

## The Influences of Water Quality on Fish Occurrences in Kuala Mai, Pahang River and Ulu Tembeling, Tembeling River, Pahang, Malaysia

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### ABSTRACT

This study assessed the fish community structures and influences of water quality on fish occurrences in Pahang and Tembeling rivers, Pahang. Fish samplings and water quality measurements were conducted in Kuala Mai, Pahang River and Ulu Tembeling, Tembeling River from 12 and eight different sampling points, from October 2007 to September 2008, and August 2006 to August 2007, respectively. The fish diversity, richness and evenness indices were determined, while the water quality parameters were compared for both rivers. Multivariate analyses were then used to explore the effects of water physicochemical parameters on the fish occurrences. A total of 2,391 individuals were collected from this study, comprising of 20 families and 65 species of fish. Using the gill nets, cast nets and fishing rods, a total of 55 fish species from 17 families were recorded in Kuala Mai, Pahang River, compared to 47 species from 15 families in Ulu Tembeling, Tembeling River. There were significant differences ( $p < 0.05$ ) for fish diversity ( $H$  and  $I-D$ ), but not for fish evenness ( $e$ ) and richness ( $D$ ) between both rivers. The mean water temperature, ammonia nitrogen and total suspended solids were significantly different ( $p < 0.05$ ) in both rivers. Apart from the influences of pH, alkalinity and phosphate in both rivers, the results showed that the temperature, dissolved oxygen and conductivity were the major influencers on the fish occurrences in

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Kuala Mai, Pahang River, while ammonia nitrogen and total suspended solids in Ulu Tembeling, Tembeling River. Fish conservation and stock management efforts are urgently needed due to the decreasing number of near-threatened, endangered and critically endangered fish species in both rivers.

*Keywords:* Community structure, fish ecology, Pahang River, physicochemical parameters, Tembeling River

## INTRODUCTION

Fishes are highly beneficial in order to understand the condition of aquatic ecosystems and this could involve relating the fish abundance with water quality (Tsai et al., 2016). The importance of physicochemical parameters in freshwater ecosystems cannot be overemphasized since they not only influence, to a large extent, fish survival but also dictate their richness and distribution (Nyanti et al., 2018). An insight into the relationship between fish and its habitat is quintessential for effective management and conservation, because fish are subservient to the quality and dynamics of the water quality in which they reside (Paller et al., 2016).

With a length of 459 km, the Pahang River remains the longest in Peninsular Malaysia, meandering through a number of districts and townships. The Pahang River is divided into the Jelai and Tembeling rivers, which meet near Kuala Tembeling at Jerantut District. Pahang and Tembeling rivers are very important freshwater fish habitats in Peninsular Malaysia, as they provide useful natural capital for beneficial ecosystem services (Bhuiyan et

al., 2014). In addition to their roles in the accommodation and breeding of aquatic life, the environment of these rivers also promotes aquaculture activities, especially of several commercially valuable freshwater fish species like *Pangasianodon* sp. and *Oreochromis* sp. (Zulkafli et al., 2015b). Locals specifically depend on these rivers as sources of protein, particularly from shrimp and fish, and in connection to this, as the main source of side income (Idris et al., 2016). More so, they also shelter some fish species which are already classified as endangered like *Fluvitrygon signifier* and *Probarbus jullieni* (Zulkafli et al., 2015b).

Tembeling River has a length of 153 km with a catchment area of 5,050 km<sup>2</sup>, which is mainly covered by forests, rubber plantations, oil palm plantations, lakes, rivers, and marshes at 66%, 13%, 12%, and 9%, respectively (Zulkafli et al., 2015b). It is located in the upper Tembeling region and impacts essentially on the socio-economics of the people in the area, as being a source of food and transportation (Idris et al., 2016; Samah et al., 2013). Pahang and Tembeling rivers are also famous for tourism activities. For example, Tembeling River specifically flows along the National Park at Kuala Tahan, Pahang, which is beneficial to some of the locals in generating great income via eco-tourism activities including water-rafting and boat-riding (Shuib, 1995).

Several studies have enumerated the fish abundance (Hashim et al., 2012; Ismail et al., 2013; Nasruddin et al., 2014; Jalal et al., 2018; Sule et al., 2016; Zaid et al., 2018; Zulkafli et al., 2015a, 2015b, 2016a, 2016b), while others have

demonstrated the impacts of water quality on fish assemblages (Ikhwanuddin et al., 2016; Sule et al., 2018; Yusof et al., 2018; Zulkaffi et al., 2018) of aquatic ecosystems around Malaysia. However, there is still a dearth of information on the dynamics of fish occurrences as dictated by water quality parameters in Pahang and Tembeling rivers. Thus, the objectives of this study are to determine the fish community structures and evaluate the influences of water physicochemical parameters on the fish occurrences, specifically in Kuala Mai, Pahang River and Ulu Tembeling, Tembeling River, Pahang, Malaysia.

## MATERIALS AND METHODS

### Study Area

The study was conducted at Kuala Mai, Pahang River in Temerloh District and Ulu Tembeling, Tembeling River in Jerantut District, Pahang, Malaysia (Figure 1). The samplings took place at monthly intervals from October 2007 to September 2008 (10 months) in Kuala Mai, Pahang River at 12 different sampling points, and from August 2006 to August 2007 (12 months) in Ulu Tembeling, Tembeling River at eight different sampling points (Table 1). All sites were accessible by road and located in the relatively undisturbed area where industrial

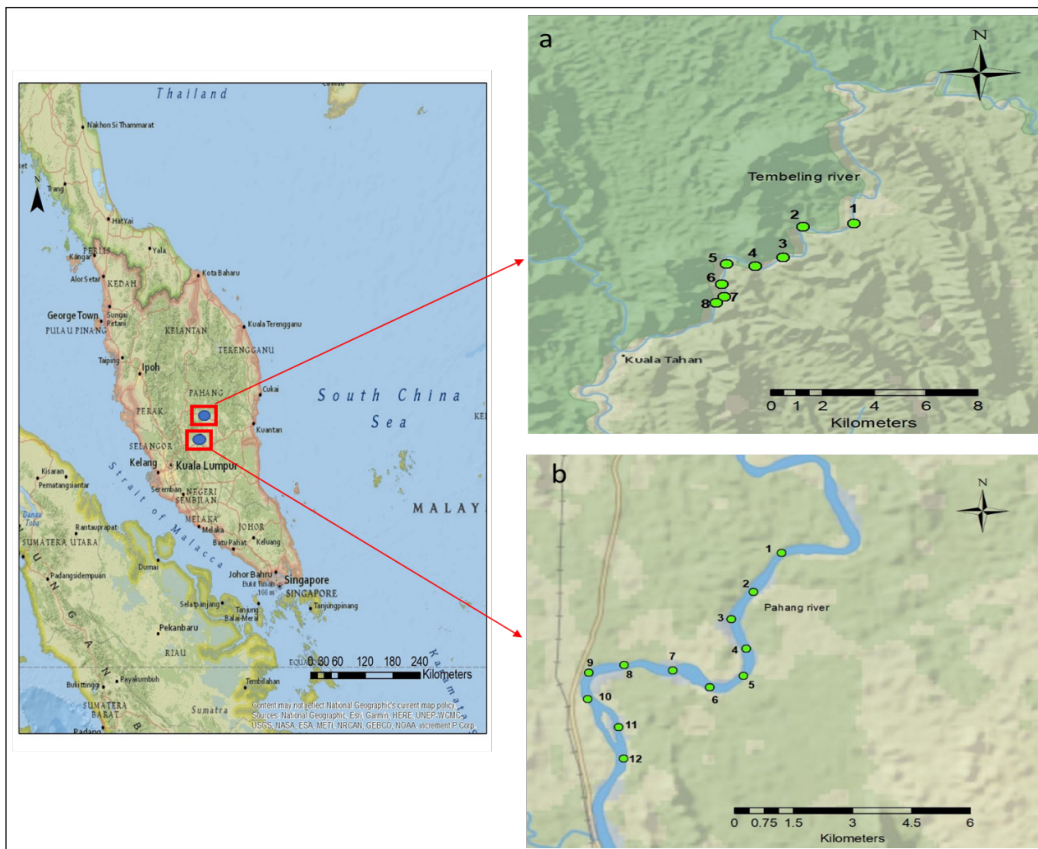


Figure 1. Sampling points location in (a) Ulu Tembeling, Tembeling River and (b) Kuala Mai, Pahang River

and agricultural activities were not visible. All of the sampling sites were characterized by a large river with deep slow reaches, a river bed that is usually covered with sand or gravel substrates, and no tidal influence.

Annual rainfall of the Pahang River is influenced by the northeast monsoon season, ranging from 1,609 mm to 2,132 mm, which occurs mostly between November and March of every year. This river empties into the South China Sea on the east coast of Peninsular Malaysia (Roseli et al., 2014). Situated near the Pahang National Park and with aboriginals occupying its banks at Ulu Tembeling, the Tembeling River is one of the main tributaries of Pahang River (Zulkafli et al., 2015b).

### Fish Sampling

In all sampling sites, three different sizes of drift and static gill nets (15 - 30 m long, 2.5 - 4.0 m wide) with mesh sizes ranging from 2.5 to 23.0 cm between knots were used. The drift and static gill nets were deployed between 7:00 - 10:00 a.m.. The static gill nets were maintained in position, checked at every 7 - 10 h, and hauled in after 24 h (Zulkafli et al., 2018). Traditional fishing gears, such as cast net and fishing rods (one and two for each gear), were also used in sites where the utilization of gill net was not suitable, and in order to diversify sampling techniques and types of collected fishes.

Table 1  
*Coordinates of sampling points in Kuala Mai, Pahang River and Ulu Tembeling, Tembeling River*

River	Point	Latitude	Longitude
Kuala Mai, Pahang River	1	3°47'34.33"N	102°24'36.92"E
	2	3°46'55.70"N	102°24'13.37"E
	3	3°46'28.45"N	102°23'55.40"E
	4	3°45'59.08"N	102°24'7.62"E
	5	3°45'31.79"N	102°24'5.22"E
	6	3°45'20.39"N	102°23'37.79"E
	7	3°45'37.26"N	102°23'7.10"E
	8	3°45'42.65"N	102°22'27.27"E
	9	3°45'34.68"N	102°21'58.02"E
	10	3°45'8.67"N	102°21'57.02"E
	11	3°44'40.24"N	102°22'22.91"E
	12	3°44'9.29"N	102°22'26.80"E
Ulu Tembeling, Tembeling River	1	4°26'53.34"N	102°28'52.98"E
	2	4°25'51.84"N	102°27'25.16"E
	3	4°25'40.47"N	102°26'14.50"E
	4	4°25'3.94"N	102°26'8.66"E
	5	4°24'40.63"N	102°26'11.02"E
	6	4°24'30.04"N	102°26'1.51"E
	7	4°26'47.37"N	102°27'49.84"E
	8	4°25'36.83"N	102°26'50.26"E

Those fish that could confidently be identified were enumerated and if still alive, were released back to their natural environment. Fish samples (about 1 to 5 samples) to represent each species were immediately preserved in 10% formalin, following 70% alcohol for deposition in Freshwater Fisheries Research Division, Fisheries Research Institute, Glami-Lemi, Jelebu, Negeri Sembilan. Collected fishes were identified to species level based on Mohsin and Ambak (1991), Zakaria-Ismail et al. (2019) and the latest scientific names and species validity followed Fricke et al. (2020).

During the fish sampling activities, the individual number of fish was recorded for each species, while the status of whether native or introduced fishes were also determined (Froese & Pauly, 2018; Zakaria-Ismail et al., 2019). The IUCN status of each collected fish species was determined using conservation assessment of the International Union for Conservation of Nature's (IUCN) Red List of Threatened Species (International Union for Conservation of Nature's [IUCN], 2019).

### Water Physicochemical Analyses

In triplicates, the water quality parameters were measured at the same site where the fish were sampled, specifically after deploying the fishing gears for fish capture. The measured parameters include water temperature ( $^{\circ}\text{C}$ ), pH (1-14), conductivity ( $\mu\text{S}/\text{cm}$ ), total suspended solids (TSS) ( $\text{mg}/\text{L}$ ) (YSI Incorporation, NY, USA), and river depth (m) (Speedtech Instrument, Logan, UT, USA). Besides that, the ammonia

nitrogen ( $\text{NH}_3\text{-N}$ ) ( $\text{mg}/\text{L}$ ), phosphate ( $\text{PO}_4^{3-}$ ) ( $\text{mg}/\text{L}$ ), nitrate ( $\text{NO}_3^-$ ) ( $\text{mg}/\text{L}$ ) and alkalinity ( $\text{mg}/\text{L}$ ) were measured using a spectrophotometer (HACH Company, Loveland, CO, USA).

### Statistical Analyses

Fish diversity (Shannon-Wiener's diversity index ( $H$ ) and Simpson's diversity index ( $I-D$ )), evenness (Pielou's evenness ( $e$ ) index) and richness (Menhinnick's richness index ( $J$ )) indices for both rivers were enumerated. These were carried out using the PAST (version 2.15) software (Hammer et al., 2001). Using the same software, diversity t-tests of Shannon-Wiener's diversity index ( $H$ ) and Simpson's diversity index ( $I-D$ ) were carried out to ascertain if there exist significant differences in the fish species diversity of both sites. Furthermore, the temporal trends in the measured water physicochemical parameters were described and presented using graphs in Microsoft Excel (Office 365, Version 2016, Microsoft Corp., Berkshire, UK). Independent samples t-test was also used to compare water physicochemical parameters measured at both rivers using IBM SPSS, Version 22.0 (IBM Corp., Chicago, IL, USA). The significant difference was determined at  $p < 0.05$ . Prior to this, the data were log-transformed since they did not follow a normal distribution.

Data reduction was performed with Principal Component Analysis (PCA) to reduce variable numbers in the dataset by clustering highly correlated variables into factors while retaining variability in the

data with IBM SPSS, Version 22.0. By using PCA, the variables that correlated with one another were combined into factors. Canonical correspondence analysis (CCA) was thereafter used to determine the relationship between water quality and fish species assemblages in each river. The CCA was performed using XLSTAT add-in (Version 2014.5.3, Addinsoft, New York, NY, USA), with 1000 permutations at a significance level of 5%.

## RESULTS

### Fish Checklist, IUCN status, and Community Structures

A checklist of recorded fish species including their family name, scientific name, number of collected individuals, abbreviations, origin status, and IUCN status is presented in Table 2. This consists of 2,391 individuals, which were collected during this study, comprising of 20 families and 65 species of fish (not including *Pangasionodon* sp.). A total of 796 individuals belonging to 55 species from 17 families were collected from Kuala Mai, Pahang River. The highest represented family was Cyprinidae (22 species), followed by Bagridae, Pangasiidae

and Siluridae with four species each. In Ulu Tembeling, Tembeling River, a total of 1,595 individuals belonging to 47 species and 15 families were collected. The family with the highest representation was Cyprinidae (22 species), followed by Danionidae with four species.

Of the 65 fish species recorded in this study, a total of seven species was considered as not evaluated (NE), four species as data deficient (DD), 52 species as least concern (LC), one species (*Bagarius yarrelli*) as near threatened (NT), one species (*Fluviotrygon signifier*) as endangered (EN), and one species (*Probarbus jullieni*) as critically endangered (CR). Furthermore, four introduced fish species such as *Barbonymus altus*, *Barbonymus gonionotus*, *Pangasionodon* sp. and *Pterygoplichthys disjunctivus* were also recorded in this study.

Fish community structures in Pahang and Tembeling rivers are presented in Table 3. Significant differences ( $p < 0.05$ ) were only existed between the Shannon-Wiener's diversity ( $H$ ) [ $t(1799.4) = 9.234, p = 0.000$ ] and Simpson's diversity ( $I-D$ ) ( $t(2186.2) = -8.617, p = 0.000$ ] indices for both study sites, but not for evenness ( $e$ ) and richness ( $D$ ) indices.

Table 2  
The family, species with number of individuals, IUCN status and abbreviation used of collected fishes in Kuala Mai, Pahang River, and Ulu Tembeling, Tembeling River

Family	Species	Pahang River	Tembeling River	IUCN status	Abbreviation
Dasyatidae	<i>Fluviotrygon signifier</i>	1	NA	EN	Hims
Anguillidae	<i>Anguilla marmorata</i>	NA	1	LC	Ang
Notopteridae	<i>Chitala lopis</i>	2	6	LC	Chil
	<i>Notopterus notopterus</i>	4	4	LC	Nop
Botiidae	<i>Syncrossus hymenophysa</i>	NA	2	LC	Synh

Table 2 (continue)

Family	Species	Pahang River	Tembeling River	IUCN status	Abbreviation	
Cyprinidae	<i>Amblyrhynchichthys truncatus</i>	23	66	LC	Ambt	
	<i>Barbichthys laevis</i>	18	71	LC	Barla	
	<i>Barbodes lateristriga</i>	1	NA	LC	Barl	
	* <i>Barbonymus altus</i>	1	NA	LC	Hypn	
	* <i>Barbonymus gonionotus</i>	3	NA	LC	Barbd	
	<i>Barbonymus schwanefeldii</i>	88	130	LC	Bars	
	<i>Crossocheilus oblongus</i>	NA	7	LC	Cro	
	<i>Cyclocheilichthys apogon</i>	49	223	LC	Cyca	
	<i>Cyclocheilichthys repasson</i>	16	11	LC	Aner	
	<i>Labeo chrysophekadion</i>	2	NA	LC	Labc	
	<i>Labiobarbus festivus</i>	57	104	DD	Labf	
	<i>Labiobarbus ocellatus</i>	NA	5	LC	Labo	
	<i>Lobocheilos rhabdoura</i>	23	160	LC	Circ	
	<i>Hampala macrolepidota</i>	10	23	LC	Ham	
	<i>Hypsibarbus pierrei</i>	3	3	DD	Hypp	
	<i>Hypsibarbus wetmorei</i>	49	19	LC	Hypw	
	<i>Mystacoleucus obtusirostris</i>	24	38	NE	Myso	
	<i>Osteochilus melanopleura</i>	7	3	LC	Osme	
	<i>Osteochilus microcephalus</i>	1	10	LC	Osmi	
	<i>Osteochilus spilurus</i>	NA	25	LC	Ospi	
	<i>Osteochilus vittatus</i>	23	10	LC	Osvi	
	<i>Osteochilus waandersii</i>	24	2	LC	Oswa	
	<i>Probarbus jullieni</i>	2	17	CR	Proj	
	<i>Puntioplites bulu</i>	2	18	LC	Pubu	
	<i>Puntioplites proctozyron</i>	NA	254	LC	Punp	
	<i>Tor tambra</i>	NA	1	DD	Tota	
	<i>Thynnichthys thynnoides</i>	43	NA	LC	Thyn	
	Danionidae	<i>Rasbora dusionensis</i>	NA	7	NE	Bal
		<i>Rasbora elegans</i>	18	48	LC	Rasu
		<i>Luciosoma setigerum</i>	12	9	LC	Lucs
<i>Raiamas guttatus</i>		4	9	LC	Ragu	
Xenocyprididae	<i>Macrochirichthys macrochirus</i>	6	5	LC	Mac	
	<i>Paralaubuca typus</i>	28	12	LC	Part	
Ailiidae	<i>Laides hexanema</i>	23	8	LC	Lahe	
Bagridae	<i>Bagrichthys macracanthus</i>	2	NA	LC	Bagm	
	<i>Hemibagrur capitulum</i>	21	49	NE	Hemn	
	<i>Hemibagrur wyckii</i>	3	5	LC	Hemw	
	<i>Mystus castaneus</i>	9	4	LC	Mytg	
Sisoridae	<i>Bagarius yarrelli</i>	18	7	NT	Bagy	

Table 2 (continue)

Family	Species	Pahang River	Tembeling River	IUCN status	Abbreviation
Pangasiidae	<i>Helicophagus waandersii</i>	5	NA	LC	Hewa
	* <i>Pangasionodon</i> sp.	8	NA	NE	Phy
	<i>Pangasius nasutus</i>	10	8	LC	Pana
	<i>Pseudolais micronemus</i>	33	160	DD	Psem
Siluridae	<i>Belodontichthys dinema</i>	4	6	LC	Beld
	<i>Kryptopterus limpok</i>	7	NA	LC	Kryl
	<i>Phalacrotonus apogon</i>	86	27	LC	Phaa
	<i>Wallagonia leerii</i>	2	NA	LC	Wale
Loricariidae	* <i>Pterygoplichthys disjunctivus</i>	1	NA	NE	Hple
Mastacembelidae	<i>Macrognathus maculatus</i>	1	4	LC	Mack
	<i>Mastacembelus erythrotaenia</i>	NA	1	LC	Mase
	<i>Mastacembelus favus</i>	2	1	LC	Masf
	<i>Mastacembelus unicolor</i>	1	NA	NE	Masu
Anabantidae	<i>Anabas testudineus</i>	1	NA	LC	Anat
Osphronemidae	<i>Osphronemus goramy</i>	5	5	LC	Ospg
	<i>Trichopodus trichopterus</i>	6	NA	LC	Tri
Channidae	<i>Channa lucius</i>	1	NA	LC	Chanl
	<i>Channa micropeltes</i>	NA	5	LC	Chanm
	<i>Channa striata</i>	1	NA	LC	Chans
Pristolepididae	<i>Pristolepis fasciata</i>	NA	2	LC	Prif
Soleidae	<i>Achiroides leucorhynchus</i>	1	NA	NE	Brpa
Belonidae	<i>Xenentodon canceloides</i>	1	NA	LC	Xenc

(\*) asterisk = indicates introduced species; numbers = number of individuals collected fish; NA = not available; NE = not evaluated; DD = data deficient; LC = least concern; NT = near threatened; EN = endangered; CR = critically endangered. The scientific names, species validity and species systematic order following California Academy of Science's Catalog of Fishes (Fricke et al., 2020)

Table 3

Fish community structures in Kuala Mai, Pahang River and Ulu Tembeling, Tembeling River, based on diversity, evenness and richness indices

River	Community structure indices			
	<i>H</i>	<i>I-D</i>	<i>e</i>	<i>D</i>
Kuala Mai, Pahang River (n = 12)	3.315 ± 0.036*	0.949 ± 0.003*	0.5	1.949
Ulu Tembeling, Tembeling River (n = 8)	2.893 ± 0.029	0.916 ± 0.003	0.384	1.177

*H* = Shannon-Wiener's diversity index; *I-D* = Simpson's diversity index; *e* = Pielou's evenness index; and *D* = Menhinnick's richness index; \* = indicates a significant difference between both sampling sites



### Water Quality Measurements

Figure 2 shows the trends in measured water quality parameters for Pahang and Tembeling rivers. In Kuala Mai, Pahang River, the river was deepest at 6.51 m in July and shallowest at 2.54 m in March, dropping from a depth of 6.03 m in January. The highest DO value of 8.33 mg/L was recorded in August, with the lowest value of 4.36 mg/L in September. Furthermore, pH ranged between 7.14 and 5.73 in January and November, while temperature ranged between 27.8°C, which was recorded in June and 25.24°C which was recorded in November. TSS was highest in August at 310.2 mg/L and lowest at 60.2 mg/L in October. During the study, NH<sub>3</sub>-N ranged from a minimum of 0.3 mg/L in September, to a maximum of 1.7 mg/L in November. The greatest difference was observed between September and October. NO<sub>3</sub><sup>-</sup> ranged from 0.008 mg/L in February and 0.3 mg/L in September, with the greatest change observed between August and September. The highest PO<sub>4</sub><sup>3-</sup> content of 0.91 mg/L was observed in January and the lowest was 0.03 mg/L in August.

For Ulu Tembeling, Tembeling River, the river depth ranged from 4.83 m in April to 2.53 m in November. The highest DO value of 7.46 mg/L was recorded in August, with the lowest value of 6.23 mg/L recorded in March. pH ranged from 7.01 in November to 5.2 in October. Alkalinity was highest in October at 24.38 mg/L and lowest in June at 12.13 mg/L. Conductivity ranged from 98.88 µS/cm in November, and 28.00 µS/cm in the month of May. The highest temperature of

30.27°C was recorded in June, while the lowest at 25.81°C was observed in January. TSS ranged from 226.38 mg/L in October to 11.13 mg/L in the month of March. During the study period, NH<sub>3</sub>-N ranged from 0.06 mg/L in November to 1.34 mg/L in October. NO<sub>3</sub><sup>-</sup> ranged from 0.02 mg/L in April to 0.21 mg/L in October. PO<sub>4</sub><sup>3-</sup> was at a minimum of 0.05 mg/L in June and a maximum of 1.20 mg/L in November.

Inferential statistical analyses revealed a significant difference ( $p < 0.05$ ) between the two rivers for only three of the measured physicochemical parameters, such as temperature, NH<sub>3</sub>-N and TSS (Table 4). Temperature ( $t(16) = -2.171$ ,  $p = 0.045$ ) was significantly ( $p < 0.05$ ) higher, while NH<sub>3</sub>-N ( $t(11.23) = 2.914$ ,  $p = 0.010$ ) and TSS ( $t(13.469) = 4.167$ ,  $p = 0.010$ ) were significantly ( $p < 0.05$ ) lower at Ulu Tembeling, Tembeling River compared to Kuala Mai, Pahang River. River depth, pH, alkalinity and NO<sub>3</sub><sup>-</sup> were numerically higher at Kuala Mai, Pahang River, while DO, conductivity, and PO<sub>4</sub><sup>3-</sup> were numerically lower at Kuala Mai, Pahang River.

### Relationships between Water Quality and Fish Occurrences

Extraction and loadings from PCA of physicochemical parameters of Kuala Mai, Pahang River and Ulu Tembeling, Tembeling River are presented in Table 5. In each river, PCA generated two axes that cumulatively accounted for 81.01% and 84.13% variation in water physicochemical parameters for Kuala Mai, Pahang River, and Ulu Tembeling, Tembeling River, respectively.

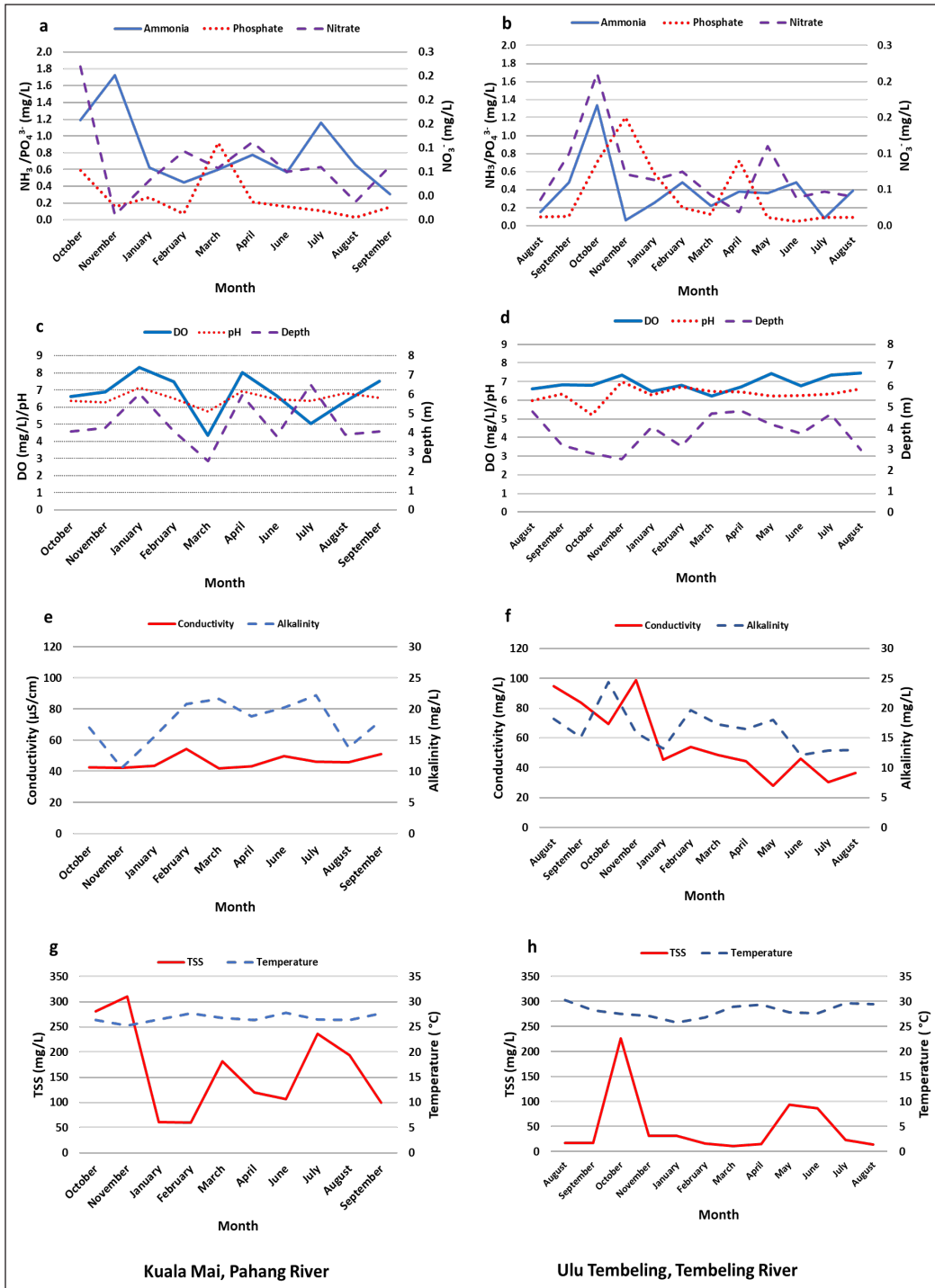


Figure 2. Monthly trends in water physicochemical parameters. (a, b): ammonia nitrogen, phosphate, and nitrate; (c, d): dissolved oxygen, pH and depth; (e, f): conductivity and alkalinity, and; (g, h): total suspended solids and temperature for Kuala Mai, Pahang River (left column), and Ulu Tembeling, Tembeling River (right column)

Table 4

Mean and range of water quality parameters for Kuala Mai, Pahang River, and Ulu Tembeling, Tembeling River

Variable	Kuala Mai, Pahang River (n = 12)		Ulu Tembeling, Tembeling River (n = 8)	
	Mean ± SD	Range	Mean ± SD	Range
Depth (m)	4.52 ± 1.24	2.50 - 6.51	3.80 ± 0.85	2.53 - 4.83
Temperature (°C)*	26.73 ± 0.80	25.24 - 27.80	28.22 ± 1.34	25.82 - 30.27
DO (mg/L)	6.72 ± 125.00	4.36 - 8.33	6.91 ± 0.40	6.23 - 7.46
pH	6.51 ± 0.39	5.73 - 7.14	6.33 ± 0.44	5.21 - 7.01
Conductivity (µS/cm)	46.07 ± 4.26	42.04 - 54.26	56.72 ± 24.32	28.00 - 98.88
Alkalinity (mg/L)	17.88 ± 3.70	10.60 - 22.20	16.35 ± 3.50	12.13 - 24.38
NH <sub>3</sub> -N (mg/L)*	0.80 ± 0.43	0.30 - 1.73	0.39 ± 0.33	0.06 - 1.34
NO <sub>3</sub> <sup>-</sup> (mg/L)	0.10 ± 0.07	0.01 - 0.26	0.07 ± 0.05	0.02 - 0.21
PO <sub>4</sub> <sup>3-</sup> (mg/L)	0.27 ± 0.27	0.03 - 0.92	0.34 ± 0.37	0.05 - 1.20
TSS (mg/L)*	164.90 ± 89.73	60.20 - 310.60	48.71 ± 62.57	11.13 - 226.40

\* = indicate significant difference ( $p < 0.05$ ) on the mean of water quality parameters between both rivers

An eigenvalue of 1 or above was the benchmark for extraction. A minimum value of 1 is considered significant. A total of 10 physicochemical parameters were measured, and only six were retained for Kuala Mai, Pahang River, while five were retained for Ulu Tembeling, Tembeling River. In Kuala Mai, Pahang River, the first axis had strong loadings for DO, pH, and PO<sub>4</sub><sup>3-</sup>, while the second axis indicated strong loadings for temperature, conductivity and alkalinity. Furthermore, at Ulu Tembeling, Tembeling River, the first axis had strong loadings for pH, alkalinity, NH<sub>3</sub>-N and TSS, while the second axis was highly loaded only by PO<sub>4</sub><sup>3-</sup>.

Six and five variables with significant contribution to the variation in the ordination resulting from the forward selection procedure of CCA were returned for Kuala Mai, Pahang River and Ulu Tembeling, Tembeling River, respectively (Table 6). The first and second ordination axes accounted for 24.39% and 21.13%, as well as 35.04%

and 31.18% for Pahang and Tembeling rivers, respectively.

In Kuala Mai, Pahang River, based on the CCA ordination map, DO, followed by PO<sub>4</sub><sup>3-</sup>, with the longest respective CCA vectors, were the most important water quality variables, while pH, conductivity and temperature presented much lower importance in structuring the fish occurrence, followed by alkalinity which was the lowest contributor among the six variables (Figure 3). Water quality parameters of pH and PO<sub>4</sub><sup>3-</sup> showed a negative correlation to alkalinity, while DO and temperature showed a negative correlation with conductivity. A total of 13 fish species including *Rasbora elegans*, *Hypsibarbus wetmorei*, *Raiamas guttatus*, *Lobocheilos rhabdoura*, *Fluviatrygon signifier*, *Channa striata*, *Bagrichthys macracanthus*, *B. altus*, *Macroglyphus maculatus*, *Barbodes lateristriga*, *Amblyrhynchichthys truncatus*, *Osphronemus goramy*, *Phalacronotus*

*apogon*, and *Hemibagrus capitulum* were positively associated with higher  $PO_4^{3-}$  and pH, but negatively associated with alkalinity levels, while the reverse was the case for other 15 species such as *Luciosoma setigerum*, *Achiroides leucorhynchus*, *Mystacoleucus obtusirostris*, *Chitala lopis*, *Wallagonia leerii*, *Hypsibarbus pierrei*, *Paralabuca typus*, *Barbonymus schwanefeldii*, *Pangasius nasutus*, *Labeo chrysophekadion*, *Macrochirichthys macrochirus*, *Puntioplites bulu*, *Cyclocheilichthys repasson*, *Laides hexanema* and *P. jullieni* which were positively associated with alkalinity levels, but negatively associated with pH and phosphate levels. Meanwhile, 18 species such as *Kryptopterus limpok*, *Belodontichthys dinema*, *Channa lucius*, *Mastacembelus unicolor*, *Barbonymus gonionotus*, *Osteochilus waandersii*, *Cyclocheilichthys apogon*, *Mastacembelus favus*, *Hemibagrus*

*wyckii*, *Anabas testudineus*, *Pterygoplichthys disjunctivus*, *Trichopodus trichopterus*, *Hampala macrolepidota*, *Osteochilus vittatus*, *B. yarrelli*, *Pseudolais micronemus*, *Notopterus notopterus*, and *Pangasionodon* sp. were negatively correlated with DO and temperature levels, but positively associated with conductivity. Conversely, species such as *Labiobarbus festivus*, *Barbichthys laevis*, *Helicophagus waandersii*, *Osteochilus melanopleura*, and *Thynnichthys thynnoides* were positively associated with DO and temperature levels but negatively associated with conductivity.

In Ulu Tembeling, Tembeling River, the CCA ordination map revealed that  $PO_4^{3-}$ , TSS and alkalinity were the most important physicochemical parameters, having the longest respective CCA vectors (Figure 4).  $NH_3$ -N concentration had less influence on the fish assemblages, while water pH

Table 5  
Loadings from the principal component analysis of water quality parameters in Kuala Mai, Pahang River and Ulu Tembeling, Tembeling River

Variable	Kuala Mai, Pahang River		Ulu Tembeling, Tembeling River	
	PC1	PC2	PC1	PC2
Depth (m)	-	-	-	-
Temperature (°C)	-0.003	0.956*	-	-
DO (mg/L)	0.880*	0.019	-	-
pH	0.894*	-0.052	-0.907*	0.189
Conductivity (µS/cm)	0.320	0.888*	-	-
Alkalinity (mg/L)	-0.482	0.740*	0.748*	0.325
$NH_3$ -N (mg/L)	-	-	0.922*	0.081
$NO_3^-$ (mg/L)	-	-	-	-
$PO_4^{3-}$ (mg/L)	-0.807*	-0.220	0.034	0.980*
TSS (mg/L)	-	-	0.916*	0.161
Percentage variance explained	42.66	38.35	61.46	22.67
Cumulative variance explained	42.66	81.01	61.46	84.13

\* = Indicate strong loadings with absolute value (> 0.7)

Table 6  
*Canonical Correspondence Analysis summary for water quality parameters in Kuala Mai, Pahang River and Ulu Tembeling, Tembeling River*

	Kuala Mai, Pahang River						Ulu Tembeling, Tembeling River					
	F1	F2	F3	F4	F5	F6	F1	F2	F3	F4	F5	
Eigenvalue	0.272	0.236	0.196	0.174	0.124	0.114	0.189	0.168	0.086	0.060	0.037	
Cumulative %	24.39	45.52	63.03	78.66	89.80	100.00	35.04	66.22	82.09	93.16	100.00	
Regression coefficients:												
pH	0.426	-0.644	1.969	-1.536	-0.084	0.966	-0.063	-0.179	-0.941	0.229	-0.163	
Alkalinity (mg/L)	-0.373	0.320	-1.296	-0.836	-0.231	-0.711	-0.120	0.449	0.083	-0.495	-1.392	
NH <sub>3</sub> -N (mg/L)	0.363	-0.876	1.169	-0.376	-1.001	1.226	-0.916	0.419	0.443	1.937	0.382	
PO <sub>4</sub> <sup>3-</sup> (mg/L)	-0.439	-0.315	-1.734	-0.564	0.905	1.067	-1.068	0.162	-0.120	-0.444	0.566	
TSS (mg/L)	-1.039	-0.364	-2.343	1.034	0.086	-1.357	2.234	0.878	-0.652	-0.304	0.563	
Temperature (°C)	0.498	0.063	4.508	0.145	-1.427	1.176						
DO (mg/L)												
Conductivity (µS/cm)												

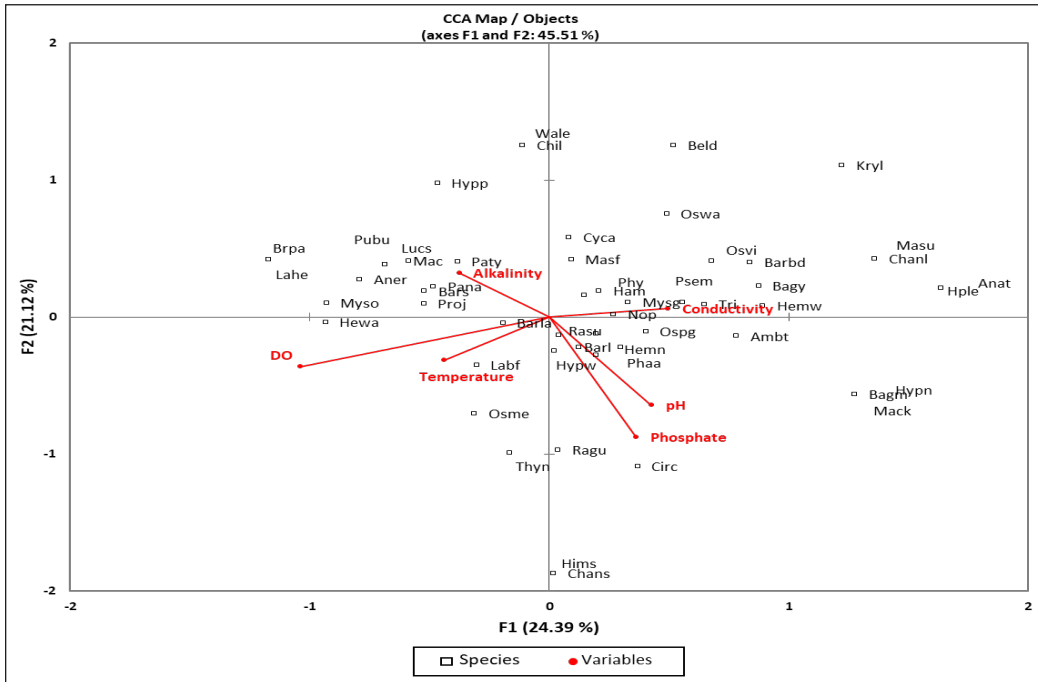


Figure 3. Canonical Correspondence Analysis ordination diagram showing the effect of environmental variables on fish assemblages in Kuala Mai, Pahang River

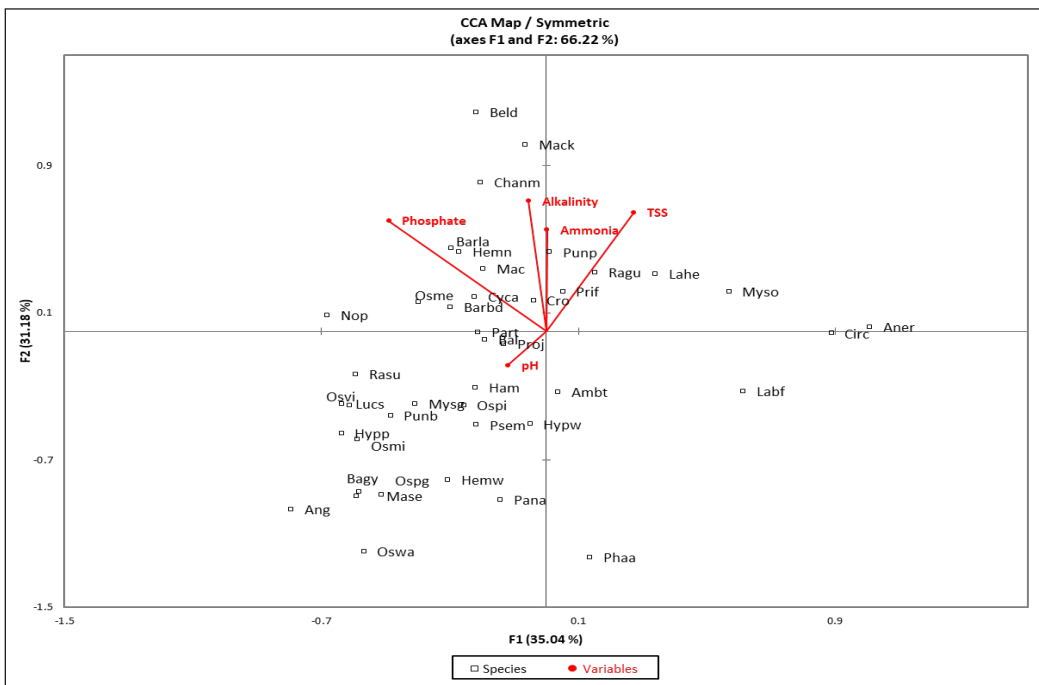


Figure 4. Canonical Correspondence Analysis ordination diagram showing the effect of environmental variables on fish assemblages in Ulu Tembeling, Tembeling River

correlated negatively with TSS. A total of 11 fish species such as *B. dinema*, *M. maculatus*, *Channa micropeltes*, *B. laevis*, *H. capitulum*, *M. macrochirus*, *O. melanopleura*, *C. apogon*, *B. gonionotus*, and *N. notopecterus* correlated positively with  $\text{PO}_4^{3-}$  and alkalinity, while three species including *A. truncatus*, *L. festivus*, and *P. apogon* correlated negatively with them. Nineteen species such as *R. elegans*, *O. vittatus*, *L. chrysophekadion*, *Puntioplites bulu*, *Mystus castaneus*, *Osteochilus spilurus*, *Pseudolais micronemus*, *Osteochilus microcephalus*, *B. yarrelli*, *O. goramy*, *Mastacembelus erythrotaenia*, *Anguilla marmorata*, *O. waandersii*, *Pangasius nasutus*, *H. wyckii*, *Paralaubuca typus*, *Probarbus jullieni*, and *Rasbora dusonensis* correlated positively with pH and negatively with TSS. Finally, six species such as *Puntioplites proctozysron*, *R. guttatus*, *L. hexanema*, *M. obtusirostris*, *C. repasson*, and *Pristolepis fasciata* correlated positively with TSS and negatively with pH levels.

## DISCUSSION

In this study, a total of 2,391 individuals that comprised of 65 fish species and 20 families were recorded for both rivers. Nevertheless, with reference to an earlier study carried out at Pahang River in the Maran District, a total of 2,075 individuals belonging to 65 species from 22 different families were recorded (Zulkafli et al., 2018), and a total of 4,834 fish individuals from 82 species and 25 families were collected from different parts of the Pahang River system, including Tembeling River (Zulkafli et al., 2015a).

These findings indicate that Pahang and Tembeling rivers harbor high fish species diversity and strengthen the facts on their importance to the local community in terms of food production and income generation (Mutrimah et al., 2015; Zulkafli et al., 2018).

Out of 65 species recorded, only three species namely *B. yarrelli*, *F. signifier*, and *P. jullieni* have been identified in this study as near threatened, endangered and critically endangered, respectively (IUCN, 2019). However, the numbers of these collected individuals were very low (mostly one individual, respectively) compared to those identified as least concern and data deficient. This signals a need for more action in the protection of biodiversity of Pahang River and its tributaries. The above-listed species should receive more attention to avoid eventual extinction. Furthermore, four introduced fish species such as *B. altus*, *B. gonionotus*, *Pangasionodon* sp., and *P. disjunctivus* were also recorded in this study, where all of them were collected from Pahang River. The occurrence *B. gonionotus* and *Pangasionodon* sp. could be related to extensive aquaculture activities in Pahang River, while it was also good news as no introduced fish species observed in Tembeling River as it specifically flows along the National Park at Kuala Tahan, Pahang.

The diversity, evenness and richness indices reported in this study for Kuala Mai, Pahang River are higher than that reported previously in other parts of Pahang River by Zulkafli et al. (2015a). They reported Shannon-Wiener's diversity indices of 2.5,

2.7 and 2.4, and Pielou's evenness indices of 0.79, 0.88 and 0.78 for Maran, Temerloh and Jerantut Districts, respectively. In this study, although the number of fishes that were sampled from Ulu Tembeling, Tembeling River is higher compared to Kuala Mai, Pahang River, the Pahang River demonstrated higher diversity, richness, and evenness, indicating generally higher fish biodiversity. It is important to note that there was a difference in the sampling frequency which could have affected the fishing effort deployed at both rivers leading to difference in the diversity indices. Furthermore, a difference in river size, flow and area may influence the number of fishes caught (Santos et al., 2010).

Some water quality parameters such as temperature,  $\text{NH}_3\text{-N}$  and TSS were significantly different between the two sites, and the ranges recorded for  $\text{NO}_3^-$  and  $\text{PO}_4^{3-}$  were considered high. This situation may be a result of the monsoon season which occurs at east coast area at Peninsular Malaysia between the months of November and March, at times leading to heavy floods like that of 2006 to 2008, and this coincides with the sampling period for this study (Alias et al., 2016). In a study of the impacts of monsoon and dry seasons on physical water quality changes and farmed *Lates calcarifer* mortality at Sri Tujuh lagoon, Tumpat, Kelantan, Malaysia, it was concluded that the monsoon season influences certain water quality parameters (Abdullah et al., 2018). According to Abdullah et al. (2018), water quality parameters like DO and turbidity fluctuated and deteriorated during the

monsoon season. The most crucial water physicochemical parameters influencing the occurrences of fishes in the Pahang River of Maran District include pH, temperature, conductivity, and  $\text{PO}_4^{3-}$  (Zulkafli et al., 2018). For both study sites in this study,  $\text{PO}_4^{3-}$  concentration was strongly related to the fish abundance, making it generally the most important physicochemical parameter as far as this study is concerned. Although alkalinity also recurred in both, it had less impact compared to that exhibited by  $\text{PO}_4^{3-}$  concentration. Being a nutrient, the presence of  $\text{PO}_4^{3-}$  may have likely influenced by primary production of food in the studied water bodies. On the other hand, if there is over enrichment in the water body, eutrophication may result leading to suboptimal water conditions. The less hardy fish species may move towards other regions with normal levels of  $\text{PO}_4^{3-}$  (Nijboer & Verdonschot, 2004).

Temperature plays a crucial role in structuring fish occurrence. The physiology of fish can be affected by the temperature which is considered as the fundamental ecological variable (Norin et al., 2016). In Pahang River, the temperature was higher during the wet season, compared to the dry season. A study that had been done in the Three Gorges Reservoir, China and Pararanga Reservoir, Brazil, proved the water temperature might increase during the wet season (Deng et al., 2016). The reason for this higher wet seasonal temperature is not so clear because numerous factors such as hydrological including the relative contribution of groundwater, discharge



or flow rate, water volume, inflow from tributaries, climatological including air temperature, solar radiation, cloud cover, wind speed, vapor pressure, precipitation and evaporation (Dallas, 2008). Furthermore, aquatic organisms' reaction towards the other biotic and abiotic stressors can be affected by thermal stress on fish (Grasset et al., 2016). In Pahang River,  $\text{PO}_4^{3-}$  and DO were the most important predictors of fish occurrence. Although water conductivity had more influence on fish occurrences in Kuala Mai, Pahang River compared to Ulu Tembeling, Tembeling River, the possible influence seems to be weak compared to other physicochemical parameters influencing that river.

For Ulu Tembeling, Tembeling River, some fish species seem to prefer high pH areas with a low concentration of TSS, alkalinity, and  $\text{NH}_3\text{-N}$ . This group was dominated by various kinds of fish families, especially Pangasiidae and Bagridae. The pH reading of 5 to 6 is considered natural acidity which is produced by organic acids, and it has been mentioned that natural acidity from organic acids has less effect on constructing fish assemblages compared to the acidity that comes from human impacts (Greig et al., 2010). In addition, the pH may not be easily predictable because of the possible influence of dissolved leachate during the wet season. This may increase the water acidity as opposed to the expectation of increased pH with a higher influx of water (Nienie et al., 2017).

The patterns of the fish assemblage were also influenced by TSS. Fewer species were found in the area with a high value of TSS.

For instance, *L. hexanema* would prefer and could live in the area with low pH and high concentration of TSS. Moreover, abiotic factors such as water temperature, pH and TSS had a significant effect on the fish survival rate, while fish survival based on suspended solids still differ across species depending upon species-specific tolerance to suspended solids (Nyanti et al., 2018).

## CONCLUSION

Useful background information for the management of Pahang and Tembeling rivers through knowledge of the diversity, dynamics of water physicochemical parameters, and interaction between fish species occurrences and water quality parameters were presented in this study. Apart from the influences of  $\text{PO}_4^{3-}$ , alkalinity and pH in both rivers, the results showed that temperature, DO, and conductivity were the major influencers of the fish occurrences in Kuala Mai, Pahang River, as  $\text{NH}_3\text{-N}$ , and TSS in Ulu Tembeling, Tembeling River. Information on the dynamics of these important parameters can help in the monitoring of water quality, and possibly in predicting the abundance of certain fish species of economic and ecological importance. The occurrence of introduced fish species in the natural water body of the Pahang River should raise some concerns to the authorities. Moreover, fish conservation and stock management efforts are urgently needed due to the decreasing number of near-threatened, endangered and critically endangered fish species in both rivers.

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## REFERENCES

- Abdullah, H. H., Rak, A. E., & Wei, L. S. (2018). The impacts of monsoon and dry seasons on physical water quality changes and farmed Asian seabass *Lates calcarifer* (Bloch, 1790) mortality at Sri Tujuh lagoon, Tumpat, Kelantan, Malaysia. *Aquaculture, Aquarium, Conservation and Legislation*, *11*(1), 167-183.
- Alias, N. E., Mohamad, H., Chin, W. Y., & Yusop, Z. (2016). Rainfall analysis of the Kelantan big yellow flood 2014. *Jurnal Teknologi*, *78*(9-4), 83-90.
- Bhuiyan, M. A. H., Ismail, S. M., Siwar, C., & Elfithri, R. (2014). The role of natural capital for ecosystem: Focusing on water resource in Pahang, Malaysia. *Life Science Journal*, *11*(5), 97-101.
- Dallas, H. (2008). Water temperature and riverine ecosystems: An overview of knowledge and approaches for assessing biotic responses, with special reference to South Africa. *Water Sa*, *34*(3), 393-404.
- Deng, X. Y., Youcai, T., & Taifu, H. (2016). Influence of Three Gorge Reservoir on water temperature between Yichang and Jianli. *Advances in Water Science*, *27*(4), 551-560.
- Fricke, R., Eshmeyer, W. N., & van der Laan, R. (2020). *Catalogue of fishes: Genera, species, references*. Retrieved Jan 03, 2020, from <http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp>
- Froese, R., & Pauly, D. (2018). *World wide web electronic publication*. Retrieved January 03, 2020, from <http://www.fishbase.org>
- Grasset, J., Ollivier, É., Bougas, B., Yannic, G., Campbell, P. G., Bernatchez, L., & Couture, P. (2016). Combined effects of temperature changes and metal contamination at different levels of biological organization in yellow perch. *Aquatic Toxicology*, *177*(8), 324-332.
- Greig, H. S., Niyogi, D. K., Hogsden, K. L., Jellyman, P. G., & Harding, J. S. (2010). Heavy metals: Confounding factors in the response of New Zealand freshwater fish assemblages to natural and anthropogenic acidity. *Science of the Total Environment*, *408*(16), 3240-3250.
- Hammer, Ø., Harper, D. A. T., & Ryan, P. D. (2001). PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia Electronica*, *4*(1), 9.
- Hashim, Z. H., Zainuddin, R. Y., Shah, A. S. R. M., Sah, S. A. M., Mohammad, M. S., & Mansor, M. (2012). Fish checklist of Perak River, Malaysia. *Check List*, *8*(3), 408-413.
- Idris, K., Shaffril, H. A. M., Yassin, S. M., Samah, A. A., Hamzah, A., & Samah, B. A. (2016). Quality of life in rural communities: Residents living near to Tembeling, Pahang and Muar Rivers, Malaysia. *PloS One*, *11*(3), 1-16.
- Ikhwanuddin, M. E. M., Amal, M. N. A., Hazman, H. H., Shohaimi, S., & Jamil, N. R. (2016). Environmental influences on fish assemblages of the upper Sungai Pelus, Kuala Kangsar, Perak, Malaysia. *Sains Malaysiana*, *45*(10), 1487-1459.
- International Union for Conservation of Nature's. (2019). *The IUCN red list of threatened species*. Retrieved January 03, 2020, from <http://www.iucnredlist.org/>

- Ismail, A., Amal, M. N. A., Mustafa, M., Aziz, N. A. A., Nadzir, M. N. H. M., & Rahman, F. (2013). A survey on fish diversity in Sungai Enam, Temenggor Lake, Perak. *Malayan Nature Journal*, 65(2&3), 30-37.
- Jalal, K. C. A., Alifah, F. K., Faizul, H. N. N., Mamun, A. A., Kader, M. A., & Ashraf, M. A. (2018). Diversity and community composition of fishes in the Pusu River (Gombak, Malaysia). *Journal of Coastal Research*, 82, 150-155.
- Mohsin, A. K. M., & Ambak, M. A. (1991). *Ikan air tawar di Semenanjung Malaysia* [Freshwater fish in Peninsular Malaysia]. Kuala Lumpur, Malaysia: Dewan Bahasa dan Pustaka.
- Mutrimah, A., Parid, M., Motoe, M., & Lim, H. (2015). Ecotourism, income generation and poverty reduction; A case of the Kuala Tahan National Park, Pahang, Malaysia. *Journal of Tropical Resources and Sustainable Science*, 3, 40-45.
- Nasruddin, N. S., Amal, M. N. A., Ismail, A., Zamri-Saad, M., Daud, H. M., & Zulkifli, S. Z. (2014). Histological features of the gastrointestinal tract of wild Indonesian shortfin eel, *Anguilla bicolor bicolor* (McClelland, 1844), captured in Peninsular Malaysia. *The Scientific World Journal*, 2014, 312670.
- Nienie, A. B., Sivalingam, P., Laffite, A., Ngelinkoto, P., Otamonga, J. P., Matand, A., ... Poté, J. (2017). Seasonal variability of water quality by physicochemical indexes and traceable metals in suburban area in Kikwit, Democratic Republic of the Congo. *International Soil and Water Conservation Research*, 5(2), 158-165.
- Nijboer, R. C., & Verdonschot, P. F. (2004). Variable selection for modelling effects of eutrophication on stream and river ecosystems. *Ecological Modelling*, 177(1-2), 17-39.
- Norin, T., Malte, H., & Clark, T. D. (2016). Differential plasticity of metabolic rate phenotypes in a tropical fish facing environmental change. *Functional Ecology*, 30(3), 369-378.
- Nyanti, L., Soo, C. L., Danial-Nakhaie, M. S., Ling, T. Y., Sim, S. F., Grinang, J., & Lee, K. S. (2018). Effects of water temperature and pH on total suspended solids tolerance of Malaysian native and exotic fish species. *AACL Bioflux*, 11(3), 565-575.
- Paller, M. H., Prusha, B. A., Fletcher, D. E., Kosnicki, E., Sefick, S. A., Jarrell, M. S., ... Feminella, J. W. (2016). Factors influencing stream fish species composition and functional properties at multiple spatial scales in the Sand Hills of the southeastern United States. *Transactions of the American Fisheries Society*, 145(3), 545-562.
- Roseli, N. H., & Akhir, M. F. M. (2014). Variations of Southern South China sea characteristics near Pahang. *Sains Malaysiana*, 43(9), 1389-1396.
- Samah, B. A., Yassin, S. M., Hamzah, A., Shaffril, H. A. M., Samah, A. A., & Idris, K. (2013). Relationship to the river: The case of the rural communities residing beside the Tembeling, Pahang and Muar Rivers. *Asian Social Science*, 9(13), 119-125.
- Santos, A. B. I., Terra, B. D. F., & Araújo, F. G. (2010). Influence of the river flow on the structure of fish assemblage along the longitudinal gradient from river to reservoir. *Zoologia (Curitiba)*, 27(5), 732-740.
- Shuib, A. (1995). Tourism in Taman Negara Malaysia its contribution as perceived by residents of Ulu Tembeling. *Akademika*, 47(2), 37-48.
- Sule, H. A., Ismail, A., & Amal, M. N. A. (2016). A review of the ichthyofauna of Malaysian peat swamp forest. *Pertanika Journal of Tropical Agricultural Science*, 39(4), 421-458.
- Sule, H. A., Ismail, A., Amal, M. N. A., & Syaizwan, Z. Z. (2018). Water quality influences on

- fish occurrence in peat swamp forest and its converted areas in north Selangor, Malaysia. *Sains Malaysiana*, 47(11), 2589-2600.
- Tsai, W. P., Huang, S. P., Cheng, S. T., Shao, K. T., & Chang, F. J. (2016). A data-mining framework for exploring the multi-relation between fish species and water quality through self-organizing map. *Science of the Total Environment*, 594, 474-483.
- Yusof, F. M., Jamil, N. R., Roseli, F. A. M., Malik, N. K. A., & Amal, M. N. A. (2018). Effects of water quality in the agricultural drainage towards the fish diversity and its abundancy in the southwest part of Bagan Datuk District, Perak, Malaysia. *Malayan Nature Journal*, 70(4), 373-385.
- Zaid, M. Z. C., Zaini, N. A. M., Rahim, N. Z. A., Ilham, H. Z., Fazliana, N., Bahari, Q. A. M. Z., ... Amal, M. N. A. (2018). Fish diversity of high-altitude small streams and ponds in Chalet Pak Lah, Janda Baik, Pahang, Peninsular Malaysia. *Malayan Nature Journal*, 70(4), 367-371.
- Zakaria-Ismail, M., Fatimah, A., & Khaironizam, M. Z. (2019). *Fishes of the freshwater ecosystems of Peninsular Malaysia*. Saarbrücken, Germany: Lambert Academic Publishing.
- Zulkafli, A. R., Amal, M. N. A., & Shohaimi, S. (2018). Water quality influences on fish occurrences in Sungai Pahang, Maran District, Pahang, Malaysia. *Sains Malaysiana*, 47(9), 1941-1951.
- Zulkafli, A. R., Amal, M. N. A., Shohaimi, S., Mustafa, A., Ghani, A. H., Hashim, S., ... Hasfairi, M. P. (2015a). Length-weight relationships of 20 fish species from Pahang River, Maran district, Pahang, Malaysia. *Journal of Applied Ichthyology*, 31(2), 409-410.
- Zulkafli, A. R., Amal, M. N. A., Shohaimi, S., Mustafa, A., Ghani, A. H., Hashim, S., ... Ayub, S. (2016a). Length-weight relationships of 15 fish species from Tembeling River, Pahang, Malaysia. *Journal of Applied Ichthyology*, 32(1), 167-168.
- Zulkafli, A. R., Amal, M. N. A., Shohaimi, S., Mustafa, A., Ghani, A. H., Ayub, S., ... Hasfairi, M. P. (2016b). Length-weight relationships of 13 fish species from Pahang River, Temerloh district, Pahang, Malaysia. *Journal of Applied Ichthyology*, 32(1), 165-166.
- Zulkafli, A. R., Asmuni, M., & Amal, M. N. A. (2015b). Fish diversity of Tembeling and Pahang rivers, Pahang, Malaysia. *Check List*, 11(5), 1-6.