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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 *1-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 km², 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; Zulkafli 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

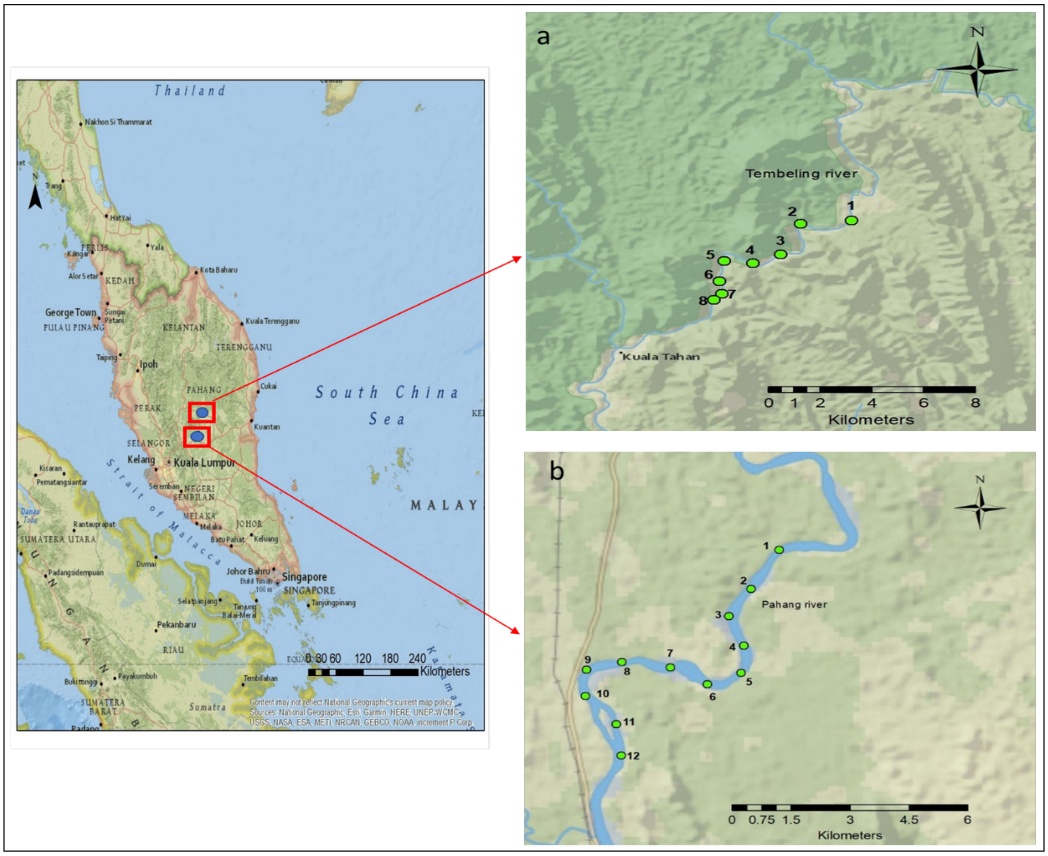

Figure 1. Sampling points location in (a) Ulu Tembeling, Tembeling River and (b) Kuala Mai, Pahang River

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 (°C), pH (1-14), conductivity (µS/cm), total suspended solids (TSS) (mg/L) (YSI Incorporation, NY, USA), and river depth (m) (Speedtech Instrument, Logan, UT, USA). Besides that, the ammonia nitrogen (NH_3-N) (mg/L), phosphate (PO_4^{3-}) (mg/L), nitrate (NO_3^-) (mg/L) and alkalinity (mg/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 (*1-D*)), evenness (Pielou's evenness (*e*) index) and richness (Menhinnick's richness index (*I*)) 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 (*1-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 (*Fluvitrygon 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 ($1-D$) (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	*Fluvitrygon signifier*	1	NA	EN	Hims
Anguillidae	*Anguilla marmorata*	NA	1	LC	Ang
Notopteridae	*Chitala lopis*	2	6	LC	Chil
	Notopterus notopterus	4	4	LC	Nop
Botiidae	*Syncrossus hymenophysa*	NA	2	LC	Synh

Table 2 *(continue)*

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

Table 2 *(continue)*

Family	Species	Pahang River	Tembeling River	IUCN status	Abbreviation
Pangasiidae	*Helicophagus waandersii*	5	NA	LC	Hewa
	**Pangasionodon* sp.	8	NA	NE	Phy
	Pangasius nasutus	10	8	LC	Pana
	Pseudolais micronemus	33	160	DD	Psem
Siluridae	*Belodontichthys dinema*	4	6	LC	Beld
	Kryptopterus limpok	7	NA	LC	Kryl
	Phalacronotus apogon	86	27	LC	Phaa
	Wallagonia leerii	2	NA	LC	Wale
Loricariidae	**Pterygoplichthys disjunctivus*	1	NA	NE	Hple
Mastacembelidae	*Macrognathus maculatus*	1	4	LC	Mack
	Mastacembelus erythrotaenia	NA	1	LC	Mase
	Mastacembelus favus	2	1	LC	Masf
	Mastacembelus unicolor	1	NA	NE	Masu
Anabantidae	*Anabas testudineus*	1	NA	LC	Anat
Osphronemidae	*Osphronemus goramy*	5	5	LC	Ospg
	Trichopodus trichopterus	6	NA	LC	Tri
Channidae	*Channa lucius*	1	NA	LC	Chanl
	Channa micropeltes	NA	5	LC	Chanm
	Channa striata	1	NA	LC	Chans
Pristolepididae	*Pristolepis fasciata*	NA	2	LC	Prif
Soleidae	*Achiroides leucorhynchos*	1	NA	NE	Brpa
Belonidae	*Xenentodon canciloides*	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			
	H	*1-D*	*e*	*D*
Kuala Mai, Pahang River (n = 12)	3.315 $\pm$ 0.036*	0.949 $\pm$ 0.003*	0.5	1.949
Ulu Tembeling, Tembeling River (n = 8)	2.893 $\pm$ 0.029	0.916 $\pm$ 0.003	0.384	1.177

H = Shannon-Wiener's diversity index; *1-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_3-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_3^- 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_4^{3-} 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_3-N ranged from 0.06 mg/L in November to 1.34 mg/L in October. NO_3^- ranged from 0.02 mg/L in April to 0.21 mg/L in October. PO_4^{3-} 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_3-N and TSS (Table 4). Temperature (t (16) = -2.171, p = 0.045) was significantly ($p < 0.05$) higher, while NH_3-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_3^- were numerically higher at Kuala Mai, Pahang River, while DO, conductivity, and PO_4^{3-} 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_3-N (mg/L)*	0.80 ± 0.43	0.30 - 1.73	0.39 ± 0.33	0.06 - 1.34
NO_3^- (mg/L)	0.10 ± 0.07	0.01 - 0.26	0.07 ± 0.05	0.02 - 0.21
PO_4^{3-} (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_4^{3-}, 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_3-N and TSS, while the second axis was highly loaded only by PO_4^{3-}.

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_4^{3-}, 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_4^{3-} 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*, *Fluvitrygon signifier*, *Channa striata*, *Bagrichthys macracanthus*, *B. altus*, *Macrognathus 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 leucorhynchos*, *Mystacoleucus obtusirostris*, *Chitala lopis*, *Wallagonia leerii*, *Hypsibarbus pierrei*, *Paralaubuca 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_3-N (mg/L)							-0.916	0.419	0.443	1.937	0.382
PO_4^{3-} (mg/L)	0.363	-0.876	1.169	-0.376	-1.001	1.226	-1.068	0.162	-0.120	-0.444	0.566
TSS (mg/L)							2.234	0.878	-0.652	-0.304	0.563
Temperature (°C)	-0.439	-0.315	-1.734	-0.564	0.905	1.067					
DO (mg/L)	-1.039	-0.364	-2.343	1.034	0.086	-1.357					
Conductivity (µS/cm)	0.498	0.063	4.508	0.145	-1.427	1.176					

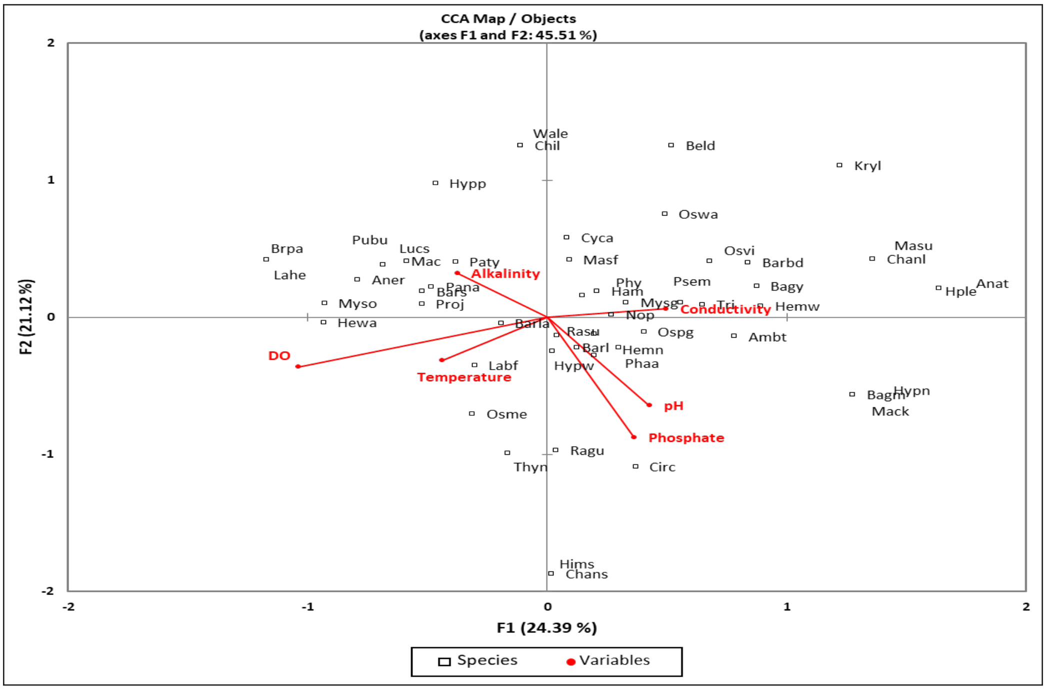

Figure 3. Canonical Correspondence Analysis ordination diagram showing the effect of environmental variables on fish assemblages in Kuala Mai, Pahang River

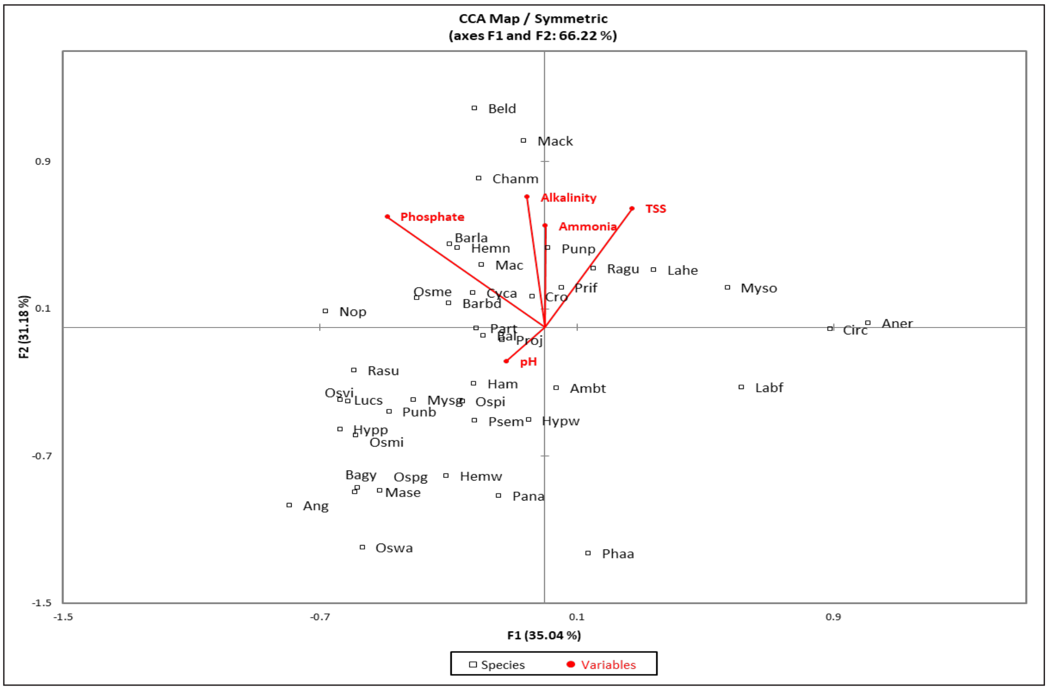

Figure 4. Canonical Correspondence Analysis ordination diagram showing the effect of environmental variables on fish assemblages in Ulu Tembeling, Tembeling River

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. notopterus* correlated positively with 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 endangred, 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, NH_3-N and TSS were significantly different between the two sites, and the ranges recorded for NO_3^- and 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 PO_4^{3-} (Zulkafli et al., 2018). For both study sites in this study, 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 PO_4^{3-} concentration. Being a nutrient, the presence of 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 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, 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 NH_3-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 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 NH_3-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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