Faculty of Resource Science and Technology

Diversity of Fish Fauna and Water Quality at the Downstream of Bakun HEP, Batang Balui, Belaga, Sarawak

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Declaration

I, **Sandra Cindy Liew Chiew Fah**, declare that the final year report entitled, **Diversity of Fish Fauna and Water Quality at the Downstream of Bakun HEP, Batang Balui, Belaga, Sarawak** and the work presented in the report are both my own, and have been generated by me as the result of my own original research. I confirm that:

- this work was done wholly or mainly while in candidature for a research degree at this University;
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- I have acknowledged all main sources of help;
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Signed: Sandra

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List of Abbreviations

DO	Dissolved Oxygen
TSS	Total Suspended Solids
BOD_5	Biological Oxygen Demand day 5
HSI	Hepatosomatic Index
GSI	Gonadosomatic Index
SL	Standard Length
TL	Total Length
H	Shannon-Weiner's Diversity Index
J	Pielou's Evenness Index
D	Margalef's Species Richness Index
K	Fulton's Condition Factor

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ABSTRACT

A study on the fish fauna diversity and water quality was conducted at six stations downstream of Bakun HEP, Batang Balui, Belaga from 20th to 26th August 2015 and from 5th to 11th Novermber 2015. The fishes were caught using monofilament gill nets with different mesh sizes and three-layered net. A total of 364 individuals were caught and dominated by the family Cyprinidae (50.82%), followed by Pangasiidae (46.43%), Bagridae (1.37%), Siluridae (0.82%), and Notopteridae (0.55%). The species from the family Cyprinidae are *Cyclocheilichthys apogon* (7.14%), *Osteochilus vittatus* (4.95%), *Parachela oxygastroides* (4.67%), *Barbonymus schwanenfeldii* (4.40%), and *Labiobarbus festivus* (4.40%). The distance of sampling stations from the dam to station in upstream of Batang Balui is approximately 3.20 km. Temperature ranged from 26.81 to 27.81 °C, pH with range of 6.32 to 7.47, turbidity from 16.8 NTU to 47.4 NTU, chl-*a* with range of 0.0032 to 0.036 µg/L and TSS from 16.33 to 30.8 mg/L, and showed significant difference between sampling. The dissolved oxygen ranged from 3.70 to 7.83 mg/L, conductivity with range of 35.0 to 45.0 µS/cm and BOD_5 ranged from 1.03 to 6.0 mg/L, and showed no significant difference between sampling periods. The PCA analysis indicated that fishes such as *Pangasius macronema, Lobocheilos bo,* and *Osteochilus vittatus* can tolerate the stated range of TSS and turbidity. The present study showed that regulated release of water from Bakun HEP might have impact on fish diversity and water quality at Batang Balui region.

Key words: Fish fauna, diversity, dominance, Batang Balui, water quality parameters

ABSTRAK

Satu kajian mengenai kepelbagaian ikan dan parameter kualiti air telah dijalankan pada 20hb hingga 26hb Ogos 2015 dan 5hb hingga 11hb November 2015 di hilir empangan Bakun, Batang Balui, Belaga. Ikan-ikan tersebut telah ditangkap dengan menggunakan pukat yang berlainan saiz jaring dan pukat tiga lapis. Sejumlah 364 ekor ikan telah ditangkap sepanjang kajian tersebut dan didominasi oleh keluarga Cyprinidae (50.82%), diikuti keluarga Pangasiidae (46.43%), Bagridae (1.37%), Siluridae (0.82%) dan Notopteridae (0.55%). Species ikan untuk keluarga Cyprinidae adalah Cyclocheilichthys apogon (7.14%), Osteochilus vittatus (4.95%), Parachela oxygastroides (4.67%), Barbonymus schwanenfeldii (4.40%) dan Labiobarbus festivus (4.40%). Jarak antara empangan Bakun dengan stesen di hilir Batang Balui adalah sejauh 3.20 km. *Suhu air adalah dalam linkungan 26.81 hingga 27.81 ℃, pH berjulat 6.32 hingga 7.47, keruhan air berjumlah sebanyak 16.8 hingga 47.4 NTU, chl-a dari 0.0032 sehingga 0.036 µg/L dan diikuti TSS dari 16.33 hingga 30.8 mg/L, dan menunjukkan perbezaan signifikan antara dua tempoh kajian yang berlainan. Kepekatan oksigen terlarut air adalah dari 3.70 hingga 7.83 mg/L, konduktiviti air berjulat 35.0 hingga 45.0 µS/cm dan BOD_5 dari 1.03 hingga 6.0 mg/L dan menunjukkan tiada perbezaan signifikan antara dua tempoh kajian yang berlainan. Analisis PCA merumuskan bahawa ikan seperti Pangasius macronema, Lobocheilos bo, Osteochilus vittatus dapat menyesuaikam diri dengan TSS dan keruhan air. Kajian terkini menunjukkan aliran air yang terkawal dari Bakun HEP berkemungkinan memberi impak terhadap kepelbagaian ikan dan kualiti air di Batang Balui.*

Kata kunci: *Fauna ikan, kepelbagaian, dominan, Batang Balui, parameter kualiti air*

1.0 Introduction

Sarawak has various river system to allow freshwater fish fauna to blossom in natural environment. The highly diverse fish fauna populations serve as the main protein source to local communities. The main river which is Rajang River in Sarawak has a total watershed area of 51,315 km^2 with a mean flow of 3,000 m^3/s (Yusoff *et al.*, 2006). Atack (2006) reported there are 256 species of freshwater fishes meanwhile Parenti and Lim (2005) documented 164 species in Rajang basin. The condition of freshwater habitat in Rajang basin is partially shaded forest river filled with mud, sand, fallen leaves and branches (Parenti and Lim, 2005).

The main Rajang River flows for 563 km from its headwater to South China Sea which passes through hilly mountains and large gorges through complex ecosystem (Liechti, 1960; Staub *et al.*, 2000). Based on Rajang River website (2015), it is the longest river in Malaysia with a distance of 563 km (http://global.britannica.com/place/Rajang-River). The main tributaries are Baleh River, Katibas River, Ngemah River, and Kanowit River.

The country's largest and tallest dam with 205 m high was impounded at the narrow Bakun Fall of Batang Balui (Rajang River, 2015). The Rajang River plays an essential role in transportation in rural areas because logging is one of the main income in Sarawak (Khoo *et al.*, 1992). This study was conducted at downstream of Bakun HEP, Batang Balui which is located at longitude N 02^0 46' and latitude E 114^0 00'.

The information on freshwater fishes in downstream of Bakun HEP, Batang Balui is scarce. The impact of dam on Batang Balui fish fauna and water quality are poorly known. Therefore, the objectives of this present study were to:

1. determine the diversity and abundance of fish fauna at Batang Balui, downstream of Bakun HEP,
2. document the selected water quality parameters at Batang Balui downstream of Bakun HEP, and
3. report the stomach content of three dominant fish species at the study area.

2.0 Literature Review

2.1 Fish Assemblages

Fishes are the most diverse, abundant and contribute around 50 % of all the described vertebrates numbering around 24,618 out of 48,170 species (Maitland, 1995). Nelson (1994) roughly estimated approximately 21,723 species of living fishes found. Therefore, spatial and temporal patterns studies are vital tools to investigate the diversity, distribution and species composition of freshwater fishes which make up the fish community (Belliard *et al.*, 1997; Galactosa *et al.*, 2004).

The ecosystem is associated with conservation of freshwater fishes. Sala *et al.* (2000) and Jenkins (2003) reported that freshwater biodiversity has plummeted at a rate higher than terrestrial and marine ecosystems. The river inundation which modifies natural hydrology is the main impact on freshwater fishes in worldwide (Nilsson *et al.*, 2005; Dudgeon *et al.*, 2006). The effects of river inundation are fragments ecosystem and extinction of native species which is fully dependent on lotic environment as well as changes in energy flow in a trophic structure (Allan and Flecker, 1993; Hoeinghaus *et al.*, 2007; 2008). The modification in river flow affects the health of riverine ecosystem due to its interruption in channel pattern (Ward and Stanford, 1983) and disrupts the interaction between channel and floodplain (Ward and Stanford, 1995).

Ribeiro *et al.* (1995) documented a drastic decline in fishery catches in tropical river which is a common trend after damming. This is because the distribution of each species of fish is closely related with food source, breeding sites, water depth, current, topography and physicochemical properties of water (Harris, 1995). Therefore, dam obstruction induces disruptions (Resh *et al.*, 1988) where fish assemblage has to endure and recover over a period of many years.

Before impoundment, natural floods are mainly affecting fish assemblages by modifying food resource and introducing floodplain habitats (Lowe-McConnell, 1987). Allan (1995) stated that flood create harsh condition where juveniles of aquatic organisms has higher percentage of being carried away by high speed of water. According to Schlosser (1985), juveniles of fishes are prone to changes in river flow. Harvey (1987) documented that these juveniles are exposed to displacement during floods.

On the other hand, there are certain authors who stated that a return in natural flooding events is one of the steps in restoration of fish assemblages (Bayley, 1995). The empirical evidence carried out by Deslandes *et al.* (1995) displayed an enhance flow at the downstream of dam can promote diversity and abundance of riverine fish assemblages.

2.2 Ecology and Freshwater Fishes of Sarawak

Borneo is known as the world's third largest island with the land area of 743,107 km^2 including a drainage basin of 50,000 km^2 which covers a total of 40% of land in Sarawak and 7% of that of Borneo (Liechti, 1960; Staub *et al.*, 2000). Sulaiman and Mayden (2012) reported that Borneo Island is renowned as third largest island worldwide with land area covering 745,567 km^2 and has pristine rainforest habitat. Borneo is situated at the equatorial zone where high temperatures during daytime can reach up to 32 ^0C and remained humid all year round.

The geographical structure for habitat of freshwater fish is shaded area with rapid flow of water and aided with silt, rocky, mud or sandy bottom (Lee and Ng, 1994). Several factors such as river depth and water current can affect the ecology and distribution of fish species. Shah *et al.* (2006) and McCabe (2010) highlighted the river with deep and slow movement of water has higher possibility to carry larger and more diverse species as compared to river with shallow water. This is because larger river have more space for movement and reproduction of fish and also possess an ample amount of food source. On the contrary, primary productivity in shallow water can be promoted with the availability of moderate light penetration into turbid river (McCabe, 2010; Turner *et al.*, 2011). This allows the growth of small-bodied fish species which feed on phytoplankton drifting in water column.

In Sarawak, the Department of Agriculture had done the study on freshwater fishes in Rajang River, Batang Ai and Baram River in 1985. This study documented 59 species in Rajang River, 31 species in Batang Ai and 43 species in Baram River. Besides that, other researchers have also conducted studies at locations such as Bario, Kelabit Highlands, Balai Ringin and Lutong River in Sarawak (Nyanti *et al.*, 1999; Khairul Adha *et al.*, 2009).

2.3 Impact of Dam

Dam is built to provide water supply for developing industries, drinking purposes, generation of electricity via hydroelectric and recreational activities (Kim *et al.*, 2002; Choi *et al.*, 2005; Sternberg, 2006). Schnitter (1994) reported that human have built dam as early as in 2600 BC at Sadd el Kafara, Egypt.

In Malaysia, the Sarawak Corridor of Renewable Energy (SCORE) is a key to masterplan to the Eleventh Malaysia Plan (2016-2020) which is the last stage for Malaysia to be renowed as a developed nation by 2020. SCORE documents national development policy (RECODA, 2007) and acts as the nerve centre in the impoundment of the Bakun Hydroelectric Project (HEP) which is located off 60 km west of Belaga at the Balui River. Sovacool and Bulan (2011) reported that the area of catchment is 14,750 km^2 and Mamat *et al.* (2011) stated that an area of 69,640 hectares is severely devastated by flooding.

The impact of damming has vigorously altered the natural condition and causing habitat loss and spawning ground. Agostinho *et al.* (2008) reported that the shaping of freshwater ecosystems is mainly caused by excessive river damming which experience transformed water flows. Seo (2005) also supported that large hydraulic structure fragments the downstream of river which affects aquatic ecosystems by formation of pools and riffles in stagnated water. Dam also alters biological invasions due to obvious changes in water level, surrounding temperature, nutrient content, and also availability of niche (Davis *et al.*, 2000; Johnson *et al.*, 2008).

Furthermore, construction of dam severely changes the dynamic of water, habitat, nutrient cycling, primary productivity and lastly the stretches of natural river systems (Nilsson *et al.*, 2005; Dudgeon *et al.*, 2006; Agostinho *et al.*, 2008). Agostinho *et al.* (1999) hypothesised that dam construction further changes the condition of ichthyofauna namely with rapid decline in population or loss of rheophilic species. Johnson *et al.* (2008) also supported that damming disrupt the dispersal of non-native species throughout the affected areas. In addition, damming causes loss of threatened, endangered and habitat-specialist species to local fauna (Brandao and Araujo, 2008). According to Liu (1997), in past decade in China, the downstream of Gezhouba Dam with 400 km of spawning ground were devastated in conjunction with damming.

2.4 Feeding Guild

Rohasliney *et al.* (2010) stated a repertoire of food organisms and organisms are provided by richness and variety of natural river habitat. The origin of raw material in an ecosystem is derived from autochthonous or allochthonous food source which are brought in via river flow or decomposition products on inundated ground mainly alluvial silt and dissolved nutrients (Helfman *et al.*, 1997). According to Ismail and Ismail (2008), the ubiquitous fish feeding guilds in tropical river is algivorous, planktivorous, insectivorous, piscivorous, herbivorous and omnivorous diet.

In a riverine habitat, Perrow *et al.* (1997) estimated a high percentage of piscivorous fish accompanied with low density zooplankton and low biomass of benthic fish. On the other hand, the same ecosystem should have a high percentage of insectivorous fish, then detritivores, followed by piscivores and accompanied with minimal percentage of herbivorous, planktivorous, and lastly omnivorous species (Rohasliney and Jackson, 2009). There are certain species which changes with time and feeding habits and also not consistent in different stages of life cycle. Nevertheless, Mohsin and Ambak (1983), Kottelat *et al.* (1993) and Ambak *et al.* (2010) have documented on trophic guild of freshwater fish in Malaysia.

Study on different feeding groups of fishes done by Walters *et al.* (2003) showed that there were impacts exerted on the stability of river's trophic level and interaction amongst aquatic organism. For example, the grazing pressure of zooplankton on phytoplankton can be reduced by selective predation from zooplanktivorous fish (Perrow *et al.*, 1996). Besides that, benthivorous fish may uproot submerged plant which may cause suspension of fine sediment in water bodies (Zambrano *et al.*, 2006).

Herbivorous species tend to possess longer intestines than carnivorous species in most vertebrate taxa. Kramer and Bryant (1995) reported that the length of gut clearly differentiate detritivorous, algivorous and herbivorous fishes from carnivorous species. This pattern for fish species is recorded by Barrington (1957) and Nikolsky (1963) meanwhile the selective comparisons between related species with different diets are documented by Fryer and Hes (1972). For example, Al-Hussaini (1947) and Kapoor *et al.* (1975) summarised a relative intestine length where 0.5 cm to 2.4 cm (carnivores), 0.8 cm to 5 cm (omnivores), and 2 cm to 21 cm (herbivores). Besides that, a similar trend was also observed by Fryer and Hes (1972) amongst the Cichlidae found in African lake basin.

2.5 Length-weight Relationship

The length-weight relationship (LWR) is defined as the relation between length and weight of fish based on their natural body shape (Schneider *et al.,* 2000). Bolger and Connolly (1989) defined LWR as evaluation between the relative fitness of fish population. According to Morey *et al.* (2003), *b* refers to growth equation which has details on fish growth while Lleonart *et al.* (2000) deduced that *a* is related to body shape of fish. Mir *et al.* (2012) reported that LWR can also evaluate the relationship changes with life development and also facilitation of taxonomic units.

2.6 Hepatosomatic index (HSI) and Gonadosomatic index (GSI)

Hepatosomatic index (HSI) and Gonadosomatic index (GSI) have been widely used by researcher as an indicator to spawning season. The HSI is used to evaluate the rate of metabolism which is closely related to digestion, absorption, synthesis, secretion of digestive enzymes and carbohydrate metabolism (McLaughlin, 1983). The role of liver is to carry out physiological functions such as converting excess sugar into glycogen, detoxification and as haemopoietic organ in destroying old erythrocytes.

The GSI refers to the percentage of gonad weight and fish weight ratio including quantitative gonadal changes (Wootton, 1992). Hogg (1976) hypothesised GSI is a better indicator during spawning period in rainy season. In general, female fishes have higher GSI value than male fishes due to increase in ovary weight during spawning.

Both HSI and GSI are co-related due to vitellogenesis process where vitellogenin refers to the precursor of yolk which is induced by estradiol 17β and synthesised in liver (Guerreiro *et al.*, 2002; Babin *et al.*, 2007; Yaron and Levavi-Sivan, 2011). The vitellogenin is transported to oocytes via blood flow which accumulates and promotes the increase in ovary weight. This process in return can increase HSI and GSI activities by enhancing liver and gonad weights (Cerda *et al.*, 1996; Cek *et al.*, 2001). Siby *et al.* (2009) conducted experiment on rainbow fishes where they concluded that higher value of HSI and GSI were due to higher level of ovary maturity.

2.7 Water Quality

Monitoring of water quality is crucial to many researches where they can investigate pollution cases, obtain baseline data, water quality surveillance and forecasting, management of reservoir fisheries and also water for human consumption (Ahamed and Krishnamurthy, 1990; Chavan *et al.*, 2004; Kirubavathy *et al.,* 2005).

The quality of river water can be affected by variation in seasonal rainfall and based on Rybak (2000), these major changes may reflect watershed geology, landscape patchiness and land usage. Seo (2005) stated that large input of organic matters and nutrients similarly with longer retention time further devastate physical, chemical and biological content of flowing streams. Agostinho *et al.* (2008) also stated that chemical, geomorphological and hydrological are also being altered in modified water flow.

Elmaci *et al.* (2008) reported that the uncontrolled management in industrial development, agricultural, sewage dumping and other anthropogenic activity mainly deteriorate water quality of both natural water bodies and man-made reservoirs. Pimenta *et al.* (2012) also reported on the impact of dam construction which can affect the quantity and quality of water on the diverse biodiversity found in the natural river ecosystems.

Therefore, water monitoring is effective in investigating chlorophyll-*a* (Chl-*a*), Total Suspended Solids (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD5), temperature, turbidity, conductivity, transparency, and depth. Firstly, the pH of natural water range from 6.5 to 8.5 (Tepe *et al.*, 2005) and is a measure of buffering capacity of both acidic and alkaline characteristics. pH can be controlled by the dissolved substances and biochemical process occurring in nature.

The transparency of water is indicated by the depth of light penetration into water body aided with the settling of particles such as sediments and debris. Besides that, turbidity is inversely proportional to transparency where light penetration is inhibited by particles such as silt, clay, debris, organic and inorganic particles. Gliwicz (1999) documented the increased in turbidity level by an influx of clay particles from the watershed during wet seasons causes minimal value in water transparency.

DO is a vital tool to estimate water quality, ecological status, primary productivity and health of a river ecosystem. It is also an index of physical and biochemical processes in water bodies. For instance, low DO is caused by decomposition of carbonaceous materials which is submerged in the water (Nyanti, 2012). The content of DO comes from diffusion with air particles or from photosynthesis process by autotrophs. The DO is strongly correlated with temperature where higher photosynthetic process will occur during strong solar radiation.

3.0 Materials and Methods

3.1 Fish fauna

3.1.1 Sampling methods

Two trips were conducted from 20th to 26th of August 2015 and also from 5th to 11th of November 2015. A total of six sampling stations were chosen in the study area. The distance from each station was approximately 1 km apart and coordinates were taken using GPS (Garmin GPSmap62S). The weather condition was observed and any ongoing activities around the river were noted.

A total of two sets of nets encompassed four monofilament gill nets of different mesh sizes (2.54 cm, 5.08 cm, 7.62 cm and 10.16 cm) and one three-layered net (2.54 cm, 7.62 cm and 17.78 cm) were randomly distributed to the six stations. These nets were set in the morning at all stations and left overnight. In addition, these nets were checked from time to time to collect trapped fishes and also to get rid of fallen leaves, twigs and trapped debris. The location of study site is presented in Figure 1.

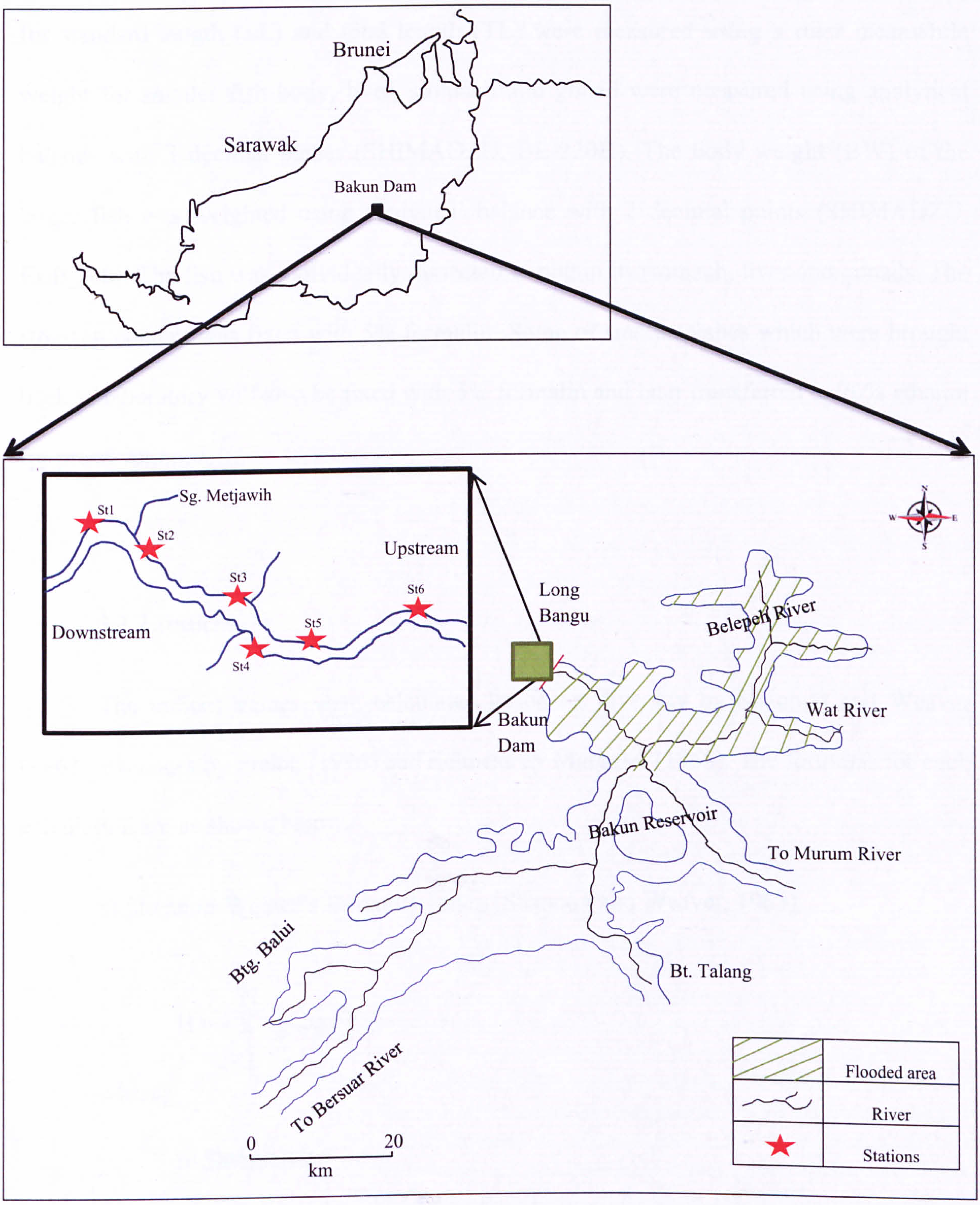

Figure 1: Location of six sampling stations at Batang Balui, Belaga.