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Diversity of Freshwater Fish in Fragmented Forest of Wilmar Oil Palm Plantation, Miri, Sarawak

KHAIRUL ADHA A. RAHIM*[1], MELISSA DENNIS CHONG[1], AHMAD SYAFIQ AHMAD NASIR[1], FATIMAH A'TIRAH MOHAMAD[1], FARAH AKMAL IDRUS[1], MOHD AZLAN JAYASILAN ABDUL GULAM AZAD[2] & AWANGKU SHAHRIR NAQIUDDIN[3]

[1]Faculty of Resource Science and Technology, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia; [2]Institute of Biodiversity and Enviromental Conservation, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia; [3]Sarawak Museum Department, Bangunan Annex, Jalan P. Ramlee, 93400 Kuching, Sarawak, Malaysia
*Corresponding author: akhairul@unimas.my
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ABSTRACT

The study was conducted in the river system located at Wilmar oil palm plantation in Miri, Sarawak. The objective of the study is to determine the fish species diversity and composition in the streams and rivers in the oil palm plantations. Fish were sampled using a variety of fishing methods, including, scoop nets, cast net, and gill nets of different mesh sizes (1.0, 1.5, 2.0, 2.5, 3.75 and 4.0 cm) from 2 to 7 of February 2014. A total of 326 individual fish including 32 species of native fishes and one species of non-native fish from 19 genera, seven families and five orders were collected from seven locations. The cyprinid fish represented 62.20% of the total fish caught and was found in all the rivers surveyed. About six endemic species in Borneo such as *Barbonymus collingwoodii, Barbodes banksi, Barbodes sealei, Hampala bimaculata Nematabramis borneensis* and *Nematabramis everetti* were identified. However, only one species from families Bagridae, Balitoridae, Clariidae, and Hemiramphidae was sampled from the study sites. The higher fish species composition found in streams and rivers of the oil palm plantation landscapes could be attributed to the conservation of some areas of the plantation as high conservation value forest (HCVF) status, which have provided suitable habitat for fish species within the plantation aquatic environments.

Keywords: *Barbonymus collingwoodii,* cyprinidae, endemic, native, oil palm plantation

INTRODUCTION

In Malaysia, 86% of all deforestation was attributed from oil palm development in the period from 1995–2000. Rapid expansion of oil palm planting has been seen in Sabah and Sarawak in the last decade (Rautner, 2005). Although the expansion of oil palm is significantly influenced by the economic development in many tropical countries (Sheil *et al.*, 2009; Vijay *et al.*, 2016), the conversion of forests to oil palm has been correlated to biodiversity lost and this has replaced the species composition of both terrestrial and aquatic fauna (Fayle *et al*., 2010; Wilcove & Koh, 2010; Wilcove *et al.,* 2013; Giam *et al*., 2015; Razak *et al.,* 2020). The establishment of oil palm plantations can threaten critical habitats such as floodplain rivers due to soil erosion, pesticide and fertilizer that flow into the rivers (Koh & Wilcove, 2008; Erik & Sheil, 2013; Schrier-Uijl *et al*., 2013).

There are many scientific studies on species diversity and composition such as on invertebrate communities (Chung *et al*., 2000; Koh, 2008), bird faunas (Aratrakorn *et al*., 2006; Najera & Simonetti, 2010; Kelvin *et al*., 2016; Razak *et al*., 2020), mammals (Azlan & Sharma, 2006; Jennings & Veron, 2011; López-Ricaurte *et al*., 2017) in oil palm plantations. However, only a few studies on the aquatic fauna such as fish in the oil palm plantation (Giam *et al.,* 2015; Ohee, *et al.*, 2016; Dosi *et al*., 2019; Nasir *et al*., 2020). Despite great fish diversity documented for various freshwater habitats in Borneo (Ng *et al*., 2017; Khairul Adha *et al*, 2018), the scientific studies that address freshwater fish diversity such in oil palm in Sarawak are still limited.

According to Giam *et al*. (2015) streams within forested riparian reserves in oil-palm plantations supported habitats for aquatic fauna such as

freshwater fish species. Thus, the objective of the study was to obtain information on the fish species diversity and composition in the streams and rivers for conservation planning of the aquatic fauna in the Wilmar oil palm plantations.

MATERIALS AND METHODS

Study Sites

Wilmar PPB Oil Palm BERHAD has been involved in oil palm cultivation began in 1986 with the acquisition of an interest in SAREMAS estate located between Miri and Bintulu. The operation of Wilmar PPB in Sarawak owns about 1136.5 hectares of oil palm plantation. The studies were carried out at seven locations at the streams and rivers within Wilmar oil palm plantation, approximately 60 km from Miri, Sarawak from 2 to 7 February 2014. Figure 1 shows seven sampling locations at fragmented forest and high conservation value forest (HCVF) areas in the oil palm plantation.

Fish Sampling

All sampling locations were determined and relocated with a differentially corrected Global Positioning System (GPS) receiver. The characteristics of the habitats chosen were recorded for all stations. General water conditions, vegetation in the surrounding area, the width (m) and depth (m) of the river, and the distance covered during sampling were also measured. The details of the locations and habitat surveyed are described in Table 1.

Fish were sampled using a variety of fishing methods, including, scoop nets, cast net, and gill nets of different mesh sizes (1.0, 1.5, 2.0, 2.5, 3.75, and 4.0 cm) depending on physical habitat conditions at each station. About one or five of representative specimens were collected and fixed in 10% formalin and later preserved in 70% ethanol for a weeks before depositing in the aquatic museum. Each captured fish was identified based on the morphological charateristic at the species level following Kottelat *et al*. (1993), Atack (2006) and Kottelat (2013).

Data Analysis

Diversity indices were used to characterise fish species abundance relationships in communities. Differences in assemblage characteristics among study sites were evaluated by using the total percentage of fish abundance (total number of individuals), species composition and fish family. The total fish sample for each sampling station was analysed in terms of the total number of individual fish (N), the total number of individual species, and Species diversity (H') (Shannon & Weaver,1963). Species richness (d') was calculated following Margalef (1958), and the evenness (J') was determined using the index described by Pielou (1969). All the indices were calculated by using PRIMER software (Version 7, 2018).

RESULTS AND DISCUSSION

A total of 326 individual fish including 32 species of native fishes and one species of non-native fish were sampled from seven stations (Table 2). The dominance of fish collected was from the family Cyprinidae which represented 62.20% of total fish caught, comprising 313 individuals of 27 species. The cyprinid fish was found in all the habitats surveyed. Fish such as *Cyclocheilichthys apogon, Nematabramis everetti*, and *Barbonymus collingwoodii* are the abundance species and represent 88.1% of the cyprinid fish collected. Similarly, the cyprinids fish were also contributed to the major collection in the survey conducted by previous researchers in Sarawak (Inger & Chin, 1990; Nyanti *et al*. 1998; Ryan *et al*. 2009 and Khairul Adha *et al*. 2009). The cyprinid species collected were commonly inhabited in various types of freshwater habitats in Sarawak. Only one species from families Bagridae (*Hemibagrus nemurus*), Balitoridae **(***Homalopteroides nebulosus*), Channidae (*Channa lucius*), Clariidae (*Clarias batrachus*) and Hemiramphidae (*Hemirhamphodon kuekenthali*) were sampled from the study sites.

However, hardy and highly tolerant native fish species such as *Hemibagrus nemurus, Channa lucius,* and *Clarias batrachus* are commonly inhabiting in with muddy and turbid water as found in ST6. According to Beamish *et al.* (2003) fish species from families Bagridae, Channidae and Clariidae showed adaptation to water with low dissolved oxygen levels and turbid water including those with accessory respiratory organs and suprabranchial cavities. In addition, tolerant species generally can survive in the organically enriched environments from agricultural, industrial, and municipal discharges (Ganasan &

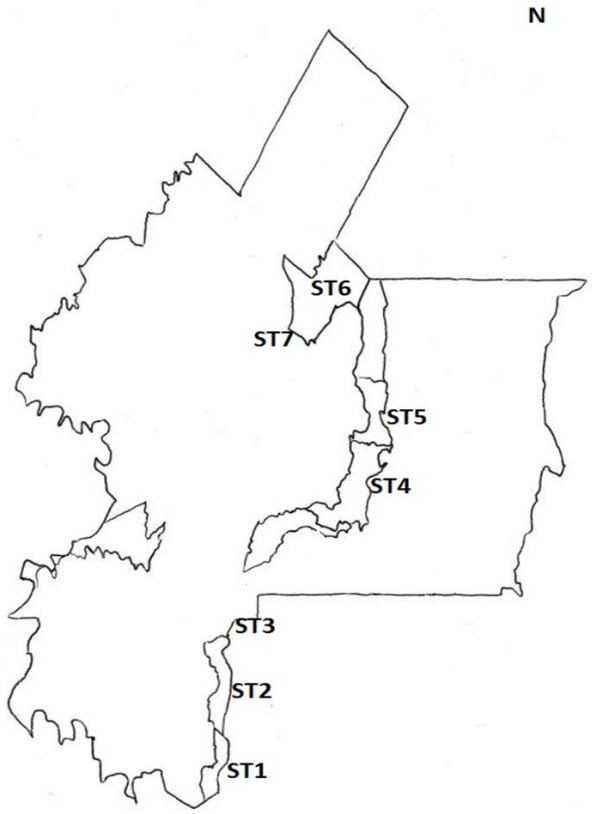

Figure 1. Map showing seven sampling locations at fragmented forest and high conservation value forest (HCVF) areas in the oil palm plantation (ST1-Unnamed river; ST2-Sg. Batu; ST3-Sg. Aquarium; ST4-Sg. Sebilak; ST5-Sg. Batu; ST6-Sg. Sibau & ST7- Sg. Linau) (ST= Sampling location)

Table 1. The characteristics habitat descriptions for seven sampling locations in Wilmar Plantation

Station	Coordinates	Depth (m)	Width (m)	Habitat description
ST1 (Unnamed river)	N 03º34'05.6" E 113 º46'03.6"	0.3-0.5	1-2	Rocky stream with stagnant water, slightly turbid and muddy bottom.
ST2 (Sg.Batu)	N 03 º30'51.5" E 113 º48'15.4"	0.3-0.5	1-2	Fast flowing stream, with rocky and gravel bottom. The is surrounded by thick bush.
ST3 (Sg.Aquarium)	N 03 º29'15.5" E 113 º49'45.1"	0.3-1.0	1-3	Clear water with slow-flowing stream. Shallow with rocky and sandy substrate. Covered by the forest canopy.
ST4 (Sg.Sebilak)	N 03 º32'02.5" E 113 º46'10.8"	1.0-3.0	3-6	Slow flowing river with turbid water, surrounded by bush and long grass at the river bank.
ST5 (Sg. Batu)	N 03 º30'02.5" E 113 º49'14.9"	0.3-1.0	3-4	Slow flowing river, slightly turbid with many decomposed materials such as leaves and tree branches. Surrounded with bushes and vegetation.
ST6 (Sg.Sibau)	N 03 º32'02.5" E 113 º46'10.8"	1.5-5	2-5	Slow-moving river and slightly turbid with a muddy bottom and surrounded by vegetation
ST7 (Sg.Linau)	N 03 º30'54.8" E 113 º47'13.8	1.0-2.0	3-5.5	The river located near the plantation area with slow moving water, slightly turbid and muddy bottom. The river is surrounded with vegetation such as ferns at the river bank.

Table 2. List of fishes, freshwater collected from the seven sites (ST1, ST2, ST3, ST4, ST4, ST6 and ST7 in the palm oil plantation

Order/Family/ Species	ST1	ST2	ST3	ST4	ST 5	ST6	ST 7	Total	Status
CYPRINIFORMES									
Balitoridae									
Homalopteroides nebulosus (Alfred, 1969)	-	4	-	-	-	-	-	4	Native
SILURIFORMES									
Bagridae									
Hemibagrus nemurus (Valenciennes, 1840)	-	-	-	-	-	2	-	2	Native
ANABANTIFORMES									
Channidae									
Channa lucius (Cuvier, 1831)	-	-	-	-	-	1	-	1	Native
CICHLIFORMES									
Cichlidae									
Oreochromis niloticus (Linnaeus, 1758)	-	-	-	-	-	2	-	2	Introduced
SILURIFORMES									
Clariidae									
Clarias batrachus (Linnaeus, 1758)	-	-	-	-	-	2	-	2	Native
CYPRINIFORMES									
Cyprinidae									
Cyclocheilichthys apogon (Valenciennes, 1842)	6	-	-	4	-	35	2	47	Native
Cyclocheilichthys armatus (Valenciennes, 1842)	-	-	-	-	-	-	1	1	Native
Anematichthys repasson (Bleeker, 1853)	-	-	3	-	-	12	-	15	Native
Hampala bimaculate (Popta, 1905)	-	1	1	-	-	-	-	2	Endemic
Hampala macrolepidota (Kuhl & van Hasselt, 1823)	-	2	1	-	-	-	-	3	Native
Nematabramis borneensis (Inger & Chin, 1962)	-	2	-	-	-	-	-	2	Endemic
Nematabramis everetti (Boulenger, 1894)	16	2	23	-	-	-	-	41	Endemic
Osteochilus vittatus (Valenciennes,1842)	-	1	-	-	-	15	1	17	Native
Osteochilus kahajanensis (Bleeker, 1856)	-	2	-	1	-	3	6	12	Native
Osteochilus waandersii (Bleeker, 1853)	-	4	-	1	-	9	5	19	Native
Parachela hypophthalmus (Bleeker, 1860)	-	-	-	1	-	1	-	2	Native
Parachela oxygastroides (Bleeker, 1852)	-	-	1	1	-	1	12	15	Native
Puntioplites bulu (Bleeker, 1851)	-	-	-	1	-	17	1	19	Native
Barbodes banksi (Herre, 1940)	5	8	-	-	-	4	2	19	Endemic
Barbodes binotatus (Valenciennes, 1842)	-	12	-	-	-	-	-	12	Native
Puntius brevis (Bleeker, 1849)	-	-	3	-	-	-	-	3	Native
Barbonymus collingwoodii (Günther, 1868)	-	18	10	-	-	5	-	33	Endemic
Systomus orphoides (Valenciennes, 1842)	-	-	-	3	-	7	-	10	Native
Barbodes sealei (Herre, 1933)	-	-	1	-	1	-	-	2	Endemic
Rasbora argyrotaenia (Bleeker, 1849)	-	-	1	-	3	-	-	4	Native
Rasbora bankanensis (Bleeker, 1853)	-	-	6	-	-	-	-	6	Native
Rasbora caudimaculata (Volz, 1903)	-	-	4	-	-	-	-	4	Native
Rasbora dusonensis (Bleeker, 1850)	-	-	2	-	-	2	-	4	Native
Rasbora kalochroma (Bleeker, 1851)	-	-	2	-	-	-	-	2	Native
Rasbora sp	14	-	3	-	-	-	-	17	Native
Rasbora tornieri (Ahl, 1922)	-	-	1	-	-	-	-	1	Native
Rasbora volzii (Popta, 1905)	-	-	1	-	-	-	-	1	Native
BELONIFORMES Hemiramphidae									
Hemirhamphodon kuekenthali Steindachner 1901	-		2	-	-	-	-	2	Native
Number of individuals	41	56	65	12	4	118	30	326	

Hughes, 1998). In addition, six endemic species in Borneo such as *Barbonymus collingwoodii, Barbodes banks*i, *Barbodes sealei, Hampala bimaculata Nematabramis borneensis,* and *Nematabramis everetti* (Inger & Chin, 1990; Sulaiman & Mayden, 2012; Ng *et al*., 2017) were

collected from the ST1, ST2 and ST3. These endemic fish were found mainly at the higher streams areas. According to Roberts (1989), the headwater streams is a sanctuary of endemic species that are specialized in inhabiting the fast-flowing stream with high dissolved oxygen concentrations and clear water habitats.

One species of non-native fish, *Oreochromis niloticus* were found at ST6. This non-native species represented about 0.3 % of the total samples collection. Atack (2006) and Khairul Adha *et al.* (2013) recorded the occurrence of non-native fish species in natural habitat in Sarawak waters. These includes *B. gonionotus, C. gariepinus, C. idella, Liposarcus pardalis, T. pectrolis, O. niloticus*, and *P. hypopthalmus.* In addition, *Oreochromis* spp. not only inhabit the highland stream such as in Kelalan River and in Bario highland streams (Nyanti *et al*., 1998; Khairul Adha *et al*., 2018) but also as in Sarawak River (Atack, 2006). This non-native species successfully survive and inhabit slow flowing and turbid water with lower pH value and oxygen concentration (Khairul Adha *et al*., 2013; Naquiddin *et al*., 2016).

The diversity indices of freshwater aquatic faunas from seven study sites are shown in Table 3. The highest samples and species collections were from ST6 with 118 individuals and 17 species. However, only two species and four individual samples were collected from ST5. In terms of fish species diversity, ST3 contained the highest fish diversity, followed by ST6, ST2, ST4, ST7, ST1 and ST5.

ST3 also has a higher species richness with a value of 3.833, followed with ST6, ST2, ST4, ST7, ST1 and ST5 with values of 3.144, 2.484, 2.415, 2.058, 0.808, and 0.721, respectively. The species evenness range from 0.792 in ST3 to 0.918 in ST1. Most of the sampling sites are covered with riparian reserves. According to Giam *et al.* (2015) streams within forested riparian reserves in oil-palm plantations not only support many fish species richness but also support higher fish biomass.

Detail collections of fish fauna at localized habitats yielded interesting results. About 33 species of freshwater fishes were collected from in the streams and rivers in the oil palm plantation. The species recorded was higher than other previous studies done in oil palm plantations such as in Borneo. For instance, Dosi *et al*. (2019) found 13 fish species from Tinbarap Conservation Area (TCA) in oil palm plantation, Sarawak and other researchers such as Nasir *et al*. (2020) showed only four species of fish belonging to three families at Lahad Datu, Sabah. However, Wilkinson *et al.* (2018) recorded 25 fish species in the land-use areas such as the oil palm plantations in Sabah. The higher fish species composition and distribution in streams and rivers in the oil palm plantation could be attributed to many factors. The oil palm company has allocated and conserved some areas in the plantation as high conservation value forest (HCVF) status. The fragmented and undisturbed forest can provide suitable habitat for some species within the plantation environments (Scriven *et al*., 2019). Sungai Cermin (ST3) which is situated in fragmented forest areas has a higher fish species diversity. Furthermore, four endemic species such

Table 3. The fish diversities of from the seven sites (ST1, ST2, ST3, ST4, ST4, ST6 and ST7) in the palm oil plantation

Stations	(S)	(N)	(H')	(J')	(D')
ST 1	4	41	1.835	0.918	0.808
ST 2	11	56	2.842	0.821	2.484
ST 3	17	65	3.237	0.792	3.833
ST 4	7	12	2.522	0.898	2.415
ST 5	2	4	0.811	0.811	0.721
ST 6	17	118	3.229	0.807	3.144
ST 7	8	30	2.436	0.812	2.058

Notes: S = Number of Species; N = Total number of individual fish, H'= Shannon & Wiener Index; J' = Pielou's Index of Evenness; D = Margalef's Index

as *Barbonymus collingwoodii, Barbodes sealei, Hampala bimaculata Nematabramis everetti* were collected from this areas. This stream is characterised by clear water with rocky, sandy, and gravel bottom and surrounded by the forest canopy. The conservation approach in the selected location by the oil palm company is observed as an important activity for a biodiversity-friendly management system in oil palm plantations (Turner *et al*., 2008; Koh & Wilcove, 2008; Vijay *et al*., 2016).

All the rivers sampled in the oil palm plantation have retention of forested riparian reserves. Riparian reserves along the rivers are not only useful in sustaining local fish diversity (Giam *et al*., 2015), but the presence of riparian reserves along the river can reduce soil erosion, sedimentation, and chemical runoff from the oil palm plantation (Fitzherbert *et al*., 2008; Dayang-Norwana *et al*., 2011; Sweeney & Newbold, 2014). Furthermore, riparian reserves seemed to increase local species richness with increasing leaf litter cover which supports fish communities by improving their food resources (Wallace *et al*., 1997; Gray *et al*., 2015; Giam *et al*., 2015). In addition, some areas of the rivers are characterised by overgrown floating vegetation such as *Eichhornia crassipes* and other submerged aquatic plants that could probably create suitable niches for a variety of fish species. Putz (1997) stated that the presence of floating meadows has provided the nursery grounds for young fishes which use the submerged roots as a refuge from predation.

Although the number of studies on fish fauna in oil palm plantation areas is still relatively small, conserving the diversity of aquatic fauna in oil-palm landscapes is crucial because many plantation areas have been dominated by oil palm (Pimentel *et al*., 1992; Nájera & Simonetti, 2010). Thus, pressures on native and endemic fishes by forest clearance for oil palm plantations should be controlled to sustain the biodiversity of aquatic fauna in the oil palm landscape.

CONCLUSION

A total of 33 species of freshwater fish, including six endemic species was identified in the stream and rivers of the oil palm landscapes. The present studies have shown that streams flows in fragmented forest and High Conservation Value forest (HCVF) areas still have high fish species diversity and richness. Thus, identifying and protecting HCVF is one of the approaches to control or decrease further biodiversity loss in oil-palm landscapes. Clearing riparian reserves, excessive use of pesticides and fertiliser should be controlled and managed properly in order to protect, sustain and conserve the diversity of freshwater fishes inhabits in the stream and rivers in the oil palm landscape.

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