Research Article

Macrofauna of Rajang River, Sarawak, Malaysian Borneo

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ABSTRACT. Surveys were carried out in the main Rajang River and its tributaries to record the community structure of macrofauna. Samplings were done in nine sampling stations using Van Veen Grab sampler and modified kick nets. Six phylla of macrofauna (Mollusca, Annelida, Arthropoda, Nematoda, Brachiopoda and Echinordermata) were recorded in which include 22 species of gastropods, three species of bivalves, 16 species of polychaetes, 10 species of oligochaetes, 51 species of insects, six species of crustacean, one species of nematode, one species of branchiopod and one species of echinoderm. The species number of aquatic insects group was high at freshwater stations while annelids groups were found to be dominant at the estuarine stations. The density of macrofauna ranged from 70-1550 individuals per m^2. The Shannon–Weaver diversity and Pielou's evenness indices ranged from 2.19-3.60 and 0.56-0.85 respectively. Based on the taxa richness values, the conditions of the aquatic ecosystem in Rajang River tributaries are good indicating recovery process in post-logging areas upstream of the sampling stations. However, water in the main Rajang River is loaded with fine silt and almost permanently turbid suggesting possible effects either detrimentally or otherwise to the range of resident fauna within the river system.

Keywords: Macrofauna, food chain, taxa richness.

INTRODUCTION

The Rajang River is the main drainage system for central Sarawak in Malaysian Borneo. It is also the longest river in Sarawak, originating from the Nieuwenhuis Mountain Range and the upper Kapuas Mountains, flowing to the South China Sea (Figure 1).

Lotic environments are more heterogenous and are known to support an extraordinary array of species (Hilsenhoff, 1991; Abang *et al.,* 1995) most of which are macrofauna. Unlike fish, the diversity of macrofauna in most parts of the world, particularly the tropics, is poorly known. Most macrofaunas are small and difficult to identify; the great diversity and abundance only add to the neglect. With the dearth of studies on macrofauna, many of them are being lost as their habitats deteriorate; some without ever being discovered and made known to science.

Very few studies were done on the lotic macrofauna in Sarawak. Reports include that of the SAMA Consortium (1982) on the molluscs of the genera *Paludomus* and *Clea* in the Pelagus area. Eleven orders of macrofauna were recorded in the upper Balui River and its tributaries, namely Mollusca, Ephemeroptera, Odonata, Plecoptera, Trichoptera, Coleoptera, Hemiptera, Diptera, Nemertea, Nematomorpha and Oligochaeta (Tan *et al.*, 1995). Five orders

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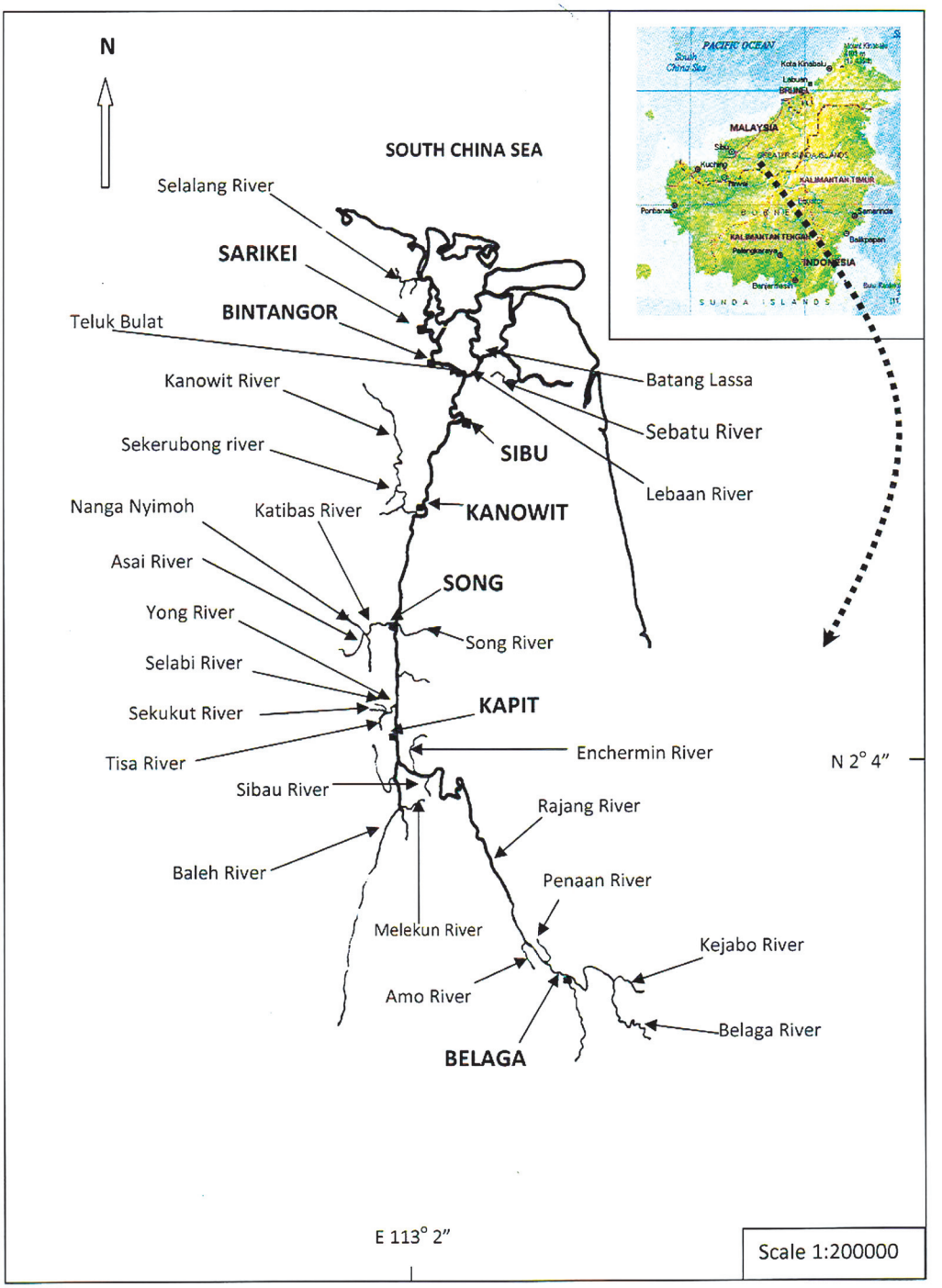

Figure 1. The location of macrofauna sampling stations along the Rajang River, Sarawak.

of macrofauna, which are mainly aquatic insects were reported from rivers in Bario, in the Kelabit Highlands of Sarawak (Shabdin & Abang, 1998). Ahmad Helmi (2005) found 12 taxa of macrofauna in Kesit River, Sarawak. Shabdin *et al.* (2001) reported seven orders of aquatic insects, namely Odonata, Ephemeroptera, Plecoptera, Hemiptera, Trichoptera, Coleoptera and Diptera, from fast flowing streams of the Crocker Range Park in Sabah.

Although the food web in forested drainage basins is more dependent on allochthonous production (input of externally produced plant matter) (Thorp & Covich, 1991), the macrofauna are an important component of food web in river ecosystems. Macrofauna serves as food for higher trophic levels in the benthic environment and can be eaten by swimming predators (e.g. fish, shrimp and crabs). Aquatic insects are also important as fish food. Hilsenhoff (1991) found that the stonefly larvae provide food for fish and invertebrate predators in the invertebrate food web, while the chironomid larvae are an extremely important part of the aquatic food webs, serving as prey for many other insects and food for most species of fish. Tan *et al*. (1995) noted that meiofauna and macrofauna play an important role in the aquatic food web of Batang (River) Balui.

The aim of this present study was to record species composition, species density, species diversity and taxonomic richness of the macrofauna in the Rajang River and its tributaries. Emphasis was also given on the documentation of the food chain in the river ecosystems within the study area.

METHODOLOGY

The Rajang and all the major rivers of the study area are characterised by frequent and abrupt changes in water level where the fluctuation could reach a maximum of about 20 metres at Belaga town. The variation in water level occurs every month in the year. The months of June, July and August are drier and the water level could be exceptionally low during this period. The water was turbid during the study period except for smaller tributaries. The colour of the water in the main channel of Rajang is generally yellowish with water transparency of between 4-5 cm.

A survey on the macrofauna of the Rajang River and its tributaries was carried out from May to December 2004. Nine sampling stations were chosen (Figure 1) and all sampling stations were located downstream from the Bakun Dam. Each station consists of several sites (Table 1). Stations 1–3 were located in the estuarine while stations 4-9 were in the freshwater areas. Streams and rivers in Rajang basins vary from high gradient, cobble dominated to low gradient streams with sandy or muddy sediments. A hand-held GPS was used to determine the latitude and longitude of the site. Due to the stony and rocky nature of the substrate as well as the fast water current at some sampling sites (Station 4 – 9), modified Kick Net was used to collect macrofauna samples. The methods employed was a multi-habitat sampling scheme, in which the benthic macrofauna were collected systematically from all available stream habitats by kicking the substrate or jabbing with a modified Kick net (standard mesh size of 500μ screen) (MACS, 1996). Sampling began at the downstream end of the reach and proceeded upstream. The macrofauna samples were collected along the 100 metres transect. A total of 20 jabs of kicks were taken over the length of 100 metres. A single jab was done by forcefully thrusting the net into a productive habitat for a linear distance of 0.5 metre. A kick is a stationary sampling accomplished by positioning the net and disturbing the substrate for a distance of 0.5 metre upstream of the net. The jabs or kicks collected from the multiple habitats were lumped together making a single homogeneous sample. The samples were then transferred

from the net to sample container (labeled) and 5% formalin was used as preservative.

In larger and deeper parts of the river, samples were collected with a Van Veen grab sampler (station 1-3). A 100 m reach representing the characteristics of the river was selected. A total of 20 grabs were taken over the length of reach. The sediments obtained were passed through a 500 µm mesh sieve, and the residue fixed in 5% formalin, and labelled. All samples were sorted in the laboratory and organisms were identified to the lowest practical taxa, generally to generic level.

Identifications follow those of Hill & Phillipps (1981), Pennak (1989), Hilsenhoff (1991), Thorp & Covich (1991), Peckarsky *et al*. (1993) and Pechenik (2000). Each taxon found in a sample was recorded and enumerated for Invertebrate Community Index calculation. The index used in this study was "Taxa Richness" to reflect the diversity of the aquatic assemblage (Resh *et al*. 1995). Shannon-Weaver diversity index (Krebs, 1978) and Pielou's evenness (Pielou, 1969) were used to calculate the species diversity and species evenness.

RESULTS AND DISCUSSION

Results showed that six phylla of macrofauna (Mollusca, Annelida, Arthropoda, Nematoda, Brachiopoda and Echinordermata) were recorded in the Rajang River and its tributaries (Table 2). Out of these, there were 22 species of gastropods, three species of bivalves, 16 species of polychaetes, 10 species of oligochaetes, 51 species of insects, six species of crustacean, one species of nematode, one species of branchiopod and one species of echinoderm. The species number of aquatic insects group was high at freshwater stations (stations 4 – 9) while annelids groups were found to be dominant at the estuarine stations (stations 1-3).

Nine orders of aquatic insects were collected from the freshwater stations (stations 4-9) (Table 2). Ephemeropterans (eg. *Compsoneuria* sp., *Ephemerella* sp. and *Baetis* sp.) form a very large group; *Compsoneuria* sp., *Ephemerella* sp. and *Baetis* sp. are relatively abundant and well represented at stations 4 to 9. *Baetis* sp. was, however, absent at stations 4 and 5. Hilsenhoff (1991) noted that most species of Ephemeroptera inhabit clean streams where they are often abundant in leaf litter, eddies or near the banks; a few species may persist in organically enriched streams. The net-spinning Trichopteran is known to be a large family found throughout the world and is represented in a great variety of habitats. In this study, they were only found at stations 6, 8 and 9.

Adults aquatic insects are also well represented (Table 2). Insects from the super family Gerroidea are exclusively surface dwelling. These bugs were commonly found at most study stations except for Station 9. The common species were *Hydrometra* sp., *Velia* sp., *Nepa* sp., *Metrobates* sp. and *Gerris* sp. The gerroids are virtually the only full-time occupants of this niche, but a few other groups share the surface films at other times, for example the whirlgig beetles (Coleoptera) of the family Gyrinidae. These beetles spend much of their time gyrating gregariously on the water surface. A large school of these whirlgigs was recorded at stations 5 and 8. The Odonata (dragonflies and damselflies) were also encountered (Table 2). They were commonly found at all freshwater stations (stations 4-9) where their breeding sites were plentiful. The habitats where collections were made consisted of rocky banks overgrown with vegetation. This serves well as breeding sites for some species. The common species encountered were *Argia* sp., *Aeschna* sp. and *Stylogomphus* sp. Stoneflies of the order Plecoptera were also represented.

Table 1. The GPS readings, sampling methods employed and habitat description of macrofauna sampling sites carried out at stations 1 – 9.

Station 1 (Selalang)			
Site	GPS Reading	Method Employed	Habitat Description
1	N 02^0 06.314' E 110^0 17.175'	Grab sampler	A tributary of Selalang River, width about 17 m and depth about 2.3 m, exposed stream with mangrove growing on both sides of the banks.
2	N 02^0 05.887' E 111^0 16.984'	Grab sampler	A tributary of Selalang River, width about 15 m and depth about 3.3 m, exposed stream with mangrove growing on both sides of the banks.
Station 2 (Pasin)			
Site	GPS Reading	Method Employed	Habitat Description
1	N 02^0 37.999' E 111^0 42.396'	Grab sampler	Along the banks of Batang Lassa, width about 500 m and depth about 27 m, exposed stream with *Nipah* sp growing on both sides of the banks.
2	N 02^0 36.664' E 111^0 39.517'	Grab sampler	Sebatu River, a tributary of Batang Lassa, width about 50 m and depth about 10 m, exposed stream with *Nipah* sp growing on both sides of the banks.
Station 3 (Lebaan)			
Site	GPS Reading	Method Employed	Habitat Description
1	N 02^0 17' 05.5" E 111^0 40' 33.4"	Grab sampler	Sand bar area at Lebaan, width of river about 300 m and depth about 3 m, exposed with *Sonneratia* sp growing on one side of bank.
2	N 02^0 15' 24.0" E 111^0 40' 26.6"	Grab sampler	Sand bar at Teluk Bulat, width of river about 150 m and depth about 2 m, exposed with *Sonneratia* sp growing on both sides of banks.
Station 4 (Kanowit River)			
Site	GPS Reading	Method Employed	Habitat Description
1	N 02^0 04.29.5" E 112^0 08.57.4"	Kick Net	At the bank of Kanowit River, between Telok Kundong and Melepeh River.

2	N 02^0 02.46.8” E 112^0 06.30.7”	Kick Net	Sekerubong River, a tributary of Kanowit River, width about 4-6 m and depth about 1.5 m, partially shaded stream with muddy bottom.

Station 5 (Katibas River)			
Site	GPS Reading	Method Employed	Habitat Description
1	N 01^0 57’ 24.7” E 112^0 32’ 51.9”	Kick Net	Nanga Nyimoh, a tributary of Katibas River, width about 3 m and depth about 1 m at pool and 0.2 m at ripples, shaded stream with clear water.
2	N 01^0 45’ 55.0” E 112^0 37’ 26.2”	Kick Net	Asai River, a tributary of Katibas River, width about 5-7 m and depth about 2 m at pool and 20 cm at ripples, partially exposed stream with clear water.

Station 6 (Song River and Batang Rajang above Song Town)			
Site	GPS Reading	Method Employed	Habitat Description
1	N 02^0 02’ 02.5” E 112^0 33’ 17.1”	Kick Net	Song River at Nanga Sebetong, width about 15 m and depth about 1.3 m at pool and 0.2 m at ripples, exposed stream with clear water.
2	N 02^0 02’ 06.3” E 112^0 34’ 11.0”	Kick Net	Ipau River, a tributary of Song River, width about 8 m and depth about 1.5 m at pool and 0.2 m at ripples, sheltered stream with clear water.

Station 7 (Yong River and Tisa River)			
Site	GPS Reading	Method Employed	Habitat Description
1	N 01^0 58’ 41.5” E 112^0 49’ 06.4”	Kick Net	Apan River, a tributary of Tisa River, width about 3 m and depth about 0.2 – 1.3 m, sheltered stream with clear water.
2	N 01^0 58’ 38.9” E 112^0 51’ 11.5”	Kick Net	Sekukut River, a tributary of Yong River, width about 15 m and depth about 1.3 m at pool and 0.2 m at ripples, exposed stream with clear water.

3	N 01^0 58’ 03.7” E 112^0 51’ 13.6”	Kick Net	Selabi River, a tributary of Yong River width about 5 m and depth about 2 m at pool and 0.2 m at ripples, sheltered stream with clear water.

Station 8 (Batang Balleh and Batang Rajang at the confluence above Kapit Town)			
Site	GPS Reading	Method Employed	Habitat Description
1	N 02^0 04’ 55.3” E 113^0 02’ 39.4”	Kick Net	Enchermin River, a tributary of Rajang River, width about 5 m and depth about 2.4 m, sheltered stream with clear water.
2	N 02^0 02’ 25.0” E 113^0 02’ 38.7”	Kick Net	Sibau River, a tributary of Rajang River, width about 4 m and depth about 5.7 m at mouth and 2 m upstream, sheltered stream with clear water.
3	N 02^0 00’ 45.0” E 113^0 01’ 01.6”	Kick Net	Melekun River, a tributary of Balleh River, width about 6 m and depth about 2 m at pool and 0.2 m at ripples, semi exposed stream with clear water.

Station 9 (Belaga River and Batang Rajang)			
Site	GPS Reading	Method Employed	Habitat Description
1	N 02^0 4’ 59.2” E 113^0 45’ 25.7”	Kick Net	Amo River, a tributary of Rajang River, width about 3 m and depth about 2 m at pool and 0.2 m at ripples, exposed stream with clear water.
2	N 02^0 46’ 35.9” E 113^0 59’ 26.8”	Kick Net	Penaan River, a tributary of Rajang River, width about 2 m and depth about 0.1 – 0.4 m at ripples, semi exposed stream with clear water.
3	N 02^0 43’ 30.5” E 113^0 46’ 06.9”	Kick Net	Kejabo River, a tributary of Belaga River, width about 8 m and depth about 0.2 – 1 m, semi exposed stream with clear water.

Table 2. Taxonomic list and density of macrofauna (no. ind./m^2) in the study area.

Taxa / Station	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8	Station 9
INVERTEBRATA									
Phylum Mollusca									
Class Gastropoda									
Nerita lineata	7	1	-	-	-	-	-	-	-
Nerita planospira	1	-	-	-	-	-	-	-	-
Nerita sp.	-	2	45	-	-	-	-	-	-
Cerithidea rhizophorarum	1	1	1	-	-	-	-	-	-
Littorina scabra	1	-	-	-	-	-	-	-	-
Strombus haemostoma	1	-	-	-	-	-	-	-	-
Morula rogusa	1	-	-	-	-	-	-	-	-
Littorina scabra	1	-	-	-	-	-	-	-	-
Strombus haemostoma	1	-	-	-	-	-	-	-	-
Morula rogusa	1	-	-	-	-	-	-	-	-
Chicoreus capucinus	1	-	-	-	-	-	-	-	-
Cymatium tigrinum	1	-	-	-	-	-	-	-	-
Neritina sp.	-	3	-	-	-	8	9	12	-
Semisulcospira libertina	-	-	-	-	2	1	-	8	-
Bithynia sp.	-	-	-	-	-	1	-	-	-
Limnaea sp.	-	-	-	-	-	3	7	12	3
Viviparous sp.	-	-	-	-	-	3	9	17	-
Viviparous georgianus	-	-	-	-	-	-	6	3	-
Laemodonta sp.	-	-	3	-	-	-	-	-	-
Clithon retropictus	-	-	2	-	-	-	-	-	-
Dostia violacea	-	-	5	-	-	-	-	-	-
Onchidium verraculatum	-	-	6	-	-	-	-	-	-
Class Bivalvia									
Crassostrea iredalei	1	-	-	-	-	-	-	-	-

Polymesoda similis	1	-	-	-	-	-	-	-	-
Marcia hiantina	-	-	2	-	-	-	-	-	-
Phylum Annelida									
Class Polychaeta									
Capitella sp.	25	15	-	-	-	-	-	-	-
Dodecaceria sp.	13	-	-	-	-	-	-	-	-
Cossura sp.	100	57	-	-	-	-	-	-	-
Hemipodus sp.	25	10	-	-	-	-	-	-	-
Glycera sp.	5	-	-	-	-	-	-	-	-
Goniada sp.	7	-	-	-	-	-	-	-	-
Podarkeopsis sp.	12	-	-	-	-	-	-	-	-
Magelona sp.	32	12	-	-	-	-	-	-	-
Ophelina sp.	35	-	-	-	-	-	-	-	-
Pisioridae sp.	21	5	-	-	-	-	-	-	-
Saccocirridae sp.	14	-	-	-	-	-	-	-	-
Autolytus sp.	71	25	-	-	-	-	-	-	-
Sphaerosyllis sp.	45	-	-	-	-	-	-	-	-
Artocama sp.	21	-	-	-	-	-	-	-	-
Nephtys sp.	-	-	70	-	-	-	-	-	-
Pilargis sp.	-	-	8	-	-	-	-	-	-
Class Clitellata									
Subclass Oligochaeta									
Tubificoides sp.	501	14	-	-	-	-	-	-	-
Monopylephorus sp.	302	6	-	-	-	-	-	-	-
Nootkadrilus sp.	10	-	-	-	-	-	-	-	-
Aktedrilus sp.	15	-	-	-	-	-	-	-	-
Marionina sp.	100	12	-	-	-	-	-	-	-
Grania sp.	25	-	-	-	-	-	-	-	-
Aulodrilus sp.	-	-	-	73	-	-	-	-	-

Enchytraeus sp.	-	-	27	-	-	-	-	-	-
Brachuria sp.	-	-	-	67	-	-	-	-	-
Lumbriculus sp.	-	-	-	-	-	1	-	1	2
Phylum Arthropoda									
Class Insecta									
Order Ephemeroptera									
Compsoneuria sp.	-	-	-	1	19	7	6	44	7
Ephemerella sp.	-	-	-	12	29	15	8	29	31
Serratella sp.	-	-	-	5	-	-	-	-	-
Ameletus sp.	-	-	-	5	-	-	-	-	-
Baetis sp.	-	-	-	-	-	4	4	22	13
Paraleptophlebia sp.	-	-	-	-	-	1	-	-	-
Ephemera sp.	-	-	-	-	-	-	4	6	-
Drunella sp.									1
Order Odonata									
Argia sp.	-	-	-	1	3	-	2	5	-
Aeschna sp.	-	-	-	1	1	-	-	2	-
Lanthus sp.	-	-	-	-	1	-	2		-
Archilestes sp.	-	-	-	-	-	6	-	2	-
Tachopteryx sp.	-	-	-	-	-	1	-	-	-
Stylogomphus sp.	-	-	-	-	-	-	8	1	1
Hagenius sp.	-	-	-	-	-	-	6	-	-
Macromia sp.	-	-	-	-	-	-	-	1	-
Order Blattaria									
Opisthoplatia sp.	-	-	-	-	-	-	-	-	1
Order Plecoptera									
Perlinella sp.	-	-	-	-	2	-	-	-	-
Pteronarcys sp.	-	-	-	-	-	-	1	3	14
Peltoperla sp.	-	-	-	-	-	-	2	5	-
Order Hemiptera									

Hydrometra sp.	-	-	-	-	2	2	-	2	-
Velia sp.	-	-	-	-	-	1	-	4	-
Nepa sp.	-	-	-	1	-	-	-	-	-
Metrobates sp.	-	-	-	-	-	-	3	1	-
Gerris sp.	-	-	-	-	-	-	1	-	-
Order Coleoptera									
Psephenus sp.	-	-	-	1	-	-	1	1	2
Orechtochilus ceylonicus	-	-	-	1	-	4	-	-	-
Stenelmis sp.	-	-	-	8	-	-	-	-	8
Hydraena sp.	-	-	-	1	-	-	-	-	-
Optioservus sp.	-	-	-	-	3	2	-	-	-
Agabus sp.	-	-	-	-	1	1	-	1	-
Celina sp.	-	-	-	-	1	-	-	1	1
Gyrinus sp.	-	-	-	-	8	-	-	3	-
Optioservus sp.	-	-	-	-	-	-	-	-	-
Hydraticus sp.	-	-	-	-	-	1	-	-	-
Scirtes sp.	-	-	-	-	-	-	1	-	1
Helophorus sp.	-	-	-	-	-	-	1	-	-
Photinus sp.	-	-	-	-	-	-	-	1	-
Dineutus sp.	-	-	-	-	-	-	-	-	1
Order Diptera									
Bezzia sp.	-	-	-	1	-	-	-	-	-
Chironomus sp.	-	-	11	1	-	-	-	-	8
Pedicia sp.	-	-	-	-	1	-	-	-	-
Leptotarsus sp.	-	-	-	-	-	1	-	-	-
Palaeodipteron sp.	-	-	-	-	-	1	-	2	-
Tipula sp.	-	-	-	-	-	-	-	2	-
Prosimulium sp.	-	-	-	-	-	-	-	-	4
Limonia sp.	-	-	-	-	-	-	-	-	3
Order Trichoptera									

Macronema latum	-	-	-	-	-	1	-	5	-
Leucotrichia sp.	-	-	-	-	-	4	-	-	-
Macrostemum sp.	-	-	-	-	-	-	-	-	11
Order Lepidoptera									
Petrophila sp.	-	-	-	-	-	-	1	-	-
Class Crustacea									
Order Cumacea									
Cumacea sp. 1	57	2	-	-	-	-	-	-	-
Order Tanaidacea									
Tanaidacea sp. 1	17	-	-	-	-	-	-	-	-
Order Amphipoda									
Amphipoda sp. 1	10	8	1	-	-	-	-	-	-
Order Decapoda									
Macrobrachium sp.	-	-	-	-	4	-	1	20	2
Potamon sp.	-	-	-	-	-	1	4	2	-
Palaemonetes sp.	-	-	-	-	-	-	-	1	-
Phylum Nematoda	21	-	20	-	-	-	-	-	-
Phylum Brachiopoda	42	3	-	-	-	-	-	-	-
Phylum Echinodermata	1	-	-	-	-	-	-	-	-
VERTEBRATA									
Unidentified juvenile fish species	4	1	-	-	-	-	4	-	-
TOTAL	1550	177	201	179	77	70	91	219	114

Twelve species of gastropods and two species of bivalves were found only in estuarine stations (stations 1-3) while five gastropods species were recorded at freshwater stations only (stations 4-9). Freshwater gastropods were found in the rivers where the water was shallow, permanently flowing and rarely turbid (e.g. stations 5-9). These conditions facilitate growing of green algae and mosses on rocks and other objects in the riverbed. However, the estuarine gastropods (at stations 1-3) were found on the roots or lower parts of mangrove trees (eg. *Sonneratia* sp. and *Nipah* sp.) and on the surface of sediments where the water was turbid. Estuarine molluscs have evolved an adaptation to live in this kind of environment where the fluctuation of salinity and suspended solids are high. Similar taxa of macrofauna in freshwater habitats were also found in Balui River (Tan *et al.*, 1995; Abang *et al.,* 1995) and Gombak River in Peninsular Malaysia (Bishop, 1973). Certain estuarine taxa found in this study were also found in the Sarawak River (Anon., 1994; Juliana, 2003), The taxa found in the study area are typical of tropical rivers.

The density of macrofauna recorded in Rajang and its tributaries ranged from 70-1550 individuals per m^2 (Table 3). The oligochaetes and polychaetes were dominant at Station 1 thus skewing the density to be much higher than those of other stations. Both taxa are known to be more tolerant to habitat perturbation (Kerans & Karr, 1994; Fore *et al*., 1996). The Shannon–Weaver diversity and Pielou's evenness indices ranged from 2.19-3.60 and 0.56-0.85, respectively (Table 3). The species diversity index reflects both the number of species in a sample and how evenly individuals are distributed among species (Moore, 1983). The number of species found in the study area ranged from 14 to 40 species (Table 3). When compared to other rivers in Sarawak, the number of macrofauna species found in the study area were higher than at Batang Balui (Abang *et al.*, 1995), Pa' Dappur River in Bario (Mohd.Long & Abang, 1998)

Table 3. Summary of the macrofauna community structure in Batang Rajang and its tributaries. N – Total individuals / m^2, H' – Shannon – Weaver Diversity Index (bits/individuals), J – Pielou's Evenness and S – Species Number.

Station/Community structure	N	H'	J	S
Station 1	1550	3.56	0.67	40
Station 2	177	3.26	0.80	17
Station 3	201	2.73	0.74	13
Station 4	179	2.19	0.56	15
Station 5	77	2.77	0.73	14
Station 6	70	3.83	0.85	23
Station 7	91	3.56	0.79	23
Station 8	219	3.60	0.73	31
Station 9	114	3.46	0.82	19

and Sarawak River (Anon., 1994) (Table 4). Therefore, the study areas were found to be rich in macrofauna assemblage.

Macrofauna play important roles in the aquatic food web. Inger & Chin (1990) illustrate the role of macrofauna in terms of their importance as food for fish. The aquatic food web involves phytoplankton, moss, algae, zooplankton, macrofauna and fishes. The aquatic food web begins with the primary producers, phytoplankton, moss and algae (Figure 2). These photosynthetic organisms capture solar energy to produce carbohydrates from carbon dioxide that are dissolved in water (Chiras, 1993). Phytoplanktons are consumed by microscopic zooplankton and herbivorous fish while benthic diatom are consumed by meiofauna. Zooplankton and meiofauna form 1st order consumers (second trophic level) of many aquatic food webs. Meiofauna are consumed by 2nd order consumers (predators) which are fishes feeding on bottom detritus. Zooplankton and meiofauna are also consumed by other 2nd order consumers (macrofauna - aquatic insects and annelids), which in turn serve as food for 3rd order consumers (fishes, crabs and shrimps) and 4th order consumers (omnivorous). These are mostly bottom dweller fishes (Inger & Chin, 1990). Fourth and 5th order consumers consume 1st, 2nd and 3rd order consumers.

Table 4. A Comparison of macrofauna taxa in Rajang River and its tributaries, Batang Balui Rivers & its tributaries, Pa' Dappur River and its tributaries (Bario) and Sarawak River (Bau station only).

Taxa	River			
	Rajang River	Balui River	Pa' Dappur River	Sarawak River
Gastropoda	++	+	-	-
Bivalvia	+	-	-	-
Polychaeta	++*	+	-	-
Oligochaeta	++*	+	+	-
Ephemeroptera	+++	+++	+	+++
Odonata	++	++	-	+
Blattaria	+	-	-	-
Plecoptera	+	++	+	-
Hemiptera	+	+	-	-
Coleoptera	++	+	+	-
Diptera	+	++	++	-
Trichoptera	+	+++	+	+++
Lepidoptera	+	-	-	-
Cumacea	++*	-	-	-
Tanaidacea	++*	-	-	-
Amphipoda	++*	-	-	-
Decapoda	++	-	-	-
Nematoda	++*	+	+	-
Brachiopoda	++*	-	-	-
Echinodermata	+*	-	-	-

* - Estuarine stations (station 1-3)

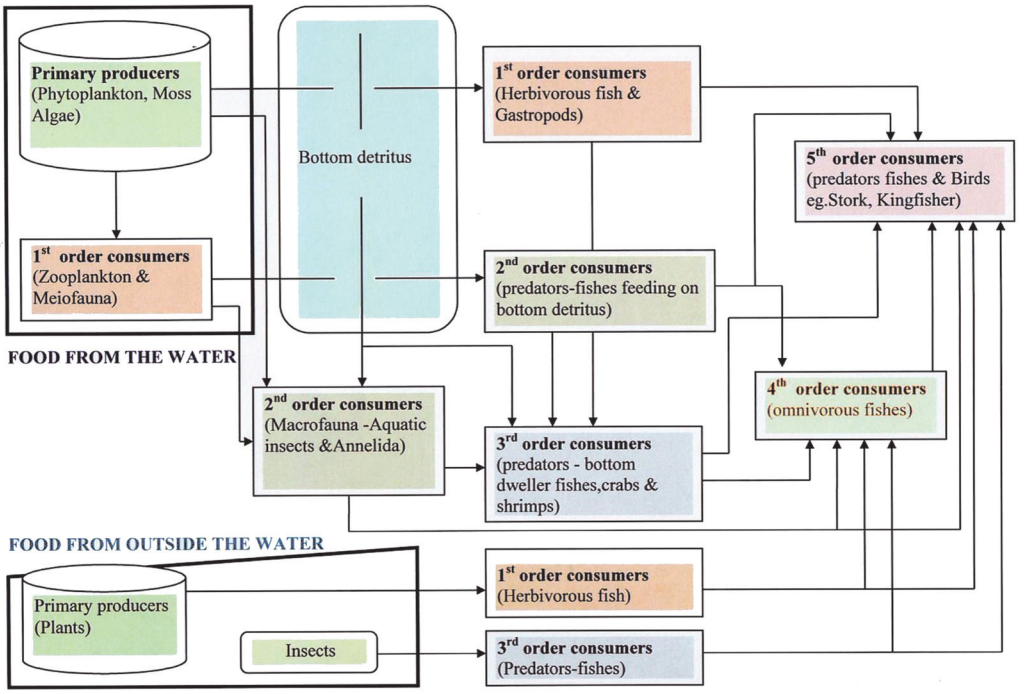

Figure 2. Hypothetical food chain in Rajang River and its tributaries (modified after Inger & Chin, 1962).

The richness of taxa as found in the Rajang River and its tributaries are presented in Table 5. The number of distinct taxa represents the diversity within a sample. It usually consists of species level identifications but may also be evaluated as designated groupings of taxa, often of higher taxonomic groups (i.e. genera, families, orders) in assessment of invertebrate assemblages (MACS, 1996). Richness measures reflect the diversity of the aquatic assemblage (Resh *et al*. 1995). Increasing diversity correlates with increasing health of the assemblage and suggest that niche space, habitat, and food source are adequate to support survival and propagation of many species (MACS, 1996). However, since the values in Table 5 is one of the first taxa richness data recorded in Rajang River Sarawak, it is hard to draw a convincing conclusion on the status of perturbation in the study area. Data from Batang Balui River and its tributaries (Tan *et al.,* 1995; Abang *et al.,* 1995; SAMA 1982), Sarawak River (Anon., 1994) and Pa' Dappur Rivers and its tributaries (Bario) (Shabdin & Abang, 1998) did not include the values of taxa richness. Therefore, comparison of the richness of taxa between rivers in the region was not done in this study.

The data on the richness of taxa obtained in this study can only be used to postulate that the aquatic ecosystem of the Rajang tributaries (streams at stations 4 to 9 - freshwater stations) are in good condition and the process of post logging recovery has been taking place after the area was logged 15-20 years ago. It was, however, untrue for a site in the Penaan River at Station 9 where macrofaunal diversity was very small. The community in the area is known to use toxic chemicals to capture fish (Lee, pers. comm.).

Table 5. Taxa richness of macrofauna at Rajang River and its tributaries.

Category	Metric	Definition	Predicted response to increasing pertubation (MACS, 1996)	Metric value (Batang Rajang and tributaries)	
Richness measures	Total number taxa	Measures the overall variety of the macrofauna assemblage	Decrease	Station	Value
				1	40
				2	17
				3	13
				4	15
				5	14
				6	23
				7	23
				8	31
				9	19
	Number EPT taxa	Number of taxa in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies)	Decrease	Station	Value
				1	0
				2	0
				3	0
				4	4
				5	3
				6	6
				7	6
				8	7
				9	6
	Number Ephemeroptera taxa	Number of mayfly taxa (usually genus or species level)	Decrease	Station	Value
				1	0
				2	0
				3	0
				4	4
				5	2
				6	4
				7	4
				8	4
				9	4
	Number Plecoptera taxa	No. of stonefly taxa (usually genus or species level)	Decrease	Station	Value
				1	0
				2	0
				3	0
				4	0
				5	1
				6	0
				7	2
				8	2
				9	1
	Number Trichoptera taxa	Number of caddisfly taxa (usually genus or species level)	Decrease	Station	Value
				1	0
				2	0
				3	0
				4	0
				5	0
				6	2
				7	0
				8	1
				9	1
	Number *Pteronarcys* species	The presence or absence of long-lived stonefly genus (2-3 year life cycle)	Decrease	Station	Value
				1	0
				2	0
				3	0
				4	0
				5	0

				6 0
				7 1
				8 1
				9 1
	Number Diptera taxa	Number of 'true' fly taxa, which includes midges (chironomid)	Decrease	Station Value
				1 0
				2 0
				3 1
				4 2
				5 1
				6 2
				7 0
				8 2
				9 3
	Number Chironomidae taxa	Number of taxa of chironomid (midge) larvae	Decrease	Station Value
				1 0
				2 0
				3 1
				4 1
				5 0
				6 0
				7 0
				8 0
				9 1
Composition measures	%EPT	Percent of the composite of mayfly, stonefly and caddisfly larvae	Decrease	Station Value
				1 0
				2 0
				3 0
				4 26.6
				5 21.4
				6 26.1
				7 26.1
				8 22.5
				9 31.5
	% Ephemeroptera	Percent of mayfly nymphs	Decrease	Station Value
				1 0
				2 0
				3 0
				4 12.8
				5 6.2
				6 38.5
				7 24.1
				8 46.1
				9 45.6
	% Plecoptera	Percent of stonefly nymphs	Decrease	Station Value
				1 0
				2 0
				3 0
				4 0
				5 2.6
				6 0
				7 3.3
				8 3.6
				9 12.3
	% Trichoptera	Percent of caddisfly larvae	Decrease	Station Value
				1 0
				2 0
				3 0
				4 0
				5 0
				6 7.1
				7 0

				8	2.3
				9	9.6
	% Diptera	Percent of all true fly larvae	Increase	Station	Value
				1	0
				2	0
				3	5.4
				4	1.1
				5	1.3
				6	2.9
				7	0
				8	1.8
				9	13.2
	%Chironomidae	Percent of midge larvae	Increase	Station	Value
				1	0
				2	0
				3	5.4
				4	0.6
				5	0
				6	0
				7	0
				8	0
				9	7.0
	% Noninsects	Composite of those organisms generally considered to be tolerant to a wide range of environmental conditions	Increase	Station	Value
				1	100
				2	100
				3	94.5
				4	78.2
				5	7.8
				6	25.7
				7	43.9
				8	34.7
				9	6.1
	% Oligochaeta	Percent of aquatic worms	Variable	Station	Value
				1	61.5
				2	18.1
				3	13.4
				4	78.2
				5	0
				6	1.4
				7	0
				8	0.5
				9	1.8
Tolerance/ Intolerance measures	No. intolerance snail and mussel species	Number of species of mollusks generally thought to be pollution intolerant	Decrease	Station	Value
				1	0
				2	0
				3	0
				4	0
				5	1
				6	4
				7	4
				8	4
				9	1
	% sediment tolerant organisms	Percent of infaunal macrofauna tolerant of pertubation	Increase	Station	Value
				1	98.5
				2	95.5
				3	99.5
				4	78.2
				5	0
				6	1.4
				7	0
				8	0.5
				9	1.8

CONCLUSIONS

The Rajang River and its tributaries shows that six phylla of macrofauna have been recorded. They are Mollusca, Annelida, Arthropoda, Nematoda, Branchiopoda and Echinodermata. Out of all mentioned above, there were 22 species of gastropods, three species of bivalves, 16 species of polychaetes, 10 species of oligochaetes, 51 species of insects, six species of crustacean, one species of nematode, one species of branchiopod and one species of echinoderm. A higher number of species was found at the upper reaches of the Rajang River indicating clean water streams in the ecosystem. Based on the taxonomic richness index, streams at the upper reaches of the Rajang River (stations 4-9) are considered to be clean. Several groups of fauna that were recorded in this project are incorporated into the existing theoretical food chain proposed by Inger & Chin (1962); which are meiofauna and gastropod (first order consumers) and macrofauna (second order consumers).

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