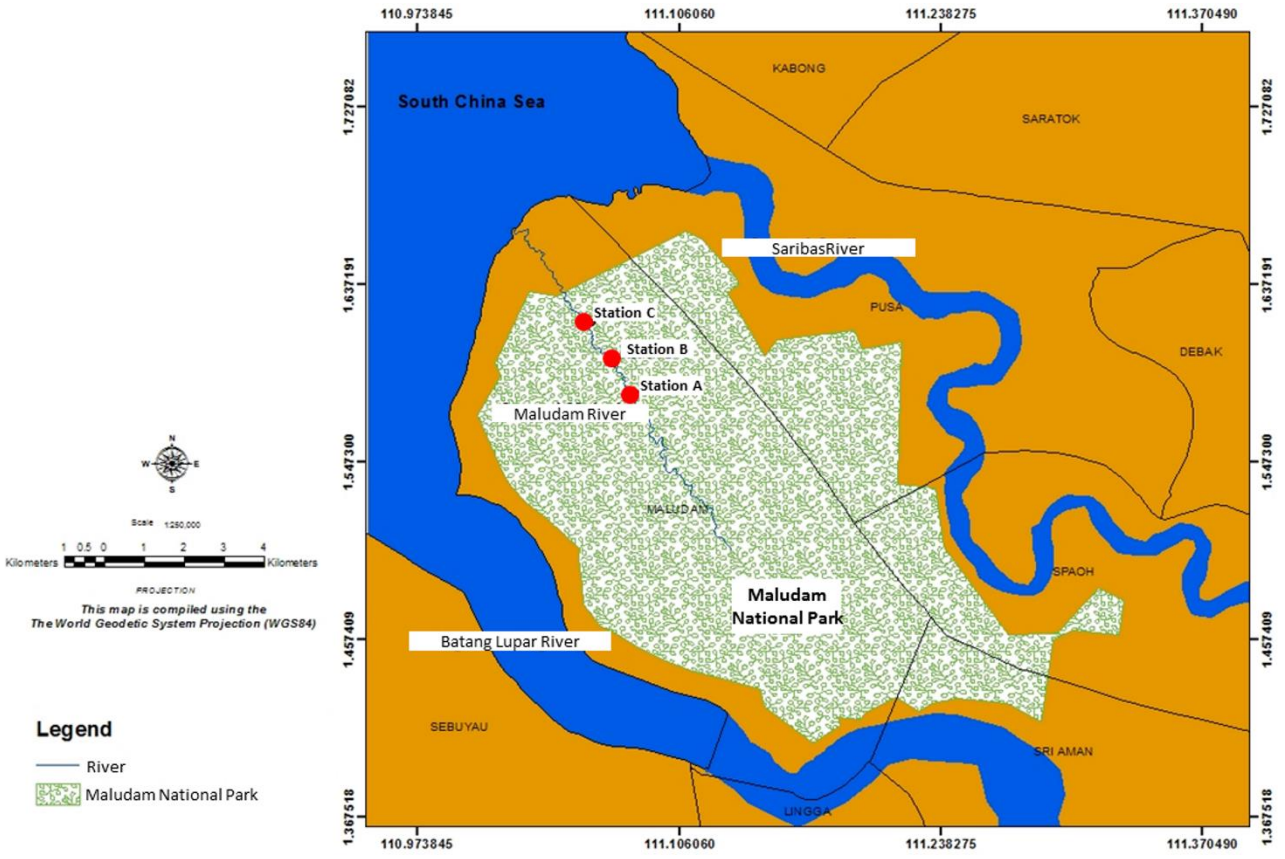

Figure 1. Locations of the three sampling stations in Maludam National Park, Sarawak, Malaysia.

Figure 2. General condition of the freshwater habitats sampled in Maludam National Park during the wet season (above); and the main channel of the Maludam River, dominated by *Pandanus* spp. (below).

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microscope. Identification was completed to the lowest possible taxonomic level following appropriate keys (Yule & Yong 2004, Duc *et al.* 2015), using morpho-species when species-level identifications could not be achieved. Some of the odonate nymphs were identified by reference to drawings by Orr (2003) followed by confirmation using the species lists of Dow *et al.* (2015), as well as by observation of the adults at the sampling stations.

In order to compare macroinvertebrate abundance across seasons, a paired sample t-test was computed using IBM SPSS Statistics 23; while Zar's (1996) method for testing significant differences between diversity indices was adopted to test for differences in Shannon diversity index (H′) between seasons. For these analyses, data from sites within each sampling station were pooled together, since the habitat types of the sampling locations within each station were similar.

RESULTS

More than 50 % of the macroinvertebrates captured were aquatic beetles (Order Coleoptera) from the families Gyrinidae, Dytiscidae and Hydrophilidae (Figure 3). Aquatic bugs (Hemiptera) represented 26 % of captures, representing the families Belostomatidae, Gerridae, Helotrephidae, Hydrometridae, Nepidae and Notonectidae. Ten percent of the macroinvertebrate specimens were dragon/damselflies (Odonata) from five families, namely: Coenagrionidae, Aeshnidae, Macromiidae, Gomphidae and Libellulidae. Flies (Diptera), mayflies (Ephemeroptera), shrimps (Decapoda), aquatic cockroaches (Blattodea) and aquatic moths (Lepidoptera) were less commonly found.

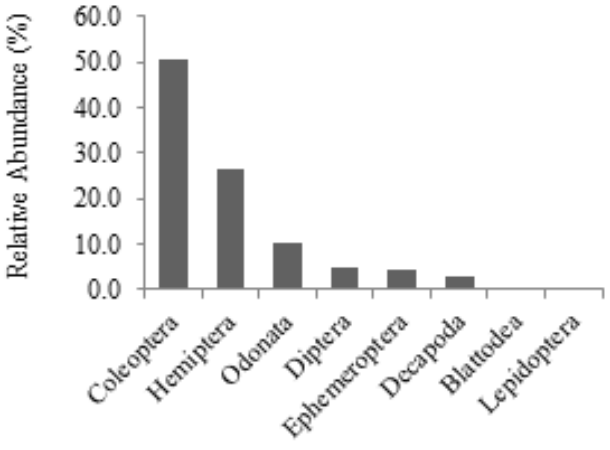

Figure 3. Relative abundance of macroinvertebrate orders recorded in Maludam National Park.

In total 3,257 individual macroinvertebrates were collected. These specimens represented 37 species from 20 families and eight orders. The most abundant species was *Dineutus unidentatus* from the beetle family Gyrinidae, which comprised 36.3 % of the total number of individuals recorded (Table 1). Some specimens could be identified to family level only, including Blaberidae, Gerridae, Helotrephidae, Aeshnidae and Coenagrionidae (Table 1).

Paired sample t-tests inidicated that macroinvertebrate abundance was significantly higher during the dry season ($t = 2.746$, $p = 0.011$), and Shannon diversity index in the dry season ($H' = 2.440$) was significantly higher than during the wet season ($H' = 2.189$) ($t = 10.955$, $p < 0.001$).

DISCUSSION

Although preliminary, our survey provides the most extensive published data available on macroinvertebrate taxa from the freshwater peat swamp habitat in Maludam National Park. We found that aquatic beetles represented half of the macroinvertebrate samples caught. The high abundance of the family Gyrinidae, represented by the species we identified as *Dineutus unidentatus*, could be related to this family's efficient morphological adaptations to slow-flowing water (Ward 1992) and mechanisms to avoid predators through aggregation (Vulinec & Miller 1989). These insects were usually found gyrating and whirling on the water surface near *Pandanus* trees, semi-submerged branches and the riverbank. The dominance of this species in the freshwater habitats of the Maludam River might suggest that it is a stenotopic habitat specialist.

The families of aquatic bugs present in our sample possess morphological adaptations for swimming (Belostomatidae, Helotrephidae, Nepidae and Notonectidae) on the one hand, and skating over the water surface (Gerridae and Hydrometridae) on the other, resulting in habitat partitioning amongst these taxa. The slow water flow, especially at some parts of the riverbank where the water is almost stagnant, might contribute to maximising the area occupied by aquatic bugs, thus facilitating their high relative abundance.

Odonata was the most speciose macroinvertebrate order recorded during our surveys, represented by 16 species. The first Odonata surveys in Maludam National Park, conducted in July 2012 by Dow *et al.* (2015), documented 48 species from nine families, of which only five families were recorded during the study described here. Our surveys added four species

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Table 1. List of macroinvertebrate species captured from freshwater habitats in Maludam National Park.

Order	Family	Genus/Species	Number of individuals	% of total captures
Blattodea	Blaberidae	Unidentified	19	0.6
Coleoptera	Dytiscidae	*Cybister* sp.	23	0.7
	Gyrinidae	*Dineutus unidentatus* Aubė, 1838	1182	36.0
		Orectochilus sp.	442	14.0
	Hydrophilidae	*Berosus* sp.	3	0.1
Decapoda	Palaemonidae	*Macrobrachium neglectum* (De Man, 1905)	35	1.1
		Macrobrachium scabriculum (Heller, 1862)	63	1.9
Diptera	Chironomidae	*Chironomus* sp.	138	4.2
	Culicidae	*Culex* sp.	15	0.5
Ephemeroptera	Baetidae	*Baetis* sp.	137	4.2
Hemiptera	Belostomatidae	*Diplonychus rusticus* (Fabricius, 1871)	37	1.1
	Gerridae	Unidentified	22	0.7
		Limnogonus sp.	23	0.7
		Limnometra octopunctata Hungerford, 1955	365	11.0
		Naboandelus sp.	87	2.7
	Helotrephidae	Unidentified	17	0.5
	Hydrometridae	*Hydrometra* sp.	19	0.6
	Nepidae	*Cercotmetus asiaticus* Amyot & Serville, 1843	20	0.6
		Ranatra longipes Stål, 1861	220	6.8
	Notonectidae	*Nychia* sp.	50	1.5
Lepidoptera	Pyralidae	*Eoophyla* sp.	13	0.4
Odonata	Coenagrionidae	*Amphicnemis* sp.	36	1.1
		Pseudagrion sp.	59	1.8
		Unidentified	14	0.4
	Aeshnidae	*Anax guttatus* Burmeister, 1839	1	< 0.1
		Unidentified I	2	0.1
		Unidentified II	9	0.3
	Macromiidae	*Macromia* sp.	1	< 0.1
	Gomphidae	*Ictinogomphus* sp.	26	0.8
	Libellulidae	*Brachygonia oculata* Brauer, 1878	41	1.3
		Hydrobasileus croceus Brauer, 1867	1	< 0.1
		Nannophya pygmaea Rambur, 1842	19	0.6
		Neurothemis ramburii (Brauer, 1866)	8	0.2
		Orthetrum sabina Drury, 1773	16	0.5
		Rhyothemis phyllis (Sulzer, 1776)	10	0.3
		Tyriobapta laidlawi Ris, 1919	28	0.9
		Urothemis signata (Selys, 1872)	56	1.7
		Total number of individuals	3,257	100
		Total number of (morpho-)species	37	
		Total number of families	20	
		Total number of orders	8	

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(i.e. *Anax guttatus, Hydrobasileus croceus, Neurothemis ramburii* and *Rhyothemis phyllis*) to the odonates list for Maludam. The absence from our samples of odonate larvae belonging to the families Argiolestidae, Chlorocyphidae, Platycnemididae and Corduliidae may be due to the sampling areas used, which were confined to the riverbank and the nearby floodplain, and did not extend far back into the forest. For instance, *Podolestes* larvae (family Argiolestidae) were absent from our samples even though the adults were found to be quite widespread by Dow *et al.* (2015). This may be partly due to their specialised microhabitat, which could be confined to many small but highly specific sites that we did not sample. For example, *P. orientalis* has been found to inhabit shallow pool edges among fallen submerged or semi-submerged leaves and sticks (Choong & Orr 2010).

Diptera (true flies) were represented in small percentages by two families, namely Culicidae (mosquitoes) and Chironomidae (non-biting midges). Although chironomid larvae are often the most abundant and diverse group in the benthic macroinvertebrate fauna (Yule & Yong 2004, Sundermann *et al.* 2007), we were able to identify only one morpho-species (*Chironomus* sp.) among our Chironomidae captures. It is likely that (many) more species of this family are actually present in the area. In addition to identification difficulties, this might also be due to our use of the kick-net sampling technique, which did not sample benthic macro-invertebrates effectively even though we did sample the bottoms of shallow areas. Welsiana *et al.* (2012) reported that Chironomidae were diverse in the peat swamp habitats of the Sebangau River in Central Kalimantan, where samples were obtained using an Ekman grab sampler.

Ephemeropteran (mayfly) nymphs are primarily aquatic, whereas the adults live in terrestrial habitats (Ward 1992). In this study, Ephemeroptera were represented by the family Baetidae, which may feed on fine organic materials suspended in slow-flowing water. Baetid nymphs are present in almost all freshwater habitats and are known to be quite abundant in running water (Yule & Yong 2004). However, many are also tolerant of slow-flowing or stagnant habitats, perhaps on account of their feeding behaviour and niche preferences (Sartori & Brittain 2015). In the Maludam River, baetid nymphs were mostly collected from submerged plant roots and debris. It is interesting to note that only baetid mayfly nymphs were collected. This could be due to the harsh environmental conditions (acidic with low dissolved oxygen) encountered in natural peat swamp forest.

In conclusion, this preliminary study presents new information about the presence and relative abundance of aquatic macroinvertebrate species in the peat swamp forest of Maludam National Park, Sarawak. In interpreting this information, it is important to note that the identification of some taxa remains unconfirmed and that not all habitats were sampled. For instance, the most intact habitats in the headwaters of the Maludam River were not sampled, as these were not accessible during periods with low water levels. Therefore, future surveys covering a wider variety of habitats and incorporating more complete species identifications are likely to increase the number of species recorded in the National Park. In addition, since the net that we used for sampling was less than totally effective in collecting samples from between root masses and amongst *Pandanus* trees, for future surveys we recommend the use of nets with a range of frame sizes, together with grab samplers, to maximise the capture of benthic macroinvertebrates such as chironomids. Despite the harsh environmental conditions at Maludam, our surveys suggest that this area is inhabited by a diverse freshwater macroinvertebrate fauna, which is likely to contribute to maintaining the important ecosystems services that peat swamp forest provides.

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