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Research Article

The ichthyofauna of Maliau Basin buffer zone at Maliau Basin Conservation Area, Sabah, Malaysia

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ABSTRACT. A survey of fish fauna at the Maliau Basin Conservation Area Buffer Zone was carried out during a scientific expedition by the Sabah Department of Fisheries from 7-11 December 2009. Generally, the streams and rivers were typical of small- and intermediate-sized channel morphology located at lower altitudes. A total of 15 species belonging to 13 genera and four families from four rivers and one off-channel creek were collected. Analyses based on the number of individuals caught showed 70% were represented by the family of Cyprinidae, Osphronemidae (23%), Gastromyzontidae (5%) and Claridae (2%). *Betta gladiator, Rasbora sumatrana* and *Lobocheilus bo* were the dominant fish caught. The presence of commercially important and of conservation concern endemic species in this Buffer Zone calls for a comprehensive management plan in order to warrant comprehensive protection of the Maliau Basin Conservation Area ichthyofauna diversity.

Keywords: Ichthyofauna, diversity, Maliau Basin Buffer Zone.

INTRODUCTION

Maliau Basin is a saucer-shaped depression enclosed by a mountainous rim in the remote south-central part of Sabah. It has undisturbed flora and fauna. An overwhelming 1,806 higher plant species, 270 bird species, 86 mammal species and 46 amphibian species have so far been recorded at Maliau Basin. The total number of known species is considerable and represent only a fraction of the true number. Three percent of Maliau's species (19 mammal species, 21 bird species, 22 amphibian species and 11 plant species) are endemic to Sabah or to Borneo. Some are very rare, while some have not been found elsewhere (Phillipps, 2000; Hazebroek *et al.,* 2004). It is also a last refuge for many species that are being lost elsewhere because of habitat disturbance. Maliau's highland heath forest cannot be found anywhere else in Sabah, and the casuarina-dominated forest community may well be unique to Maliau Basin. Scientific explorations have only recently started and undoubtedly, many mysteries remain unveiled (Hazebroek *et al.,* 2004). The Maliau Basin represents a single catchment, and is drained by a set of radiating streams that converge to form the Maliau River. Maliau holds Malaysia's record for the highest number of waterfalls within a gorge. Outside the Basin, it joins the Kuamut River, a major tributary of the Kinabatangan River (Hazebroek *et al.,* 2004).

Previous studies on fish fauna of the Maliau Basin Conservation Area were carried out by Marsh (1988), Martin Smith *et al.* (1998) and Jimmy *et al.* (2010). Marsh (1988) and Martin-Smith *et al.* (1998) recorded three species of fish at the upland of the Maliau Basin Conservation Zone, namely *Puntius sealei* (Herre 1993), *Hemibagrus nemurus*

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(Valenciennes 1839) and *Betta unimaculata* (Popta 1905). Marsh (1988) obtained the ichthyofauna from the Maliau River and within two small streams, one of them draining from a hill dipterocarp forest (450 m a.s.l) while the other is from a blackwater stream (950 m a.s.l). Martin-Smith *et al.* (1998) reconfirms the same three species from the Maliau River main channel and in small tributaries at different altitudes (up to 1000 m a.s.l). Jimmy *et al.* (2010) reported two species, *Puntius sealei* and *Hemibagrus nemurus,* surveyed at Sungai Ginseng (600 m a.s.l) located in the interior part of the Maliau Basin Conservation Area.

The freshwater ichthyofauna of Maliau River and its tributaries carried out by Marsh (1988), Martin-Smith *et al.* (1998) and Jimmy *et al.* (2010) were only confined to the rivers in the interior upland towards the headwater part of the conservation zone, namely Maliau River and its tributaries. No information on the fish fauna from the buffer zone of the lowland area of the Maliau Basin Conservation Area is available. This present study was carried out during the First Maliau Basin Scientific Expedition from 7-13 December 2009 by the Sabah Fisheries Department. This article records for the first time the fish fauna from rivers and streams located in the lowland buffer zone of the Maliau Basin Conservation Area, namely Tembadau River and Agathis River.

The objective was to collect data on freshwater ichthyofauna in the streams of the Maliau Basin Buffer Zone. This data will complement previous data for the Maliau Basin Conservation Area and be used as baseline data that will be valuable for management and conservation purposes, and to assess future environmental impacts of economic development in the area.

MATERIALS AND METHODS

Study Sites

The first expedition was carried out from 7 – 13 December 2009 at three rivers at the Maliau Basin Buffer Zone namely Tembadau River, Maliau River, Agathis River and one unnamed creek within the vicinity of Agathis River. A description of the study sites visited during the present study is given in Table 1. Sampling sites were randomly selected and were limited to the survey accessibility during the sampling period and manpower (Figure 1). Emphasis was given to streams or rivers that were not previously surveyed.

Sampling Methods

Fish were collected mainly using cast netting with stretched mesh of 7.6 cm. Scoop nets, kick nets and seine-nest were used where permitted, to collect fish. Effort and type of gear used at rivers varied widely. River morphology and characteristics of the chosen habitat were recorded for all locations. General water conditions, several physicochemical parameters and the width of the river were also recorded. All fish were identified and their standard length measurements were taken. Identification in the field and subsequent confirmation in the laboratory were based on findings from Mohsin & Ambak (1992), Inger & Chin (2002) and Tan (2006). Specimens were indentified to the lowest taxonomic level where possible. Voucher specimens were preserved in 10% formalin in the field but replaced with 75% ethanol after 2 weeks in the laboratory. Specimens used for genetic identification were preserved in 95% ethanol. Sequences of each of the specimens were deposited into the GenBank under accession nos. JN646091-JN646092 and JN646097-JN646103. Voucher specimens are currently deposited at the Ichthyological Collections at the Likas Fisheries Research Centre.

RESULTS AND DISCUSSION

River characteristics

The characteristics and morphology of each sampling location observed are described in Table 1. Maliau River at Station 1 and 2 show the features of a typical undisturbed cobble-riffle-pool intermediate-size channel morphology at lower altitude with cobble and

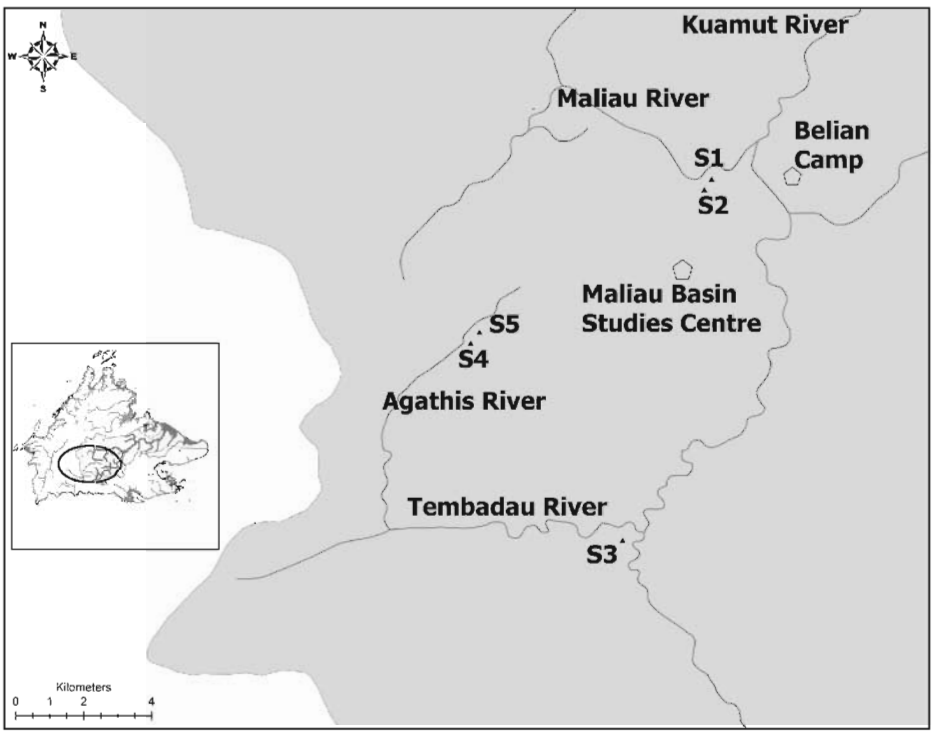

Figure 1. Map of the Maliau Basin catchment and its environs. The locations of study site 1-5 are indicated. The inset shows the areas of collection in relation to Sabah.

gravel bottom (Hogan & Ward, 1997). The riverbanks were lined by sand, gravel and cobble, while shore vegetation consisted of primary forest. Tembadau River at Station 3 have features of a disturbed small-size channel at lower altitude (Hogan & Ward, 1997) as shown by the presence of secondary forests in its riparian zone, rocky and silt bottom and turbid water. Agathis River show features of a typical undisturbed small debris-boulder-step-pool small-size channel morphology at middle altitude (Hogan & Ward, 1997). The morphology is formed by clusters of boulders and cobbles and some large woody debris which clusters into lines that cross the channel and form stable steps with intervening pools. The riparian vegetation consisted of primary forest. Station 5 is an off-channel habitat with very slow moving, almost stagnant water with silt bottom and abundant organic debris.

The physiochemical water parameters for the rivers surveyed were summarized in Table 2. The water temperature was generally cool, ranging from 23-25°C with an average of 23.6° C for all the stations. It was probably due to Maliau Basin being located at high elevation and the study location was enclosed by forest canopy in most part (Harun *et al.*, 2010). Dissolved oxygen level of the water was high ranging from 8.32-9.55 mg/L with a mean of 8.9 mg/L, except in Station 5. The high concentration of dissolved oxygen indicated good aeration, which attributed to lower temperature and rapid flow. Low dissolved oxygen concentrations in forested streams are associated with low stream flow velocities and organic channel bottoms (Ice & Sugden, 2003). The low level of dissolved oxygen at Station 5 (0.26 mg/L) was probably due to slow moving, almost-stagnant water flow, and the presence of

Table 1. The characteristics of each station surveyed at five sampling stations in Maliau Basin Buffer Zone.

Station	Location	Habitat Descriptions
1 (Maliau River A)	N 04°44.517' E 116°58.295' 100 m from Belian Camp	Large (12-15 m wide and 0.6-2.1 m deep) downstream channel of Maliau River main channel located at 223 m a.s.l. River is acidic with clear tea-colored water. Moderate flow of runs with small boulders, some cobbles and gravels with sand. Riffles with cobble, pebble and sand substrate shallow, fast water. Riverbank materials consist of cobbles, peebles and sand. Mostly unshaded except for edge of some pools. Riparian zone (up to 100 m to the land) mostly dominated by shrubs and herbs, vines and dipterocarp tree. Drains entire catchment area (heath, coniferous and dipterocarp forest).
2 (Maliau River B)	N 04°44.350' E 116°58.177' 200 m upstream from Station 1	Large (15-30 m wide and 0.6-2.7 m deep) downstream channel of Maliau River main channel located at 338 m a.s.l. River is acidic with clear tea-colored water. Moderate flow of runs and pools with gravel and sand substrates. Shallow, fast water of big riffles with small boulders, cobble, pebble and sand substrates. Riverbank materials with cobble, pebbles and sand. Mostly unshaded except for edge of some pools. Riparian zone (up to 100 m to the land) consists of grass, vines and dipterocarp tree. Drains entire catchment area (heath, coniferous and dipterocarp forest).
3 (Tembadau River)	N 04°38.758' E 116°56.843' 15-20 km from Belian Camp	Small (3-6 m wide and 0.3-1.6 m deep) Tembadau River main channel joining to Kuamut River. Located at 252 m a.s.l. The water is neutral and turbid with silt. Substrate rock and silt. A series of shallow pool in this station. Abundant in stream debris. Pools abundant with large wooden log debris and leaf debris. Mostly unshaded except for edge of some pools. Riparian zone (up to 15 m to the land) mostly dominated by shrubs, herbs and grass, vines. Drains dipterocarp and disturbed forest.
4 (Agathis River)	N 04°41.920' E 116°54.448' 25 km from Belian Camp	Small stream (3-5 m wide and 0.3-1.0 m deep) headwater of Tembadau River located at 503 m a.s.l. Small stream with shallow, neutral and turbid water. A series of shallow step-pool in this station. Substrate consisted of bedrock and cobble. Abundant in stream debris and debris dams (wooden log debris and leaf debris). Moderate to heavily shaded. Abundant in-stream aquatic vegetation. Drains lower montane and mixed dipterocarp forests.
5 (Agathis River Creek)	N 04°41.963' E 116°54.470' 25 km from Belian Camp	Small creek (off-channel habitat) (1.0-1.5 m wide and 0.1-0.2 m deep) headwater of Tembadau River at 523 m a.s.l. Creek with shallow, slowly moving, neutral and turbid water. Substrate consisted of silt. Abundant in stream debris (dominantly leaf debris and wooden log debris). Heavily shaded. Drains lower montane and mixed dipterocarp forests.

Table 2. Mean of the physio-chemical parameters of water measured at each station surveyed at five sampling stations in Maliau Basin Buffer Zone.

Station	Temperature (°C)	Dissolved Oxygen (mg/l)	pH	TDS (ppm)
1	23.3	8.32	4.8	10
2	24.0	8.53	4.8	10
3	25.2	9.10	7.4	60
4	22.0	9.55	6.9	30
5	23.9	0.26	6.9	10

dead leaves at the bottom of the creek. The pH of the channels range from 4.8-7.4. Low pH value of Maliau River is due to the existence of heath forest vegetation which is more acidic (Hazebroek *et al.*, 2004). Humic acid is leached from the vegetation, particularly from the peat on top of a sandy soil layer found at higher elevations at tropical heath forests (Harun *et al.*, 2010). Station 3, 4 and 5 draining into low montane and mixed dipterocarp forests show neutral pH value (6.9-7.4).

Fish fauna

Analyses based on the number of individuals caught showed that 70% were represented by the family Cyprinidae, Osphronemidae (23%), Gastromyzontidae (5%) and Claridae (2%) (Figure 2). A total of 15 species of fish belonging to13 genera and four families were collected from four rivers and one off-channel creek (Table 3). *Betta, Rasbora* and *Lobocheilus* species were the dominant genera of fish caught.

Studies on distribution and composition of species in each habitat in small to intermediate tropical streams worldwide have identified four main factors, namely distance of a study site from the river mouth (Martin-Smith & Laird, 1998; Hoeinghaus *et al.*, 2003; Ibanez *et al.*, 2007), upstream and downstream longitudinal channel changes (Rayner *et al.*, 2008), individual biological characteristics of the species including dietary composition and feeding morphology, life-history requirements

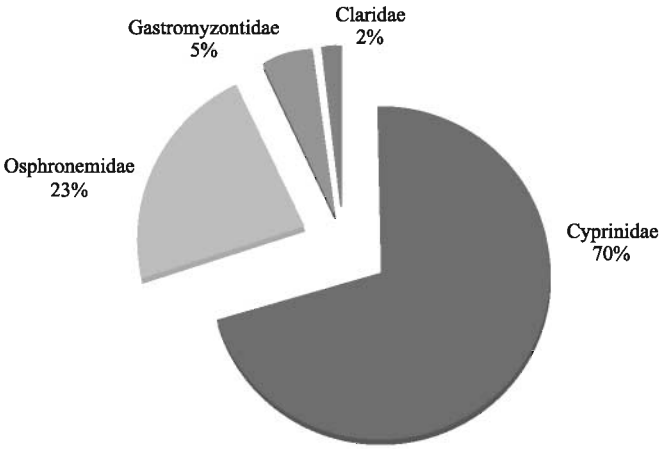

Figure 2. The percentage of fish family collected from five locations in Maliau Basin Buffer Zone.

Table 3. Fish genus based on the number of individuals collected from five locations in Maliau Basin Buffer Zone.

Genus	Number of Individuals
Betta sp.	14
Rasbora sp.	13
Lobocheilus sp.	10
Tor sp.	6
Garra sp.	4
Puntius sp.	4
Gastromyzon sp.	3
Leptobarbus sp.	3
Osteochilus sp.	1
Nematabramis sp.	1
Neogastromyzon sp.	1
Epalzeorhynchos sp.	1
Clarias sp.	1
Total:	62

and water quality tolerances (notably salinity and pH), wet season flooding duration and intensity (Hoeinghaus *et al.,* 2003) and micro- and mesohabitat diversity and complexity features (Pearsons & Li, 1992). General distribution of fish species collected from four rivers and one off-channel creek at Maliau Basin Buffer Zone is shown in Table 4. The fish richness from the stations range from one to 11 species.

In this collection, lower altitude mountain streams were more diverse by all measures. This pattern is often attributed to a downstream increase in habitat size, habitat diversity or both, and in environmental stability (Tejerina-Garro *et al.,* 2005; Casatti, 2005). Robert (1989) and Inger & Chin (2002) reported over one-third of all freshwater fishes at lower altitudes in Sabah belong to the family of Cyprinidae. Kavanagh (2002), Jimmy *et al.,* (2005) and Ahmad *et al.,* (2006) observed their ichthyofauna collections from lower-altitude rivers in Sabah had a large percentage of Cyprinidae. In this expedition, higher representation from the family Cyprinidae was due to habitat characteristic. Pools and runs habitats structurally had more complex

Table 4. The composition and distribution of fish fauna in Maliau Basin Buffer Zone.

Family/Species	Station			
	S1 and S2	S3	S4	S5
CYPRINIDAE				
Rasbora sumatrana	+	+	+	-
Osteochilus microchepalus	+	-	-	-
Nematabramis everetti	+	-	-	-
Tor douronensis	-	+	-	-
Tor cf. *tambroides*	-	+	-	-
Garra cf. *borneensis*	-	+	-	-
Puntius binotatus	-	+	+	-
Puntius sealei	-	+	+	-
Lobocheilos bo	-	+	-	-
Leptobarbus melanotaenia	-	+	-	-
Epalzeorhynchos kalliurus	-	+	-	-
CLARIDAE				
Clarias leiacanthus	-	-	+	-
ANABANTIDAE				
Betta gladiator	-	-	-	+
GASTROMYZONTIDAE				
Gastromyzon sp.	-	+	-	-
Neogastromyzon sp.	-	+	-	-

(+): present (-): absent

microhabitat diversity, often with debris, roots or groups boulders with extensive spaces in between and were invariably deeper (Martin-Smith, 1998).

Station 2 (Tembadau River) which shows much slower current and larger stream seems to be more abundant in ichthyofauna, and most of the fish collected in the recent study were from this area. Cyprinids inhabit this habitat and some are economically important such as *Tor* species (Ng, 2004; Nguyen *et al.*, 2009). Others are species that might have the potential of being commercialized as ornamental fish such as species from the genus *Nematabramis* and *Puntius*. Nevertheless, Tembadau River has lower fish species diversity relative to other studies at the same altitude (Kavanagh, 2002; Jimmy *et al.*, 2005; Ahmad *et al.*, 2006). The physical characteristics (large woody debris, turbid water with silt, rocky and finer substrate, grass- and shrubs-dominated riverbank vegetation) and water characteristic (higher temperature and total dissolved solids values) show that this river is influenced by a recently (<10 years) disturbed forest (Heartsill-Scalley & Aide, 2003).

Low species of cyprinids collected at Maliau River is due to acidic conditions and low ionic content of the water causing low primary productivity. The productivity of primary producers such as microalgae, is important as food and energy sources to survive and grow. Anton *et al.* (1998) reported that there were only 35 species of freshwater microalgae in Maliau's stream which is considered as low productivity and not enough to support fish production (Jimmy *et al.*, 2010).

Headwater streams such as Agathis River and its off-channel habitat by far contribute significantly low fish species. The same observation was reported by Ahmad *et al.* (2006). Small, high gradient, swift flowing streams at the headwater in small tropical rivers are subject to rapid modification by natural processes such as heavy rain. A high wet-season flow causes the mobilization of bed sediments led to scouring of aquatic vegetation and a dramatic reduction in habitat heterogeneity (Rayner *et al.*, 2008). Habitat modifications within a short period of time unable animals to flourish.

One immediately apparent notable observation from the Station 5 collection data was the sampling of high population densities of *Betta gladiator*. This species is endemic to Sabah (Tan & Ng, 2005; Chong *et al.*, 2010). Other reported endemic *Betta* species from highly acidic blackwater habitats are *Betta livida* from the North Selangor peat-swamp forest, *Betta waseri* and *Betta tussyae* from the South East Pahang peat-swamp forest. Despite rather similar habitat environments, blackwater *Betta* spp. are very different at each reported site. Abundant population of *Betta gladiator* shows that Maliau Basin provides a specific habitat structure for this species. *Betta* sp. was regarded as a highly valuable fighting and ornamental fish (Monvises *et al.*, 2009). The result of this data emphasizes the importance of Maliau Basin in protecting highly valuable and endemic species of Sabah.

In general, the species collected at the study area was low compared to other studies at lower attitude rivers (<500 m) by Kavanagh (2002) and Samat (1990). Two plausible explanations for lower fish species numbers would be the challenge presented by the acidic, nutrient poor water directly through the modification of food webs (Martin-Smith *et al.*, 1998) and the long-term side effects caused by logging activities that changes riparian vegetation. Modifications in riparian vegetation affect the structure and processes within streams. Stream bank stability is lost when riparian vegetation is removed, resulting in an increase in light and sediment load, which alters stream-reach microhabitats (Tabacchi *et al.*, 1998). Riparian vegetation influences stream processes by acting as a sink and/or source of matter and energy. As a sink, riparian vegetation dissipates the energy of flowing water while it retains and absorbs particles from upland areas (Kindler, 1998). As a source, production of leaf litter contributes matter to the stream ecosystem and woody debris

contributes to structure (Tabacchi *et al.* 1998). Disturbed forests especially vegetation along the riverbank could cause reduction of food resources, apart from it being the rearing and spawning ground for fish. Other possible reasons might be the shorter period of sampling and observation.

CONCLUSION

Five of the 15 Maliau Basin Buffer Zone fish species (*Betta gladiator, Puntius sealei, Nematabramis everetti, Osteochilus microcephalus* and *Rasbora sumatrana*) are endemic to Sabah. Habitats of endemic species should be given the highest priority in terms of protection and conservation. Habitat modification combined with species endemicity appear to be very potent forces that cause fish extinctions.

Irrespective of fish commercial status or value, the ongoing sustainable conservation efforts by the State Government and Yayasan Sabah should be fully supported and implemented not only in the conservation area but also in the buffer zone in order to warrant comprehensive protection of its ichthyofauna diversity.

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