*Borneo Journal of Resource Science and Technology (2019), 9(1): 14-25*
*DOI: https://doi.org/10.33736/bjrst.1352.2019*

# Fish Assemblages, Growth Pattern and Environmental Factors in Upper Baleh River, Kapit, Sarawak

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Received: 19 March 2019 Accepted: 15 April 2019 Published: 31 June 2019

## ABSTRACT

A survey of the freshwater fish composition in the upper Baleh River, Sarawak was conducted in 2015. A total of 1,538 specimens, comprising 45 species from nine families were collected using electrofishing devices and cast nets. The family Cyprinidae was the most dominant (62.9%) as well as diverse (42.2%) family, followed by the Balitoridae (31.0%; 31.1%) in the river. The three most dominant species were *Tor tambra* (18.1%), *Lobocheilos ovalis* (12.9%), and *Parhomaloptera microstoma* (11.3%). Shannon's diversity index, Margalef's richness index, and Pielou's evenness index were 2.9, 6.0, and 0.8, respectively, an indication of moderate species diversity. Canonical Correspondence Analysis demonstrate that elevation, stream order and sedimentation were the most significant factors related to fish assemblages in the river, particularly for members of the families Cyprinidae and Balitoridae. The coefficient 'n' value in length-weight relationship for *T. tambra*, *L. ovalis*, and *P. microstoma* were determined as 2.92, 2.72, and 3.15, respectively. *T. tambra* and *L. ovalis* exhibited a negative allometric growth pattern which could be due to food competition whereas *P. microstoma* exhibited a positive allometric growth pattern as mountainous forest stream habitat offers favourable environmental conditions. The Fulton's condition factor of each species indicates that *T. tambra* and *L. ovalis* were in poor condition, whereas *P. microstoma* was in extremely poor condition. It is hypothesized that environmental degradation caused by logging activities have affected the health of the most dominant fish species in the upper Baleh River. Further study should be conducted to determine the underlying factors that are affecting the fish diversity.

Keywords: biological indices, Canonical Correspondence Analysis, condition factor, Cyprinidae, length-weight relationship,



## INTRODUCTION

Since the pioneering work of Lelek (1987), the documentation of freshwater fishes in Sarawak has been undertaken continuously (Nyanti *et al*., 1999; Inger & Chin, 2002; Parenti & Lim 2005; Jeffrine *et al*., 2009; Khairul Adha *et al.*, 2009; Nasarudin *et al*., 2010). There are over 600 species of freshwater fish in Malaysia (Froese & Pauly, 2016), and approximately 254 freshwater fish species have been recorded in Sarawak (Kottelat & Lim, 1995; Atack, 2006). However, knowledge on fish assemblages in Sarawak's river is still patchy, as the surveys have been mostly restricted to major rivers in Sarawak (Parenti & Lim, 2005). Due to the difficulties in conducting research in rural areas of Sarawak, studies on the fish assemblages in the upper part of forest streams remain scarce.

A recent study has shown that forest streams in Sarawak are subjected to sedimentation problem, due to logging activities (Ling *et al*., 2016). Fish fauna composition is greatly affected by environmental change caused by natural or anthropogenic factors (Dudgeon, 2000). Teresa *et al*. (2015) demonstrated that changes in habitat, food resources, and physicochemical conditions affect fish community structure in the deforested areas. Freshwater fishes are also facing major extinction risk due to those uncontrolled developments (Kottelate & Whitten

1996). Therefore, studies on the fish assemblages in the disturbed forest stream, coupled with growth patterns and well-being of fishes in streams are crucial.

The Baleh River is the left representative tributary of the Rajang River – the longest river in Sarawak. A national park with an area of approximately 66,000 ha has been proposed at approximately 182 km from the mouth of the Baleh River. Data on fish species composition and distribution in these upstream areas are lacking. The growth pattern and well-being of fishes in this forest stream are topics that remain unstudied. Hence, this study aimed to establish the baseline data on fish fauna composition in the upper Baleh River associated with environmental parameters in the stream. The length-weight relationship and Fulton condition factor of the three most dominant fish species were also determined in the present study.

## MATERIALS AND METHODS

Field samplings were conducted at 23 stations (Station 1 to Station 23), located along the upper Baleh River in April and November 2015. Three stations were located at upper (Station 1), middle (Station 15), and lower (Station 21) parts of the main river, while 20 stations were located at tributaries (Figure 1). Fish samples were collected using an electrofishing device consisting of two copper electrodes on wooden handle and powered by a 1000-watt portable generator (Stephill SHX1000 KVA Honda). Stunned fishes were collected using scoop nets (40 cm by 35 cm frame, 1 cm mesh size). The electroshocking process was carried out for 30 to 45 minutes and the area of sampling varied with the width of the stream and accessibility. When no fishes were caught, electroshocking distance was increased up to a maximum distance of 150 m. Besides electrofishing device, cast nets (height = 280 m; diameter = 240 cm; mesh size = 2 cm) were used to collect fishes from shallow pools. The environmental parameters were measured concurrently with the sampling of fish. Temperature, dissolved oxygen (DO), turbidity, pH, and conductivity of streams were measured by using a multi-parameter Sonde (YSI 6820 V2). Elevation was taken using a Portable Global Positioning System (Garmin GPSmap 62Sc). Physical stream habitat was characterized following Barbour *et al*. (1996) and Iwata *et al*. (2003). The habitats in the upper Baleh River consist of partially shaded stream with sediment substrates, fallen branches, as well as rocky bottom streams. Sedimentation, canopy cover, and order of streams were recorded. Scores were given based on the condition of stream habitat.

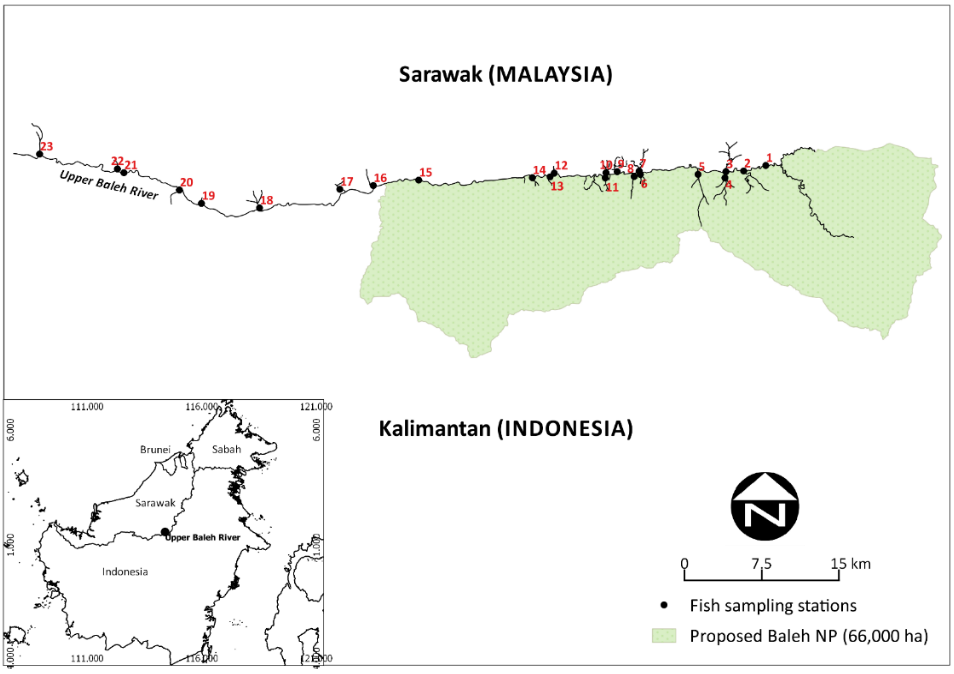


**Figure 1.** The location of the 23 sampling stations at upper Baleh River, Kapit, Sarawak

Fish were counted and identified *in situ* to the species level according to the taxonomic keys available (e.g., Mohsin & Ambak, 1983; Kottelat & Tan, 2008; Inger & Chin, 2002; Roberts, 1989), and an online global species database of fish species (Froese & Pauly, 2016). Samples that were unidentifiable in the field were fixed in 10% formalin and preserved in 70% ethanol for further study in the laboratory. Taxonomics status of the species was also confirmed with Kottelat & Tan (2008) and Kottelat (2012) and Kottelat (2013). The fresh specimens were measured for standard length (SL), total length (TL) (to the nearest millimeter) and weight (to the nearest gram).

Species diversity, richness and evenness in the whole upper Baleh River and at each station were calculated using the formula below:

Shannon's diversity index (H) (Shannon & Weaver, 1963),

$$H = \sum \frac{N_i}{N} \log_e \frac{N_i}{N}$$

Pielou's evenness (J) (Pielou, 1966), and

$$J = \frac{H}{\log_e S}$$

Margalef index of species richness (D) (Margalef, 1968),

$$D = \frac{S - 1}{\log_e N}$$

where N = sample size, Ni = number of specimen per species, S = total number of species

The fish abundance data were restructured by excluding the fish species that occurred in less than 1% of the samples. An ordination technique of Canonical Correspondence Analysis (CCA) was used in the direct analyses of the relationships between fish assemblages and environmental parameters (Ter Braak, 1986). Ten environmental parameters were used in the present study. Statistical significance (p value ≤ 0.05) of the CCA relationships between the set of environmental factors and fish species was evaluated using a permutation test with 999 permutations (Ter Braak & Verdonschot, 1995). Length-weight relationship (LWR) and general well-being of fish expressed in Fulton's condition factor (K) value of the top three most dominant fish species in the upper Baleh River were determined. The LWR of selected fish species was established using the formula BW = aTLn and expressed in the logarithmic form as Log BW = log a + n log TL (Le Cren, 1951). The constants 'a' and 'n' were estimated using linear regression analysis. The statistical significance of regression was tested by Analysis of Variance (ANOVA) at p value ≤ 0.05. The Fulton's condition factor (K) was calculated using the formula K = BW*100/TL3 (Pauly, 1983; Binohlan & Pauly, 1998). CCA was carried out by using the PAleontological STatistics software package (PAST, Palaeontological Association, 2001) whereas all the other statistical analyses were carried out by using the Statistical Software for Social Sciences (SPSS Version 24, SPSS Inc., 1995).

## RESULTS AND DISCUSSION

### Fish Assemblage and Species Abundance

A total of 1,538 specimens comprising 45 species from nine families were captured in the upper Baleh River (Table 1). Eighteen species individually contributed more than 1% of the total individuals, and collectively accounted for 93.2% of the total fish caught. The most dominant (62.9%) and diverse (42.2%) family was Cyprinidae, followed by Balitoridae (31.0%; 31.1%). The most dominant species was *Tor tambra* (18.1%) and *Lobocheilos ovalis* (12.9%) from the family Cyprinidae, followed by *Parhomaloptera microstoma* (11.3%) from family Balitoridae. Twelve species were extremely low in abundance, with only one or two specimens were caught in the present study, are *Acrochordonichthys melanogaster*, *A. rugosus*, *Hemibagrus wyckii*, *Gastromyzon* sp. III, *Glaniopsis multiradiata*, *Homalopteroides wassinkii*, *H. zollingeri*, *Nemacheilus kapuasensis*, *Rasbora* sp., *Macrognathus maculatus*, *Pangasius macronema* and *Kryptopterus lais*.

Dominance by the family Cyprinidae in the present study is a common pattern, and has been widely reported elsewhere including Malaysia (Jeffrine *et al*., 2009; Khairul Adha *et al*., 2009; Nasarudin *et al*., 2010; Rashid *et al*., 2015), Thailand (Beamish *et al*., 2006), Indonesia (Muchlisin & Siti Azizah, 2009), and South Korea (Jang *et al*., 2003). The dominance of

**Table 1.** Summary of the fish abundance and measurement at the upper Baleh River

| Family | Species | Fish specimen | | Total length (cm) | | Standard length (cm) | | Body weight (g) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Count | % | Mean | SD | Mean | SD | Mean | SD |
| Akysidae | *Acrochordonichthys melanogaster* | 1 | 0.1 | 13.4 | na | 11.5 | na | 29.8 | na |
| Akysidae | *Acrochordonichthys rugosus* | 1 | 0.1 | 8.7 | na | 6.7 | na | 5.9 | na |
| Sub-total number of species | | 2 | 4.4 | | | | | | |
| Sub-total number of fish caught | | 2 | 0.2 | | | | | | |
| Bagridae | *Hemibagrus planiceps* | 13 | 0.8 | 19.8 | 5.2 | 15.4 | 4.2 | 77.5 | 59.6 |
| Bagridae | *Hemibagrus wyckii* | 1 | 0.1 | 37.4 | na | 31.2 | na | 460.0 | na |
| Bagridae | *Leiocasis micropogon* | 10 | 0.7 | 14.4 | 4.8 | 12.0 | 4.1 | 34.9 | 29.5 |
| Bagridae | *Mystus nigriceps* | 4 | 0.3 | 24.7 | 2.3 | 19.6 | 1.6 | 101.5 | 21.7 |
| Sub-total number of species | | 4 | 8.9 | | | | | | |
| Sub-total number of fish caught | | 28 | 1.8 | | | | | | |
| Balitoridae | *Homaloptera orthogoniata* | 3 | 0.2 | 9.0 | 0.8 | 7.6 | 0.9 | 5.4 | 1.6 |
| Balitoridae | *Homalopteroides tweediei* | 3 | 0.2 | 4.1 | 0.3 | 3.4 | 0.4 | 0.6 | 0.1 |
| Balitoridae | *Homalopteroides wassinkii* | 2 | 0.1 | 4.7 | 0.1 | 3.9 | 0.1 | 1.0 | 0.0 |
| Balitoridae | *Homalopteroides zollingeri* | 1 | 0.1 | 3.5 | na | 3.0 | na | 0.4 | na |
| Balitoridae | *Gastromyzon fasciatus* | 82 | 5.3 | 4.3 | 0.9 | 3.5 | 0.7 | 1.2 | 0.7 |
| Balitoridae | *Gastromyzon punctulatus* | 15 | 1.0 | 4.4 | 1.3 | 3.7 | 1.1 | 2.0 | 1.8 |
| Balitoridae | *Gastromyzon* sp. I | 6 | 0.4 | 3.6 | 0.3 | 3.2 | 0.9 | 0.9 | 0.8 |
| Balitoridae | *Gastromyzon* sp. II | 35 | 2.3 | 5.8 | 1.0 | 4.5 | 0.8 | 2.2 | 1.0 |
| Balitoridae | *Gastromyzon* sp. III | 1 | 0.1 | 4.6 | na | 3.7 | na | 1.4 | na |
| Balitoridae | *Glaniopsis multiradiata* | 2 | 0.1 | 4.6 | 0.7 | 3.9 | 0.6 | 1.1 | 0.5 |
| Balitoridae | *Neogastromyzon chini* | 82 | 5.3 | 4.3 | 1.0 | 3.5 | 0.8 | 1.2 | 1.0 |
| Balitoridae | *Neogastromyzon pauciradiatus* | 63 | 4.1 | 5.2 | 1.2 | 5.2 | 1.2 | 2.3 | 1.1 |
| Balitoridae | *Neogastromyzon* sp. | 8 | 0.5 | 3.3 | 0.4 | 2.6 | 0.3 | 0.3 | 0.1 |
| Balitoridae | *Parhomaloptera microstoma* | 174 | 11.3 | 5.4 | 1.3 | 4.3 | 1.0 | 1.3 | 0.8 |
| Sub-total number of species | | 14 | 31.1 | | | | | | |
| Sub-total number of fish caught | | 477 | 31.0 | | | | | | |
| Nemacheilidae | *Nemacheilus kapuasensis* | 1 | 0.1 | 7.5 | na | 5.4 | na | 2.7 | na |
| Nemacheilidae | *Nemacheilus spiniferus* | 6 | 0.4 | 7.0 | 1.8 | 5.4 | 1.3 | 2.2 | 1.2 |
| Sub-total number of species | | 2 | 4.4 | | | | | | |
| Sub-total number of fish caught | | 7 | 0.5 | | | | | | |

***Continued Table 1***

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Cyprinidae | *Cyclocheilichthys armatus* | 7 | 0.5 | 18.1 | 7.6 | 14.0 | 6.0 | 69.0 | 58.1 |
| | *Barbonymus collingwoodii* | 67 | 4.4 | 19.9 | 3.2 | 15.0 | 2.3 | 78.6 | 29.7 |
| | *Barbonymus schwanenfeldii* | 48 | 3.1 | 20.7 | 5.7 | 15.3 | 4.0 | 116.2 | 83.0 |
| | *Crossocheilus cobitis* | 83 | 5.4 | 5.9 | 1.2 | 4.8 | 0.9 | 2.4 | 1.4 |
| | *Cyclocheilichthys apogon* | 6 | 0.4 | 16.5 | 2.7 | 12.7 | 2.2 | 47.6 | 18.8 |
| | *Hampala bimaculata* | 7 | 0.5 | 23.7 | 3.4 | 18.2 | 3.0 | 127.4 | 114.4 |
| | *Labiobarbus fasciatus* | 5 | 0.3 | 30.7 | 3.3 | 24.1 | 2.1 | 242.0 | 46.0 |
| | *Lobocheilos ovalis* | 198 | 12.9 | 13.2 | 7.0 | 11.2 | 5.3 | 43.2 | 73.3 |
| | *Lobocheilos falcifer* | 78 | 5.1 | 13.6 | 6.1 | 11.1 | 4.7 | 36.9 | 56.4 |
| | *Luciosoma setigerum* | 34 | 2.2 | 27.4 | 2.7 | 21.8 | 2.0 | 121.2 | 46.0 |
| | *Luciosoma spilopeura* | 4 | 0.3 | 25.8 | 0.5 | 20.3 | 0.6 | 96.3 | 6.3 |
| | *Osteochilus schlegelii* | 3 | 0.2 | 28.3 | 2.0 | 22.3 | 2.2 | 286.0 | 72.8 |
| | *Osteochilus vittatus* | 22 | 1.4 | 20.3 | 6.3 | 15.7 | 4.8 | 106.6 | 61.4 |
| | *Oxygaster anomalura* | 24 | 1.6 | 19.0 | 1.8 | 15.2 | 1.4 | 40.6 | 13.7 |
| | *Rasbora borneensis* | 80 | 5.2 | 10.7 | 2.3 | 8.5 | 1.9 | 10.1 | 5.0 |
| | *Rasbora* sp. | 1 | 0.1 | 6.1 | na | 4.7 | na | 1.7 | na |
| | *Rasbora rutteni* | 4 | 0.3 | 7.2 | 3.5 | 5.7 | 2.8 | 5.7 | 3.4 |
| | *Tor tambra* | 279 | 18.1 | 13.7 | 8.2 | 11.1 | 6.6 | 63.0 | 140.3 |
| | *Tor tambroides* | 17 | 1.1 | 16.2 | 6.1 | 13.1 | 5.1 | 48.1 | 53.0 |
| Sub-total number of species | | 19 | 42.2 | | | | | | |
| Sub-total number of fish caught | | 967 | 62.9 | | | | | | |
| Mastacembelidae | *Macrognathus maculatus* | 1 | 0.1 | 25.1 | na | 24.0 | na | 42.4 | na |
| Sub-total number of species | | 1 | 2.2 | | | | | | |
| Sub-total number of fish caught | | 1 | 0.1 | | | | | | |
| Pangasiidae | *Pangasius macronema* | 2 | 0.1 | 35.4 | 3.0 | 28.9 | 2.1 | 277.5 | 74.2 |
| Sub-total number of species | | 1 | 2.2 | | | | | | |
| Sub-total number of fish caught | | 1 | 0.1 | | | | | | |
| Siluridae | *Kryptopterus lais* | 2 | 0.1 | 39.3 | 5.8 | 33.6 | 5.2 | 210.0 | 70.7 |
| Sub-total number of species | | 1 | 2.2 | | | | | | |
| Sub-total number of fish caught | | 2 | 0.1 | | | | | | |
| Sisoridae | *Glyptothorax major* | 52 | 3.4 | 7.8 | 7.0 | 5.7 | 1.7 | 4.7 | 4.4 |
| Sub-total number of species | | 1 | 2.2 | | | | | | |
| Sub-total number of fish caught | | 52 | 3.4 | | | | | | |
| Total number of species | | 45 | 100 | | | | | | |
| Total number of fish caught | | 1538 | 100 | | | | | | |
| Shannon’s diversity index, H (e) | | 2.9 | | | | | | | |
| Margalef’s richness index, D (e) | | 6.0 | | | | | | | |
| Pielou’s evenness index, J (e) | | 0.8 | | | | | | | |

Note: “na” indicates not available.

members of the family Cyprinidae is mostly due to their highly adapted body forms and mouth structure that make them thrive at all environmental conditions (Ward-Campbell *et al.*, 2005). The Balitoridae, which is the second most dominant family in the present study, is typical in high elevation areas, such as that in the upper Baleh River, which consist of mainly montane forest stream habitats. *T. tambra* which has a high economic value was found to be the most dominant species in the upper Baleh River. However, the much higher valued species, *T. tambroides* was less abundant. Studies have shown that distribution of these species are restricted to upstream and a few protected areas in Malaysia (Litis *et al*., 1997; Nyanti *et al*., 1999; Nadiatul *et al.*, 2011). The wild population of these species was low in abundance and distribution particularly in Sarawak due to deforestation, agricultural development, and overfishing (Sungan *et al*., 2006). In Peninsular Malaysia, Chong *et al*. (2010) reported that *T. tambra* and *T. tambroides* are highly threatened due to overharvesting, habitat degradation, pollution and damming of rivers. Hence, it is important to retain the upper Baleh River as a living habitat for *T. tambra* since it was found in abundance in the area.

Fish diversity in the upper Baleh River with a Shannon's diversity index of 2.9 (Table 1) is considered moderate (Odum & Barret, 2004). Species richness of the upper Baleh River with an index value of more than 5 is considered high (Magguran, 1988). The fish assemblages in the upper Baleh River with an evenness index of 0.8 are considered evenly spread (Pielou, 1966). On the other hand, the Shannon's diversity index, Margalef's richness index, and Pielou's evenness index among the 23 stations ranged from 0.4 to 2.6, from 0.3 to 4.2, and from 0.6 to 0.9 at main river and tributary stations in the upper Baleh River (Table 2). The variation in the biological indices among the 23 stations might have indicated the species richness and eveness of fish fauna corresponded to the size and quality of the streams. All three indices fluctuated at tributary stations along the upper Baleh River but showed sign of an increase at the main river. Eighteen stations were categorized as 'low' diversity (< 2) (Odum & Barret, 2004). Five stations were categorized as having 'moderate' diversity (2-4) which include three stations located at the main river and two tributary stations (Sg. Sengayuh and Sg. Bekakap). The highest species richness was found at Station 21 which was located at the lower part of the Baleh River followed by a tributary station at Sg. Bekakap. The richness index at these two stations were more than 3.5 and thus categorized as 'moderate' whereas all the other stations were categorized as 'low' species richness (Magguran, 1988). The fish assemblages are considered evenly spread over most of the stations in the upper Baleh River where 20 out of 23 stations had an evenness index of 0.7 and above (Pielou, 1966).

**Environmental Influences on Fish Assemblages**

Eighteen species that individually contributed more than 1% of the total fish caught and 10 environmental parameters were loaded in the CCA. Table 3 summarized the ten environmental parameters used in the present study. The first CCA axis (CCA1) had an eigenvalue of 0.590 and explained 27.2% of the species-environment relation variance. The CCA2 and CCA3 accounted for 20.7% and 15.7% of total variance with eigenvalues of 0.448 and 0.341, respectively. These three axes were statistically significant ($p$ value $\leq 0.05$) according to the permutation test. The CCA1 was negatively correlated with elevation and positively correlated with stream order and sedimentation. Five species including *Barbonymus collingwoodii*, *B. schwanefeldii*, *Luciosoma setigerum*, *Osteochilus vittatus*, and *Oxygaster anomalura* from family Cyprinidae had positive loadings on CCA1 and grouped together at the right portion of the CCA ordination triplot (Figure 2). This indicates that fishes in these assemblages live in the lower part of relatively larger streams and can tolerate sedimentation. Figure 2 also illustrates that those species were found abundant at stations 1, 15, and 21 which were located at the main river and stations 19 and 20 which were located at downstream. On the other hand, *Neogastromyzon chini* from family Gastromyzontidae was negatively loaded on CCA1 which indicates that the fish is living in the hilly area at the upper Baleh River with high elevation and low sedimentation. This is not surprising as fishes from the Gastromyzontidae family are often referred to as 'hill stream loaches', due to their ability to cope with fast flowing waters (Roberts, 1989). Stream order, loaded on CCA2. Among the 18 species, *Gastromyzon fasciatus*, *G. punctulatus*, and

**Table 2.** Fish biological indices in the upper Baleh River

| Station | River | Individual | Species | H (e) | D (e) | J (e) |
|---|---|---|---|---|---|---|
| 1 | Btg Baleh (upper) | 92 | 15 | 2.0 | 3.1 | 0.7 |
| 2 | Sg. Entakun | 76 | 5 | 1.3 | 0.9 | 0.8 |
| 3 | Sg. Singut | 49 | 9 | 1.9 | 2.1 | 0.9 |
| 4 | Sg. Puun | 70 | 3 | 1.0 | 0.5 | 0.9 |
| 5 | Sg. Jambu | 21 | 2 | 0.4 | 0.3 | 0.6 |
| 6 | Sg. Naah | 63 | 6 | 1.5 | 1.2 | 0.8 |
| 7 | Sg. Selentang | 71 | 5 | 1.4 | 0.9 | 0.9 |
| 8 | Sg. Penganen | 94 | 9 | 1.5 | 1.8 | 0.7 |
| 9 | Sg. Senentang Kanan | 27 | 6 | 1.4 | 1.5 | 0.8 |
| 10 | Sg. Sebatu | 33 | 10 | 1.9 | 2.6 | 0.8 |
| 11 | Sg. Irak | 163 | 9 | 1.8 | 1.6 | 0.8 |
| 12 | Sg. kerangan | 92 | 8 | 1.3 | 1.5 | 0.6 |
| 13 | Sg. Tor | 96 | 5 | 1.4 | 0.9 | 0.9 |
| 14 | Sg. Kian | 166 | 8 | 1.5 | 1.4 | 0.7 |
| 15 | Btg Baleh (middle) | 51 | 14 | 2.1 | 3.3 | 0.8 |
| 16 | Sg. Sengayuh | 21 | 10 | 2.1 | 3.0 | 0.9 |
| 17 | Sg. Nibong | 46 | 9 | 1.6 | 2.1 | 0.7 |
| 18 | Sg. Bekakap Besar | 33 | 6 | 1.1 | 1.4 | 0.6 |
| 19 | Sg. Bekakap | 80 | 17 | 2.3 | 3.7 | 0.8 |
| 20 | Sg. Kuran | 25 | 5 | 1.0 | 1.2 | 0.7 |
| 21 | Btg Baleh (lower) | 123 | 21 | 2.6 | 4.2 | 0.8 |
| 22 | Ng. Nangsang | 13 | 6 | 1.7 | 1.9 | 0.9 |
| 23 | Sg. Sekawai | 33 | 10 | 1.8 | 2.6 | 0.8 |

*Crossocheilus cobitis* were positively loaded on CCA2 and grouped together at the upper part of the first CCA ordination triplot whereas *Gastromyzon* sp. II, *Neogastromyzon chini*, *Rasbora borneensis*, and *Glyptothorax major* were negatively correlated with CCA2 and grouped together at the lower part of the first CCA ordination triplot (Figure 2). These results indicate that the first three species were mostly found at relatively larger streams with higher pH and temperature value, while the latter four fish species mostly inhabit at smaller tributaries with lower pH and temperature. The CCA3 was positively correlated with canopy cover and habitat assessment score point and negatively correlated with turbidity. Fish species that are positively correlated with CCA3 prefer to live in a stream with better habitat condition which include greater shade and low turbidity. *Gastromyzon* sp. II, *G. fasciatus*, *G. punctulatus*, *Lobocheilos falcifer* and *Rasbora borneensis* are those species that were found positively correlated with CCA3 in the present study. On the other hand, *Neogastromyzon chini*, *N. pauciradiatus*, and *T. tambroides* were found negatively loaded on CCA3 indicating that they might be more tolerant to the poorer habitat. Lastly, *T. tambra*, *L. ovalis*, and *P. microstoma* which are the top three most dominant species in the present study were comparatively distributed more around the centre of the triplot than the other species (Figure 2), indicating that they are living in a wide-ranging environment. It is hypothesized that adaptation of these fishes to a great variation of habitats occupied may be associated with their abundance at the upper Baleh River.

## Length-weight Relationship (LWR) and Fulton's Condition Factor (K)

The *Gastromyzon chini* was the smallest fish species captured in the upper Baleh River, with mean values of TL and BW of 3.3 ± 0.4 cm and 0.3 ± 0.1 g, respectively. *Kryptopterus lais* had the greatest length, 39.3 ± 5.8 cm in TL, while the heaviest fish captured was *Hemibagrus wyckii* (460.0 g) (Table 1). The LWR study was conducted on the top three most dominant species in the present study. The linear regression analysis showed significant $R^2$ values ($p$ value ≤ 0.05), ranging from 0.934 to 0.977, indicating that TL and BW of each of the species fitted well into the linear model (Table 4). The LWR for *T. tambra*, *L. ovalis*, and

**Table 3.** Ten environmental parameters in the upper Baleh River

| Station | River | Elev (m) | Stream order | Canopy cover | Sedimentation | Score | pH | Temp (°C) | Turb (NTU) | DO (mg/L) | Cond (µS/cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Btg Baleh (upper) | 120 | 5 | 1 | 2 | 16 | 7.6 | 25.1 | 41.3 | 7.9 | 37.3 |
| 2 | Sg. Entakun | 307 | 4 | 1 | 0 | 22 | 7.9 | 26.9 | 8.4 | 7.7 | 59.7 |
| 3 | Sg. Singut | 289 | 4 | 1 | 1 | 23 | 7.8 | 26.6 | 21.6 | 7.7 | 44.2 |
| 4 | Sg. Puun | 327 | 2 | 1 | 1 | 25 | 7.9 | 26.9 | 8.8 | 7.7 | 59.7 |
| 5 | Sg. Jambu | 306 | 3 | 1 | 1 | 21 | 7.4 | 24.3 | 1149.0 | 7.9 | 37.0 |
| 6 | Sg. Naah | 311 | 3 | 2 | 0 | 30 | 7.6 | 25.1 | 5.4 | 8.0 | 23.9 |
| 7 | Sg. Selentang | 249 | 2 | 1 | 0 | 17 | 7.4 | 24.3 | 25.8 | 8.0 | 48.0 |
| 8 | Sg. Penganen | 269 | 2 | 2 | 0 | 21 | 7.5 | 24.6 | 21.5 | 8.1 | 52.0 |
| 9 | Sg. Senentang Kanan | 223 | 3 | 2 | 0 | 23 | 7.8 | 26.2 | 35.8 | 7.9 | 48.9 |
| 10 | Sg. Sebatu | 242 | 1 | 3 | 0 | 31 | 7.8 | 24.3 | 8.4 | 8.1 | 47.2 |
| 11 | Sg. Irak | 268 | 3 | 1 | 0 | 17 | 7.5 | 25.4 | 14.7 | 7.9 | 50.0 |
| 12 | Sg. kerangan | 204 | 2 | 3 | 0 | 26 | 7.5 | 23.9 | 12.1 | 8.1 | 45.7 |
| 13 | Sg. Tor | 190 | 2 | 2 | 0 | 17 | 7.4 | 24.5 | 7.8 | 7.9 | 47.0 |
| 14 | Sg. Kian | 251 | 3 | 1 | 0 | 16 | 7.4 | 24.5 | 6.9 | 8.0 | 45.0 |
| 15 | Btg Baleh (middle) | 160 | 5 | 1 | 2 | 16 | 7.2 | 23.8 | 702.1 | 8.0 | 31.0 |
| 16 | Sg. Sengayuh | 220 | 3 | 3 | 0 | 33 | 7.6 | 26.2 | 2.1 | 7.8 | 44.5 |
| 17 | Sg. Nibong | 252 | 3 | 3 | 0 | 28 | 7.7 | 27.1 | 2.1 | 7.8 | 42.5 |
| 18 | Sg. Bekakap Besar | 163 | 4 | 2 | 0 | 22 | 7.8 | 25.7 | 1.5 | 8.0 | 57.0 |
| 19 | Sg. Bekakap | 128 | 3 | 2 | 1 | 25 | 7.6 | 25.3 | 3.8 | 7.9 | 47.6 |
| 20 | Sg. Kuran | 99 | 3 | 2 | 0 | 23 | 7.4 | 25.0 | 5.3 | 7.9 | 43.0 |
| 21 | Btg Baleh (lower) | 160 | 5 | 1 | 2 | 16 | 7.2 | 23.8 | 544.9 | 8.0 | 33.7 |
| 22 | Ng. Nangsang | 121 | 1 | 3 | 0 | 27 | 7.4 | 26.6 | 14.6 | 7.6 | 28.0 |
| 23 | Sg. Sekawai | 109 | 2 | 2 | 0 | 17 | 7.2 | 29.2 | 5.8 | 7.5 | 39.5 |

*P. microstoma* in the upper Baleh River was determined as $W = 0.013L^{2.919}$, $W = 0.020L^{2.719}$ and $W = 0.005L^{3.153}$ respectively. The coefficient 'n' value for *T. tambra* and *L. ovalis* of less than 3 indicates that they were exhibiting a negative allometric growth. On the other hand, *P. microstoma* grew heavier in the upper Baleh River as indicated by the 'n' value of more than 3. All 'n' values in the present study fall within the range of 2.5 to 3.5 for most fish (Froese, 2006).

Interestingly, the most dominant species, *T. tambra*, and the second most dominant species, *L. ovalis*, exhibited negative allometric growth, while the third most dominant species, *P. microstoma* exhibited a positive allometric growth. Food availability, environmental conditions or other life-history strategies could be reasons for the different growth patterns exhibited by these species. Competition for food may occur when *T. tambra* and *L. ovalis* are in abundance. On the other hand, a mountainous forest stream in the present study area is considered to be a more suitable environmental condition for *P. microstoma,* since the Gastromyzontidae family is typical in high elevation areas.

The Fulton's condition factors (K) of *T. tambra*, *L. ovalis*, and *P. microstoma* were 1.07 ± 0.30, 1.13 ± 0.49, and 0.70 ± 0.22, respectively, in the upper Baleh River (Table 5). More than 80% of K values of *T. tambra* were found in the range between 0. 8 and 1.2 which indicates that most of the fish in this species were in fair to poor conditions. More than 70% of K values of *L. ovalis* were found to be less than 1.0,

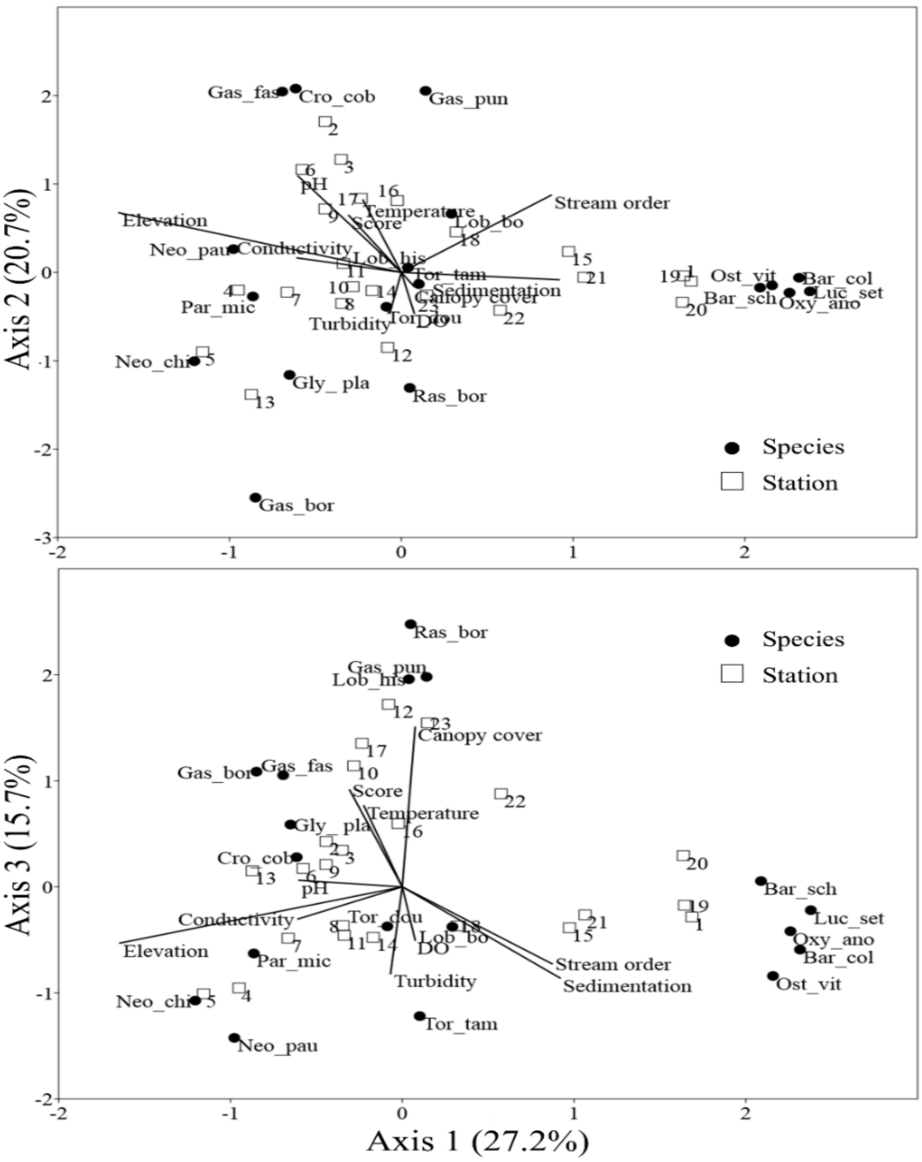


**Figure 2.** CCA ordination triplots of the abundance of the 18 species (> 1%) with ten environmental parameters at 23 stations in the upper Baleh River. Gas_bor = *Gastromyzo*n sp. II, Gas_fas = *G. fasciatus*, Gas_pun = *G. punctulatus*, Neo_chi = *Neogastromyzon chini*, Neo_pau = *N. pauciradiatus*, Par_mic = *Parhomaloptera microstoma*, Bar_col = *Barbonymus collingwoodii*, Bar_sch = *B. schwanefeldii*, Cro_cob = *Crossocheilus cobitis,* Lob_bo = *Lobocheilos ovalis*, Lob_his = *L. falcifer*, Luc_set = *Luciosoma setigerum*, Ost_vit = *Osteochilus vittatus*, Oxy_ano = *Oxygaster anomalura*, Ras_bor = *Rasbora borneensis*, Tor_dou = *Tor tambra*, Tor_tam = *T. tambroides*, Gly_ pla = *Glyptothorax major*

indicating that they were in poor to extremely poor conditions. Most of the *P. microstoma* (85.1%) were found to be less than 0.8 in K values, indicating that they were in extremely poor condition (Barnham & Baxter, 1998). The value of K is influenced by season, age, sex, and gonad development of the fish, feeding and stomach fullness, as well as proximate body composition (Le Cren, 1951; Mohsin & Ambak, 1983; Barnham & Baxter, 1998; Schneider *et al*., 2000; Gupta *et al*., 2011; Mozsar *et al*., 2015). Since water samples taken from the upper Baleh River contained high suspended solids, particularly after rain (Ling *et al*., 2016), exposure to high turbidity and suspended solids could have reduced their feeding rate and growth (Bergstedt & Bergersen, 1997; Rowe & Dean, 1998; Lake & Hinch, 1999).

**Table 4.** Summary of regression analyses of length-weight relationship of the top three dominant species in the upper Baleh River

| Species | Log BW = Log a + nLog TL | | | Parameter estimates | | Standard error | *p* value | 95.0% confidence interval | | LWR: W = aL$^n$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | N | $R^2$ | *p* value | | | | | Lower bound | Upper bound | |
| *Tor tambra* | 279 | 0.977 | 0.000 | a | -1.891 | 0.029 | 0.000 | -1.948 | -1.833 | $W = 0.013L^{2.919}$ |
| | | | | n | 2.919 | 0.027 | 0.000 | 2.866 | 2.971 | |
| *Lobocheilos ovalis* | 198 | 0.934 | 0.000 | a | -1.704 | 0.056 | 0.000 | -1.815 | -1.594 | $W = 0.020L^{2.719}$ |
| | | | | n | 2.719 | 0.052 | 0.000 | 2.618 | 2.821 | |
| *Parhomaloptera microstoma* | 174 | 0.938 | 0.000 | a | -2.280 | 0.045 | 0.000 | -2.369 | -2.191 | $W = 0.005L^{3.153}$ |
| | | | | n | 3.153 | 0.062 | 0.000 | 3.031 | 3.274 | |

**Table 5.** Summary of Fulton’s condition factor (K) of the top three dominant species in the upper Baleh River

| Species | N | Fulton's condition factor (K) | | | | Percentages of individual | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Min | Max | Mean | SD | ≤ 0.8 | 0.8 < x ≤ 1 | 1 < x ≤ 1.2 | 1.2 <x≤ 1.4 | 1.4 < x ≤1.6 | >1.6 |
| *Tor tambra* | 279 | 0.27 | 2.49 | 1.07 | 0.30 | 2.5 | 44.1 | 37.6 | 6.5 | 1.1 | 8.2 |
| *Lobocheilos ovalis* | 198 | 0.54 | 2.95 | 1.13 | 0.49 | 36.4 | 34.3 | 6.6 | 0.0 | 0.5 | 22.2 |
| *Parhomaloptera microstoma* | 174 | 0.25 | 2.88 | 0.70 | 0.22 | 85.1 | 12.6 | 0.6 | 1.1 | 0.0 | 0.6 |

## CONCLUSION

The fish assemblages in the upper Baleh River are moderately diverse and rich in species, the richness values spread evenly along the river. Environmental parameters including elevation, stream order, and sedimentation were the most significant factors related to the fish assemblages in the river. The three most dominant fish species were *T. tambra* (18.1%) and *L. ovalis* (12.9%) from the Cyprinidae family, followed by *P. microstoma* (11.3%) from the Balitoridae family. Length-weight relationship analysis showed that the first two species exhibited a negative allometric growth pattern while the latter exhibited a positive allometric growth pattern. All of them did not show healthy conditions, according to the Fulton’s condition factor. It is suggested that various factors including food competition and environmental condition could have contributed to the different growth pattern and condition of these fishes. Further studies need to be conducted to investigate the underlying factors that are affecting the fish’s health in the upper Baleh River.

## ACKNOWLEDGEMENTS

The authors would like to thank Forest Department Sarawak and Institute of Biodiversity and Environmental Conservation, Universiti Malaysia Sarawak for organizing the expedition in November 2015, Sarawak Energy Berhad for the financial assistance, and Mustapha Kamal, Lai Wei Sing and Chai Hui Ping for their field assistance. Data collected in April 2015 was made possible by the financial assistance of Sarawak Energy Berhad through Grant No. GL(F07)/SEB/1A/2013 (12) and is gratefully acknowledged.

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