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Freshwater Fish Diversity and Composition in Batang Kerang Floodplain, Balai Ringin, Sarawak

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ABSTRACT

The diversity and composition of fish communities in brown and black water habitats at Batang Kerang in Balai Ringin, Sarawak, were evaluated during high and low water seasons. A total of 234 individual fish representing 36 species belonging to 13 families were captured. The fish communities in both the habitats were apparently from 32 species belonging to 12 families in brown water, and only 12 species from 7 families in the black water habitats. The fish fauna in the brown water was dominated by the Cyprinidae (63.8%) family, while the Helostomatidae (59.8%) family dominated the black water habitat. Various water parameters, such as dissolved oxygen, pH values, conductivity and water transparency, total suspended solid (TSS) and ammonium-nitrogen concentrations were significantly different ($p<0.05$) between the black and brown water habitats. The brown water habitat supports more diverse and abundant populations of freshwater fishes than the black water habitat. However, introduced species such as *H. temmincki* and the increase of commercial fishing may also have affected the population of native fish.

Keywords: Black water, brown water, floodplains, *Helostoma temminckii*, fish diversity

INTRODUCTION

Studies of spatial and temporal patterns of diversity, distribution and species composition of freshwater fishes are useful to examine factors influencing the structure of the fish community (Belliard *et al.*, 1997; Galactosa *et al.*, 2004). The distribution and composition of the fish species in each habitat were closely associated with various factors such as the availability of food, breeding sites, water current, depth, topography and physicochemical properties of water (Harris, 1995). There have been a number of studies, conducted within the floodplain of Amazon River, examining the distribution patterns of fish in the white water and black water, poor and rich nutrient (Henderson and Crampton, 1997; Saint-Paul *et al.*, 2000; Hoeinghausa *et al.*, 2003; Cetra and Petrere, 2006). The icthyofauna survey in Amazon has shown that floodplains, including black and white water habitats, support diverse and abundant populations of freshwater fishes. However, there has been limited information documented on the ichthyofauna of the floodplain and freshwater swamp forest in Malaysia (Zakaria *et al.*, 1999).

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The importance of fish fauna in a particular habitat such as in black water and swampy habitats in Peninsular Malaysia and Borneo has been outlined in several publications (Johnson, 1967; 1968; Mizuno and Furtado, 1982; Davies and Abdullah, 1989; Ng, 1994; Ng *et al.*, 1994; Murtedza *et al.*, 2000; Beamish *et al.*, 2003; Khairul and Yuzine, 2006; Nyanti *et al.*, 2006). The documentation of blackwater fish in Malaysia probably varies from that of the Amazonian rivers (Henderson and Crampton, 1997; Putz, 1997; Francisco *et al.*, 1998; Saint-Paul *et al.*, 2000; Hoeinghausa *et al.*, 2003). Johnson (1968) described that blackwater swamps in Malaysia are generally low in biodiversity and productivity. However, Saint-Paul *et al.* (2000) found that black water fish communities are more diverse in blackwater than white water in the Central Amazonian river.

Batang Kerang floodplain, which is located in Balai Ringin, Sarawak, can be classified on the basis of its water quality into two different types, namely brown water river and black water river. The difference, between the brown water of Batang Kerang and its tributaries i.e. black water is apparent, where the two rivers meet (*Fig. 1*).

Despite of many studies on the ecological characteristics of fish assemblages and species composition in Borneo are available (Watson and Balon, 1984; Roberts, 1989; Abdullah, 1990; Inger and Chin, 1990; Kottelat *et al.*, 1993; Kottelate and Lim, 1995; Nyanti, 1995; Leh, 2000; Khairul Adha *et al.,* 2001; Nyanti *et al.*, 2006), comparative data on the different habitats such as black and brown water floodplain forests within a localized area are still lacking. Flooded forests and floating vegetations of Batang Kerang floodplain are important habitats for fishes. However, the composition of species, as well as the distribution and abundance of fish in these habitats are poorly known. Thus, the aim of the current research was to study the community structure and composition of fish from the brown and black water habitats at the rivers of Batang Kerang floodplain.

MATERIALS AND METHODS

Study Site

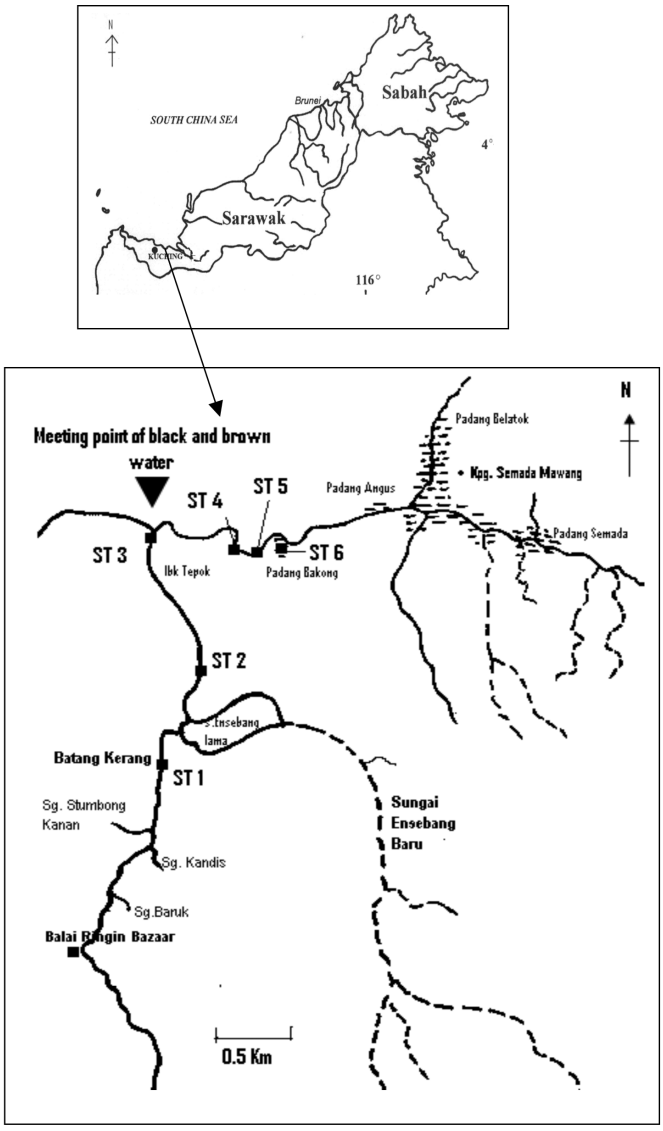
Fishes were sampled from black and brown water habitats in Batang Kerang floodplain (N 01° 14' 00", E 110°41'00") of Balai Ringin, Serian, Sarawak, during high and low water seasons from September 15–18, 2004 and January 27–30, 2005 (*Fig. 1*), respectively. The lower Batang Kerang transverses through a flood plain of largely undisturbed riverine mixed-dipterocarp, swamp forest and marshland. Brown water river is muddy due to its high sediment contents. The mean width and depth of brown water river during sampling were 15.8±1.30 m and 4.2±0.46 m, respectively, with flowing waters at 0.19±0.02 m/s. Some areas of the brown water are characterized with extensive mats of floating vegetation, such as *Hanguana malayana* and *Eichhornia crassipes,* and other submerged aquatic plants. Water draining out of the black water habitat is generally acidic with low pH, inorganic ion and dissolved oxygen level. Black water river has high concentration of humid acids which give the characteristics of dark appearance of the water. Slow flowing water was observed in the black water habitat (0.02±0.01 ms^{-1}) with the mean width of 2.2±0.14 m and depth of 1.4±0.15 m. High and low water level seasons are well defined in this river system. Within the floodplain area, floodplain forests may be inundated from three to eleven months a year.

Sampling

Fish fauna at Batang Kerang floodplain were sampled using monofilament gill nets with different mesh sizes (2.0, 2.5, 3.75, and 5.0 cm) at three stations in brown and black water areas, during low and high water seasons (*Fig. 1*). The gill nets were placed at a suitable depth at the selected stations, and left overnight. Samples were also obtained using a traditional fishing method locally know as 'Selambau'.

Physico-chemical Water Parameters

Water temperature (°C), pH and dissolved oxygen (DO) were measured *in situ* using Hydrolab Water Quality Multiprobe (SVR3, Austin, Texas, U.S.A). Water transparency (Secchi disk), depth and wide of both habitats were measured at the same site. Total suspended solid (TSS) concentrations were estimated using the standard method APHA (1998). The total ammonium-nitrogen concentration was determined using the standard method 8038, based on Nesseler Methods (Hach, 2000) and nitrate was analyzed using the standard methods 8192 based on cadmium reduction method (Hach, 2000).



(ST1, ST2, ST3: Brown water; ST4, ST5, ST6: Black water)

Fig. 1: Maps showing sampling stations at brown water and black water habitats in Batang Kerang floodplains, located in Balai Ringin, Sarawak

Data Analyses

Fish diversity (H') was measured using the Shannon-Weaver (1963) indices. The evenness was determined using the index described by Pielou (1969). Species richness was calculated following Margalef (1958), and modified t-test (Zar, 1996) was used to test for the differences in the fish diversity between the two habitats. Sørensen's index (CC) (Sørensen, 1948) was used to compare the species compositions between the brown and black water habitats. This index considers the number of species common to two sites, and the computed similarity can be between 0% and 100%. The t-test was used to compare the differences in the physicochemical water parameters between the black and brown water habitats.

RESULTS

Physico-chemical Water Parameters

The physico-chemical water parameters for the rivers surveyed are summarized in Table 1. In general, dissolved oxygen, pH, conductivity and water transparency, TSS and total ammonium-nitrogen concentrations were found to be significantly different ($p<0.05$) between the black and brown water habitats. The brown water habitat had higher dissolved oxygen concentrations, pH, conductivity and rich in TSS than those in the black water habitat. However, water transparency and ammonium nitrogen concentration in brown water were significantly lower ($p<0.05$) than those in the black water habitat. Nevertheless, there were no significant differences ($p>0.05$) in terms of water temperature and nitrate concentration between the two habitats.

TABLE 1
Physicochemical water characteristics of black and brown water habitats at Batang Kerang floodplain, Balai Ringin, Serian, Sarawak (Mean ± SD)

Parameters	Brown water	Black water	Significant
pH	5.45 ± 0.10	4.55 ± 0.10	*
Temperature (°C)	25.60 ± 0.60	26.65 ± 0.40	ns
Dissolved oxygen (mg l^{-1})	1.66 ± 0.10	1.15 ± 0.10	*
Secchi transparency (cm)	63.20 ± 4.70	126.30 ± 17	*
TSS (mg/l)	2.20 ± 0.13	0.85 ± 0.20	*
Nitrate (mg/l)	0.05 ± 0.00	0.05 ± 0.01	ns
Conductivity (µS cm^{-1})	31.00 ± 2.30	21.44 ± 0.50	*
Ammonia-nitrogen (mg/l)	0.46 ± 0.10	0.81 ± 0.12	*

Notes: (*) Significant different, (ns) No significant different, n = 18, df =17; (P< 0.05)

Fish Composition

Fish species were identified following Mohsin and Ambak (1983), Robert (1989), Inger and Chin (1990), Kottelat *et al.* (1993) and Kottelat and Lim (1995). In this study, a total of 234 individual fish from 36 species and 13 families were collected from Batang Kerang (Table 2). Black and brown water habitats in Batang Kerang showed different fish species compositions. A total of 152 individual fish from 32 species were caught in brown water, out of which 25 were exclusively found in this habitat. The fish fauna in the brown water habitat were dominated by the Cyprinidae family representing about 63.8% of the total fish caught. *Oxygaster anomalura,* with the mean weight of 24.03±1.63 gm and the standard length of 13.73±0.27 cm, was abundant and presented 25.7% of the fish collection, followed by *Cyclocheilichthys apogon* and *Osteochilus* spp. with 15.8% and 9.9% of fish collection, respectively.

In the black water habitat, 82 individual fish from 12 species were caught. The most abundant black water fish was the *Helostoma temminckii* (Helostomatidae) which represented 59.8% of the total fish caught. This species, with the mean standard length of 13.28±0.44 cm, was found in all stations. *Trichogaster pectoralis, Clarias batrachus, Clarias macrocephalus, Clarias nieuhofi,* and *Rasbora pauciperforata* were found only in the blackwater habitat. Meanwhile, seven species from seven families were found in both habitats. These include *Anabas testudineus, Channa lucius, Clarias teijsmanni, Hemibagrus nemurus, Helostoma temminckii, Oxygaster anomalura*, and *Trichogaster trichopterus.* It is important to highlight that *Helostoma temminckii* and *Oxygaster anomalura* were the most abundant species caught in both habitats. However, about 94.2% of *Helostoma temminckkii* were found in blackwater and 97.5% of *Oxygaster anomalura* in brown water habitats.

The number of individuals and species composition were significantly higher during

TABLE 2
Fish species collected from the black and brown water habitats at Batang Kerang floodplain of Balai Ringin, Serian, Sarawak

Family	Species	Brown	Black
Anabantidae			
	Anabas testudineus	4	7
Bagridae			
	Leiocassis micropogon	4	0
	Hemibagrus baramensis	7	0
	Mystus micracanthus	5	0
	Hemibagrus nemurus	1	1
Belontidae			
	Trichogaster pectoralis	1	5
	Trichogaster trichopterus	1	3
Channidae			
	Channa lucius	2	1
Clariidae			
	Clarias batrachus	0	3
	Clarias macrocephalus	0	1
	Clarias nieuhofi	0	1
	Clarias teijsmanni	4	8
Cobitidae			
	Pangio semicincta	3	0
Cyprinidae			
	Cyclocheilichthys apogon	24	0
	Hampala macrolepidota	4	0
	Osteochilus enneaporos	1	0
	Osteochilus hasseltii	12	0
	Osteochilus kahajanensis	2	0
	Oxygaster anomalura	39	1
	Puntius kuchingensis.	3	0
	Puntius orphoides	4	0
	Puntius lineatus	1	0
	Rasbora caudimaculata	7	0
	Rasbora pauciperforata	0	2
Eleotrididae			
	Bostrychus sinensis	3	0
	Oxyeleotris marmorata	2	0
	Eleotris acanthopomus	1	0
	Prinobutis dasyrhynchus	1	0
Helostomatidae			
	Helostoma temminckii	2	49
Luciocephalidae			
	Luciocephalus pulcher	1	0
Pangasiidae			
	Pangasius sp.	1	0
Siluridae			
	Krytopterus macrochephalus	1	0
	Krytopterus schilbeides	2	0
	Ompok leiacanthus	2	0
	Silurichthys hasseltii	3	0
	Silurichthys phaiosoma	2	0
Tetraodontidae			
	Carinotetraodon salivator	2	0
Total (N)		152	82

the low water level than the high water level (Chi-square, $p< 0.05$). In brown water habitat, only 37 individual fish of 14 species were found during high water level. However, about 115 individual fishes from 24 species were sampled during low water level. In particular, *Carinotetraodon salivator, Hemibagrus nemurus, Puntius lineatus, Bostrychus sinensis, Eleotris acanthopomus, Krytopterus macrocephalus, K. schilbeides and Ompok leiacanthus* were mostly caught during high water level. During low water level, fish species such as *Pangasius* sp., *Anabas testudineus, Mystus baramensis, M. micracanthus, Trichogaster pectoralis, Channa lucius, Clarias teijsmanni, Pangio semicincta, Puntius lineatus, Puntius orphoides, Osteochilus enneaporos, Osteochilus kahajanensis, Rasbora caudimaculata* and *Oxyeleotris marmorata* were collected.

From the black water area, only 10 individual fish belonging to seven species and 72 individual fish from eight species were caught during high and low water seasons, respectively. Fish species such as *Clarias batrachus, C. macrocephalus, C. nieuhofi, and Oxygaster anomalura* were caught during high water level, whilst *Hemibagrus nemurus, Trichogaster pectoralis, T. trichopterus, Channa lucius, and Clarias teijsmanni* were caught during low water level. However, *H. temminckii* was the most abundant during the low water season.

Fish Species Diversity

The fish diversity indices of Batang Kerang floodplain is shown in Table 3. The ecological indices for the two habitats showed that brown water had a significantly higher ($p<0.05$) species diversity, evenness and richness, and the number of individual caught than those in blackwater (t-test). Meanwhile, the diversity indices for brown water were 2.09, and this was 0.65 for the black water. The evenness indices for the two habitats were also different; the indices of 0.60 and 0.26 were detected for brown and black waters, respectively. The richness of the fish species was also higher in the brown water than in the black water habitat. The Sørensen coefficient of community similarity between the brown and black water habitats was 31.8%, in which only 7 species were found in both habitats.

DISCUSSION

The brown water habitat in Batang Kerang floodplains has more species than the adjacent black water habitat, which was 32 and 12 species, respectively. The fish fauna in the brown water habitat were dominated by the Cyprinidae family (63.8%). Robert (1989) stated that about one-third of all the freshwater fishes in Western Borneo were represented by cyprinids. Nyanti (1995) and Leh (2000) reported that approximately 66% and 46% of the fish collections in Sarawak were from the Cyprinidae family.

The unequal fish species composition and distribution in Batang Kerang floodplains could be attributed to many factors. Brown water habitat are characterized by overgrown floating vegetation such as *Eichhornia crassipes* and fringed with tall grasses. The floating meadows are known as the nursery grounds for young fishes which use the submerged roots as refuge from predation and foraging substrate (Putz, 1997). This characteristic could probably create suitable niches for a variety of fish species, and subsequently higher fish abundance and species richness found in that habitat. Brown water has also facilitated wider and deeper habitat than the black water habitat. Zakaria *et al.* (1999) stated that river with wider, deeper and longer channel should be rich in fishes. The presence of macrophytes and larger habitats provide more heterogeneous living spaces, which could support

TABLE 3
The fish diversities of the black and brown water habitats in Batang Kerang, Balai Ringin, Serian, Sarawak

Habitats	s	N	H'	J'	D"
Brown water	32	152	2.09	0.60	14.21
Black water	12	82	0.65	0.26	9.09

Notes: s = number of species, N = number of individuals, H'= species diversity, J'= Pielou eveness index, D"= species richness

a large number of fish species through habitat segregation (Lemly and Dimmick, 1982).

The black water habitats were dominated by *Helostoma temminckii*. This species generally prefers stagnant to slow moving water. This species was abundant and dominant in Baram areas, including Bakong black water river and Logan Bunut, based on the number of individual fish caught (Murtedza *et al.*, 2000; Nyanti *et al.*, 2006). Predator fish such as *Hemibagrus nemurus, Mystus baramensis, Mystus micracanthus, Channa lucius, Clarias batrachus, Clarias teijsmanni, Clarias nieuhofi, Clarias macrocephalus* and *Oxyeleotris marmorata* were commonly found in this habitat.

Most of the specimens caught are native to Borneo and only three fish species (*Clarias macrocephalus, Trichogaster pectoralis* and *Helostoma temminckii*) have been identified as introduced in this river. Local inhabitants reported that the population of *H. temminckii* were abundant during low water level. For instance, *Helostoma temminckii*, which is also known as kissing gouramy, was introduced into Sarawak in 1956 for aquaculture and it was believed that this species escaped from the ponds into the surrounding streams during heavy floods in the Baram area in 1963 (Hans and Morshidi, 2000). Since 1963, the population of *Helostoma temminckii* has increased dramatically and invaded many lakes and rivers of the lower Baram (Hans and Morshidi, 2000; Murtedza *et al.*, 2000). The establishment of non-indigenous species has substantially changed the community structure in some areas, and in some cases, the numbers of introduced fish are greater than the native (Sublette *et al.*, 1990; Vitousek *et al.*, 1996; 1997). The increasing number of the introduced fish (such as *Helostoma temminckii* population) may threaten the biodiversity of indigenous fishes in the areas. However, the effects of the introduced fishes in Batang Kerang floodplain are less understood. Therefore, further studies to examine the degree of habitat-use overlap between native and non-native species in this area must be obtained.

The aquatic system at Batang Kerang floodplains varied considerably between the black and brown habitats. The blackwater habitat of Batang Kerang is a typical Malaysian black water habitat with low pH, dissolved oxygen and conductivity, poor in suspended and dissolved solids, high dark transparent water and low fertility (Ng, 1994; Ng *et al.*, 1994; Murtedza *et al.*, 2000; Beamish *et al.*, 2003; Khairul and Yuzine, 2006). The low TSS reading of 0.85 mg/l and high water transparency suggest that the black water habitat is still in pristine environment. The oxygen concentration level in the brown water was found to be higher than the black water habitats, and this was probably because of the turbulent mixing of the water. The brown water is also rich in TSS reading (2.20mg/l) which may be reflected by the lower light penetration and a high nutrient content, where more aquatic macrophytes plants are found. However, spatial and temporal variations of the water quality, during high and low water seasons, and the correlation with fish species compositions and abundance were not well addressed in this study.

Fish species in the blackwater habitat of Batang Kerang showed adaptation to water with low dissolved oxygen levels and high acidic water including those with accesory respiratory organs and suprabranchial cavities. They were from the families of Anabantidae, Belontiidae, Bagridae, Channidae, Helastomatidae, and Siluridae. The patterns of species composition and abundance indicated that the availability of dissolved oxygen and pH value are the important factors in determining the presence of fish. According to Beamish *et al.* (2003), the abiotic conditions within the swamp, particularly the low pH and dissolved oxygen concentrations, are the indicators of a generally unfavourable environment for fish. The same phenomenon was observed for the fish composition found in Bakong black water rivers, Samarahan peat swamp habitat and Logan Bunut National Park in Sarawak (Murtedza *et al.*, 2000; Khairul and Yuzine, 2006; Nyanti *et al.,* 2006).

Seasonal fluctuations of water level in Batang Kerang floodplains have influenced the fish composition. The greater number of individual fish caught and species composition were observed during the low water season. Different fish communities found during high and low water seasons may be associated with variations in the migratory movements of the fish species (Renato *et al.,* 2000). High water levels increase the size of the aquatic environment and some fish species have migrated from the floodplains to the upper reaches of the river for breeding or expanding their food and habitat resources, then migrated back to downstream after spawning as the water recedes (Lowe-McConnel, 1975; 1987; Welcomme, 1979). Floodwater recession reduces the availability of aquatic habitats and thus,

increases fish densities and biotic interactions (Winemiller, 1989; Rodr'iguez and Lewis, 1994; 1997). This may explain the quantity of fish captured was always lower during raising water than during receding water seasons.

Most of the popular aquarium fishes are from peat swamp forest. Ng *et al.* (1994) noted that 27 species of black water fish have been recognized as the potential valued species for the aquarium industry. Fish species from genera *Rasbora*, *Puntius*, *Trichogaster* and *Sphaeritchys osphromenoides* have been traded as ornamental fish (Khairul and Yuzine, 2006). Pikehead, *Luciocephalus pulcher, Pangio semicincta* and *Carinotetraodon salivator* are known to be popular fish for aquarium found at the study sites. Presently, the market demand for ornamental fish has increased drastically, but the catch from the wild stock is still insufficient. It is important to highlight that sustainable utilization of the fish resources in the black water of Batang Kerang for the aquarium trade may contribute to the economy of the country.

In general, species diversity was considerably higher in brown water than that of black water habitats. Comparing the two sampling sites, the number of species in brown water was found to be 55.6% higher than that of the black water with 31% similarity. The differences in terms of diversity indices between the two habitats may be related to the physicochemical properties of the brown and black waters. Galacatosa *et al.* (2003) found that the diversity indices of fish composition were significantly influenced by both seasonal and habitat differences between the white and black water habitats in the Amazon river. Furthermore, Johnson (1969) and Zakaria *et al.* (1999) found that several environmental factors, such the physicochemistry of the water quality, topographical, hydrological characteristics and habitat destruction, could play major roles in species richness, diversity and species survival in aquatic habitats.

CONCLUSIONS

In this research, the brown water habitat supports diverse and abundant populations of freshwater fishes compared to the black water habitat at Batang Kerang River systems. The present study also provided evidence which showed there were certain distinctive characteristics between the community structure of fish captured in black water and brown water habitats. However, seasonal flooding also seemed to be an important factor which influenced the assemblage and composition of fish. The results of the present study suggested that studies on the spatial and temporal of species compositions, distribution and abundance of floodplain fish should be carried out in Borneo.

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