The Migratory Pattern and Condition of Tiny Scale Barb, *Thynnichthys thynnoides* (Bleeker, 1852) at Rui River, Perak, Malaysia

A.M. Radhi[1], H. Rohasliney[1,*], M.N.A. Amal[2] and H.H. Zarul[3]

[1] Department of Environmental Management, Faculty of Environmental Studies, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia
[2] Biology Department, Faculty of Science, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia
[3] School of Biological Sciences, Universiti Sains Malaysia, 11800 USM Minden, Penang, Malaysia
* Corresponding author: rohasliney@upm.edu.my
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ABSTRACT

A study on the migratory behavior and condition of potamodramous *Thynnichthys thynnoides* and its environmental attributes was studied from May to October 2015 in Rui River, the main tributary of Perak River. The migration pattern and condition of *T. thynnoides* were examined by using two catch techniques which are active (scoop net) and passive (gill net) sampling, while water quality parameters were determined by using standard methods. *Thynnichthys thynnoides* were caught between August and October as the migration season began, with peak migration occurring in September and October. The longest observed migration from the refugee habitat to the possible spawning ground was 52 km. There was a significant variation in turbidity concentration between spawning and non–spawning seasons ($F = 13.23$, $P < 0.05$). The length–weight relationships of *T. thynnoides* exhibited isometric body growth, and the condition of *T. thynnoides* declined over the spawning migration. From these results, it was concluded that the migration of *T. thynnoides* was dependent on environmental conditions.

Keywords*:* Freshwater, *Thynnichthys thynnoides*, behavior, environmental factors, Perak River

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INTRODUCTION

The tiny scale barb, *Thynnichthys thynnoides* is a relatively small riverine cyprinid species inhabiting river basins and lakes (Ali and Lee, 1995; Thuok and Sina, 1997; Vidthayanon *et al*., 1997). This species inhabits large river canals of Perak River and moves to small tributaries (i.e. Rui River) during spawning season. Although this migratory species has been spotted spawning in Rui River, the details of distribution and spawning activity have not been adequately assessed (Amal *et al*., 2015). *Thynnichthys thynnoides* can be found in Chenderoh Reservoir, Perak (Kah–Wai and Ali, 2001), Pahang River in Maran and Temerloh districts (Zulkafli *et al*., 2015; Zulkafli *et al*., 2016) and in Chini Lake, Pahang (Kutty *et al*., 2009). This species also scattered around Brunei, Cambodia, Indonesia, Laos, Myanmar, Thailand and Vietnam (Ambak *et al*., 2010). Furthermore, *T. thynnoides* is recognized as an important fish species for human consumption in both Khone Falls, Cambodia and Chenderoh Reservoir, Perak, Malaysia (Ali and Lee, 1995; Bishop, 2002).

Currently, IUCN Red List Status reports that *T. thynnoides* is categorized as a species of least concern (LC) (Vié *et al*., 2008). However, Chong *et al*. (2010) classified *T. thynnoides* as being under medium threat due to overfishing and water pollution. It is anticipated that fishing pressure on *T. thynnoides* is increasing since this fish is high in commercial value and selectively targeted during the spawning season. In 2014, an occurrence of fish kill in Rui River has became a concern to regarding food safety of fishes caught there, particularly *T. thynnoides* (Dolasoh, 2014). Tin mining activity affects the water quality of Rui River based on its water treatment compound, particularly in the water of Kepayang River, a tributary of Rui River. The mining company directly introduces lime into the river water to reduce the water pH from acidic to normal range (pH 6 – 8). During heavy rainfall, the accumulated lime sediment is then flushed into Rui River. It is therefore necessary to provide information on the condition factor (length–weight relationship (LWR)) and migratory pattern of *T. thynnoides* in order to assist the stakeholders' decision–making process. The informed decision from stakeholders will ensure the well–being of *T. thynnoides* in Rui River, Gerik, Perak. as well as to safeguard the spawning habitat of this species and introduction of sustainable fisheries to the local community. Thus, this study aimed to determine the migratory pattern and condition of this species, and also environmental attributes that influence the well–being of the species.

MATERIALS AND METHODS

Study Location

This study was conducted in Perak River, Perak, including one of the main tributaries, the Rui River, which is located in Kenering dam. With a surface area of 40 km^2, mean depth of 15 m, and water volume of 352 million m^3, Kenering Reservoir was built mainly for hydropower generation and flood control (Zarul, 2013). Kenering Reservoir has the second largest surface area in Perak River after Temenggor (152 km^2) followed by Chenderoh (21 km^2) and Bersia (10 km^2) Reservoirs. Eight sampling sites were selected based on the suggestions from local villagers and fishermen on the locations of *T. thynnoides*. The selected sites at Rui River were: S1 (Alai), S2 (Kg Baharu), S3 (Kg Plang), S4 (Kerunai), S5 (Kuala Rui), while S6 (Kg Perah), S7 (Air Ganda) and S8 (Bersia) were located in Perak River, named from upstream to downstream (Figure 1).

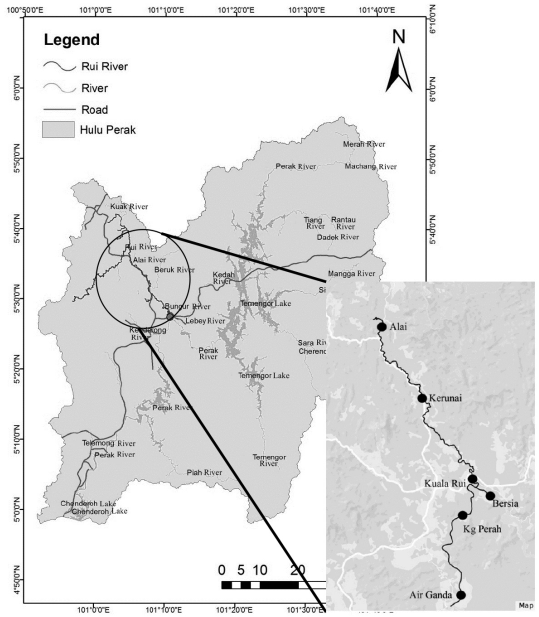

Figure 1 Location of sampling sites at Rui River, Gerik, Perak

Fish Collection

The primary data collection was conducted in selected months: May, August, September and October 2015. Samples were collected at eight sampling sites along the Rui River and Perak River according to season, which are normal season (May and August), and wet season (September and October). Active (scoop net) and passive (gill net) gears were both used in this study for fish sampling based on the locations of *T. thynnoides*, as informed by the local fishermen and villagers at Rui River and Perak River. During normal season, the population of *T. thynnoides* is expected at the lower stream area (S5, S6, S7 and S8), thus, gill nets (passive samples) were used for the study. Four gill nets with mesh sizes of 2.5 cm, 5.0 cm, 7.6 cm and 10.0 cm were used at the littoral areas of all sampling sites (N = 4 sampling months × 3 days × 1 year × 3 replicates × 4 gill net sets = 144 samplings/river). The gill nets were set up from 8.00 am to 6.00 pm before the samples were collected after three continuous 24 hour intervals (72 hours). During spawning season, the scoop net was used as the gill net is not suitable due to the fast water current at sampling sites S1, S2, S3, S4 and S5 (N = 2 sampling months × 1 hour × 1 day × 20 replicates × 1 scoop net = 40 samplings/river). The length of the net handle was 371 cm, and the net circumference was 97 cm with a depth of 74 cm and mesh size of 2.5 cm. The gill net was first set up during spawning season at sampling sites S6 and S7 from 8.00 am to 12.00 pm, and the samples were then collected after three continuous 24 hour intervals (72 hours). Sampling site S8 was not included because the main objective was to record the migration activity upstream of Rui River during the spawning season. Subsequently, the sampling activity proceeded with scoop net technique from 12.00 pm to 6.00 pm at S1, S2, S3, S4 and S5.

The total length of individual fish in cm was taken from the tip of the snout to the extended tip of the caudal fin, using a measuring board. Body weight was taken to the nearest gram using an electronic balance (Smith LT2002, China).

Environmental Data

Temperature (°C), dissolved oxygen (DO) (mg/L), pH and electrical conductivity (EC) (µS/cm) were measured with a multi–probe metre (YSI 556 MPS, USA). Turbidity measurement was conducted using the light extinction spectrophotometer (HACH 2100P, USA), and in compliance with the Hach procedure. All *in–situ* physico–chemical parameters involving: (1) pH, (2) temperature, (3) DO and (4) turbidity were measured three times on the surface water (10 cm) at littoral zone of each sampling site. Total Suspended Solid (TSS) analysis was carried three times out based on Eaton *et al*. (2005).

Data Analyses

LWR was calculated by using log W = log a + b log L, where W is the weight of the fish (g), L is the total length of the fish (cm), a is the intercept, and b is the growth coefficient.

The condition factor (K) was estimated from K = 100 (W/L^3) based on Froese (2006) where W is the weight of an individual fish specimen (g), L is the total length (cm), and 100 is a constant. One–way ANOVA test was performed by using IBM SPSS Statistics 21 to distinguish variance of regression coefficients (b value) and K value between different group sizes (small, medium and large).

The selected physicochemical parameters data are subjected to descriptive statistics and one–way ANOVA to test the variance of temperature and dissolved oxygen between sampling sites.

The Pearson’s correlation is performed to investigate the correlation among: (i) physicochemical parameters (ii) fish condition, and (iii) body weight. For habitat assessment parameters, non–parametric independent–samples Kruskal–Wallis test is used to compare and relate the distribution of score across all sampling sites. Mann Whitney U test is also used to compare the median between each group of sampling sites.

RESULTS AND DISCUSSION

Migration Pattern

A total of 238 specimens of *T. thynnoides* were collected during this study. *Thynnichthys thynnoides* were only caught in August, September and October 2015. There was no *T. thynnoides* caught in May 2015 due to the location of these fishes at further downstream of Perak River, which excluded from the studied area. According to local fishermen, Basharudin, (personal communication, April 15, 2015), the species may not have migrated in the month of May (non–spawning season) and thus, they are populated at the lower reach of Kenering Reservoir as a refugee habitat. In August 2015, *T. thynnoides* was spotted moving upstream from S7 and S8 to S5 (Figure 2). However, *T. thynnoides* was not observed at S6. In September and October 2015, *T. thynnoides* started to migrate further to the upper stream of Rui River and was caught at S2 and S3 (Figure 2).

Among 238 fishes recorded in this study, 167 fishes were caught from S5; 26 fishes were caught from S7; 23 fishes were caught from S2; 19 fishes were caught from S3; and 7 fishes were caught from S8 (Figure 2). As for sampling sites S1 and S4, no *T. thynnoides* species was caught. S1 was selected to identify the furthest migration location of *T. thynnoides* at Rui River. Presumably, the highest end site for the migration of this species is S2. While at S4, the gill nets captured other fish species. The distance travelled by *T. thynnoides* from S8 to S2 was 52 km. Findings from this study suggest that spawning sites in Rui River are S2, S3 and S5, on the basis that there were notable assemblages of fishes at these sites. Sampling site S7 was identified as the feeding and growing habitat, as most of the smaller sized (11–14.7 cm) *T. thynnoides* was caught at this location.

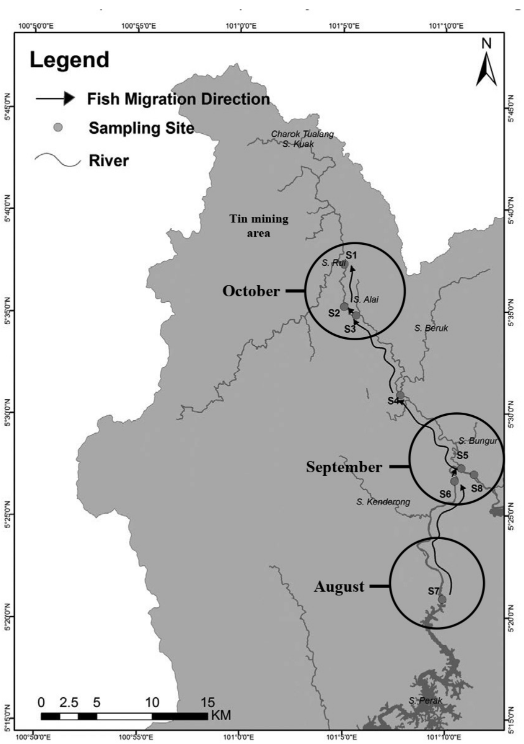

Figure 2 Migration of *Thynnicthys thynnoides* from downstream (S7) to upstream (S2) during the study period from May to October 2015

This study suggested that the spawning sites in Rui River are at S2, S3 and S5 as these sites are the most suitable spawning ground. These sites supported favourable substrate for epifaunal colonisation and fish cover. The river bank's intact forest protects the river from being exposed to the direct sunlight. The stream channel consists a mixture of substrate materials, gravel and sand, root mats and submerged vegetation. Sampling sites S2 and S3 were found to have deeper pools with fast water flow after the stream sections. The mixture of four different velocities (slow–deep, slow–shallow, fast–deep and fast–shallow) were observed at these sampling sites. Sampling site S5 has an average habitat condition. The most obvious establishment built at S5 is called The Loma Square (Loma is the local name for *T. thynnoides*). This area was built to facilitate the locals and outsiders to capture *T. thynnoides* and trade it fresh or as pickled fish. S7 was found to be a nursery ground, as most of the smaller sized *T. Thynnoides* was caught here. Similarly, Amal *et al*. (2015) also collected *T. thynnoides* from Kuala Rui area (S5) (n = 122) during the migration period on October 2013. Apparently, the spawning cycle timing has not changed in Rui River. Conversely, the migration of *T. thynnoides* in the Mekong River, Laos into floodplains for spawning purpose was recorded from August to September.

The migration direction is both longitudinal and lateral (Baird *et al*., 1999). Lateral migration is usually associated with an abundance of food, in the form of flora and fauna from flooded active channels (Junk *et al*., 1989). According to a researcher, Tuantong, these fishes have to migrate to an area with relatively fast flow for spawning. In fact, these fishes are able to survive in a man–made lake but they have to migrate to the inlet for spawning activity (personal communication, July 3, 2015). Uniquely, Ali and Kadir (1996) found that *T. thynnoides* have three inconsistent breeding cycle patterns in Chenderoh Reservoir: the first gonadosomatic index (GSI) peak was recorded in August 1991 (June to November), the second peak was recorded in January 1992 (December to February), and the third peak was recorded in November 1992 (August to November).

This study provides several insights into the *T. thynnoides* distribution at Rui River, Perak, where such information was previously lacking. *Thynnichthys thynnoides* was spotted starting its migration in September and October from downstream to upstream. By definition, migratory species are mobile and adjust their migration behaviour to pursue a suitable environment throughout the progression of their lifecycle (Robinson ***et al***., 2009). Migration of fishes has traditionally been associated with three purposes: spawning, feeding and refuge (Lucas and Baras, 2008).

Length–Weight Relationships and Condition Factor

The total length (TL) of *T. thynnoides at* all sampling sites at Rui River ranged from 11 cm to 22 cm with a mean of 18.95 ± 2.48 cm. The weight ranged from 14.13 g to 106.37 g with a mean value of 63.39 ± 20.05 g and a median value of 66.82 g. The majority of fish caught (80.6% from total catch) were large sized (18.5–22.1 cm), 11.6% were small sized (14.8–18.4 cm) and 7.6% were medium sized. There was a positive variation in the total length and weight of *T. thynnoides* in all sampling sites seasonally (Length: F = 3.12, Weight: F = 88.74, $P < 0.05$). The highest mean values recorded for the measurement of length and weight for *T. thynnoides* are 20.27 cm and 74.64 g respectively in September, followed by measurements taken in October (19.70 cm, 67.96 g) and August (14.88 cm, 35.53 g). This could be attributed to the types of habitat and migration ability. Small sized *T. thynnoides* were found in the stagnant littoral area only (S7 and S8) while large and medium sized *T. thynnoides* could adapt in the fast current of Rui River during spawning season.

Froese (2006) indicated that the expected range of *b* value is $2.5 < b < 3.5$. The LWR of *T. thynnoides*, based on 238 individuals, was calculated as:

$$W = 0.00824L^{3.02}$$

The mean *b* value for *T. thynnoides* in this study was 3.02 (Table 1), which indicated that their growth was still in the normal range for freshwater fish. The *a* value for *T. thynnoides* was 0.00824 in Rui River, Perak (Figure 3). According to Froese and Pauly (2015), the body shape of *T. thynnoides* in this study was fusiform. Similar body form of *T. thynnoides* was observed in Pahang River, Temerloh (a = 0.0114). Separate LWR were made for different groups, as mentioned below:

Small (11–14.7 cm): $W = 0.0854L^{2.12}$
Medium (14.8–18.4 cm): $W = 0.0054L^{3.18}$
Large (18.5 –22.1 cm): $W = 0.0099L^{2.95}$

These coefficients varied from 2.12 to 3.18 and were significantly different (F = 1,421) at the 5% level.

Table 1 Estimated parameters of the length–weight relationships; mean total length and weight (mean ± SE), growth pattern of *T. thynnoides* in the Rui River, Perak

Species	n	Total length (cm)			Weight (cm)			*a*	*b*	SE of *b*	95% of CI	R^2	Growth pattern
		Min	Max	Mean ± SE	Min	Max	Mean ± SE						
T. thynnoides	238	11	22	18.95 ± 0.16	14.13	106.37	63.39 ± 1.30	0.00824	3.02	0.05	2.93–3.12	0.94	Isometric

Note: n = number of samples, min = minimum, max = maximum, *a* = intercept of regression line, *b* = slope of regression line, SE = standard error, CI = confidence interval, R^2 = coefficient of determination

The *b* value of *T. thynnoides* at Rui River was relatively similar to other places: Pahang River, Temerloh (b = 3.13) and Chi River, Thailand (b = 3.23) (Zulkafli *et al*., 2016; Froese and Pauly, 2015). *Thynnichthys thynnoides* have a steep growth rate from small sized (2.12) to medium sized (3.18). Small fish have the lowest *b* value (2.12) due to their growing state. Different *b* values between total length (small, medium, large) of *T. thynnoides* were due to their physiological needs. For example, the isometric body growth of stone loach, *Barbatula barbatula* changes to allometric when the fish reach a certain standard length in order to become an adult (Copp *et al*., 2013). The condition of appetite and gonad content of the fish are also reflected by high *b* values ($2.5 < b < 3.5$) (Pervin and Mortuza, 2008). The fusiform body type is crucial for *T. thynnoides* during the spawning season as this body type allows more adapted and energy-efficient migration, similar to brook trout, *Salvelinus fontinalis. Salvelinus fontinalis* is able to withstand a longer migration route, as compared to other migratory freshwater species such as common bream (*Abramis brama*), barbel (*Barbus barbus*) and chub (*Leuciscus cephalus*) (Nilsson *et al*., 2014).

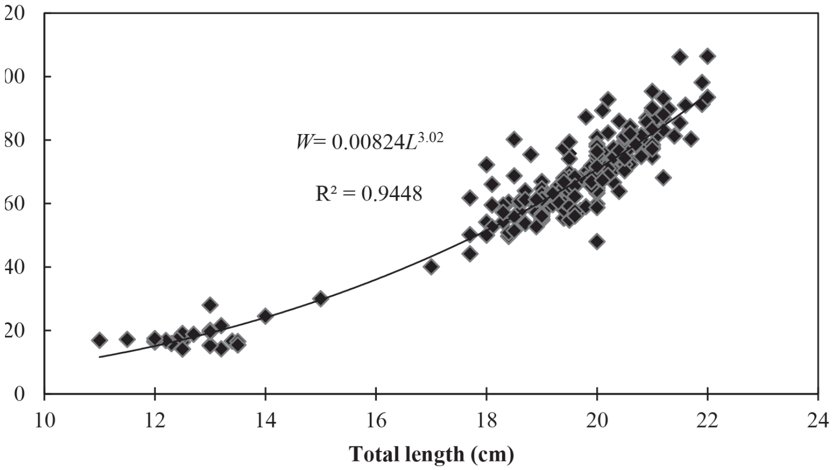

Figure 3 Length–weight relationships of *Thynnichthys thynnoides* at Rui River from May to October 2015 (n = 238)

Barnham and Baxter (2003) proposed that if the *K* value is 1.00, the condition of the fish is poor, which means its body is long and thin. A *K* value of 1.20 indicates that the fish is of moderate condition and acceptable. A good and well–proportioned fish has a *K* value of approximately 1.40. The mean condition factor, *K* of *T. thynnoides* population in Rui River was 0.99. Hence, based on the Barnham and Baxter (2003) criterion, the sampled *T. thynnoides* was in poor condition (long and thin). As the spawning season approached to the peak, the condition factor of *T. thynnoides* declined. The lowest recorded *K* value was 0.88 in October, followed by a mean *K* value of 0.89 recorded in September. However, in August, a highest mean *K* value (1.08) was recorded (Table 2).

Table 2 Monthly mean *K* value of *Thynnichthys thynnoides* in Rui River

Season	Month	*K* value	LWR equation
Non spawning	August	1.07	$W = 0.0059\ L^{3.15}$
Spawning	September	0.89	$W = 0.0063\ L^{3.11}$
	October	0.88	$W = 0.0067\ L^{3.09}$

One reason for high *K* value may have been the increasing size of female ovaries. Low values of condition factor, *K* are usually interpreted as the result of spawning seasons (Froese, 2006). For example, burrowing goby, *Trypauchen vagina* exhibited larger ovaries during spawning season compared to non–spawning season, thus resulting in an increase in weight and *K* value (Dinh, 2016). The occurrence of condition factor less than 1.0 is considered common in Malaysia. Muzzalifah *et al*. (2015) have stated that, in Temengor Reservoir, five out of seven fish species exhibited $K < 1.0$, namely *Pristolepis fasciata, Cyclocheilichthys apogon, Hampala macropleidata, Mystacoleucus marginatus* and *Osteochilus hasseltii*. The logging activity at the reservoir was believed to be one of the factors, as the water quality and hydrological regimes changed.

Water Quality Data

Most environmental variables varied across the sampling period: temperature (25.93–27.43°C), DO (3.35–5.81 mg/L), TSS (32.5–78.8 mg/L), turbidity (15.68–95.69 NTU), pH (7.00–7.13), and EC (0.06–0.31 mS/cm) (Figure). In October, temperature recorded the lowest (25.93°C) compared to other months of sampling – May (27.18°C), August (27.43°C), and September (26.43°C) (Figure 4a). Mean temperature throughout the sampling period does not have significant differences ($F = 1.215$, $P > 0.05$), which recorded 26.75 ± 0.69°C. Mean concentration of DO recorded 4.71 mg/L. There is no seasonal variation throughout the sampling period ($F = 1.389$, $P > 0.05$) (Figure 4b).

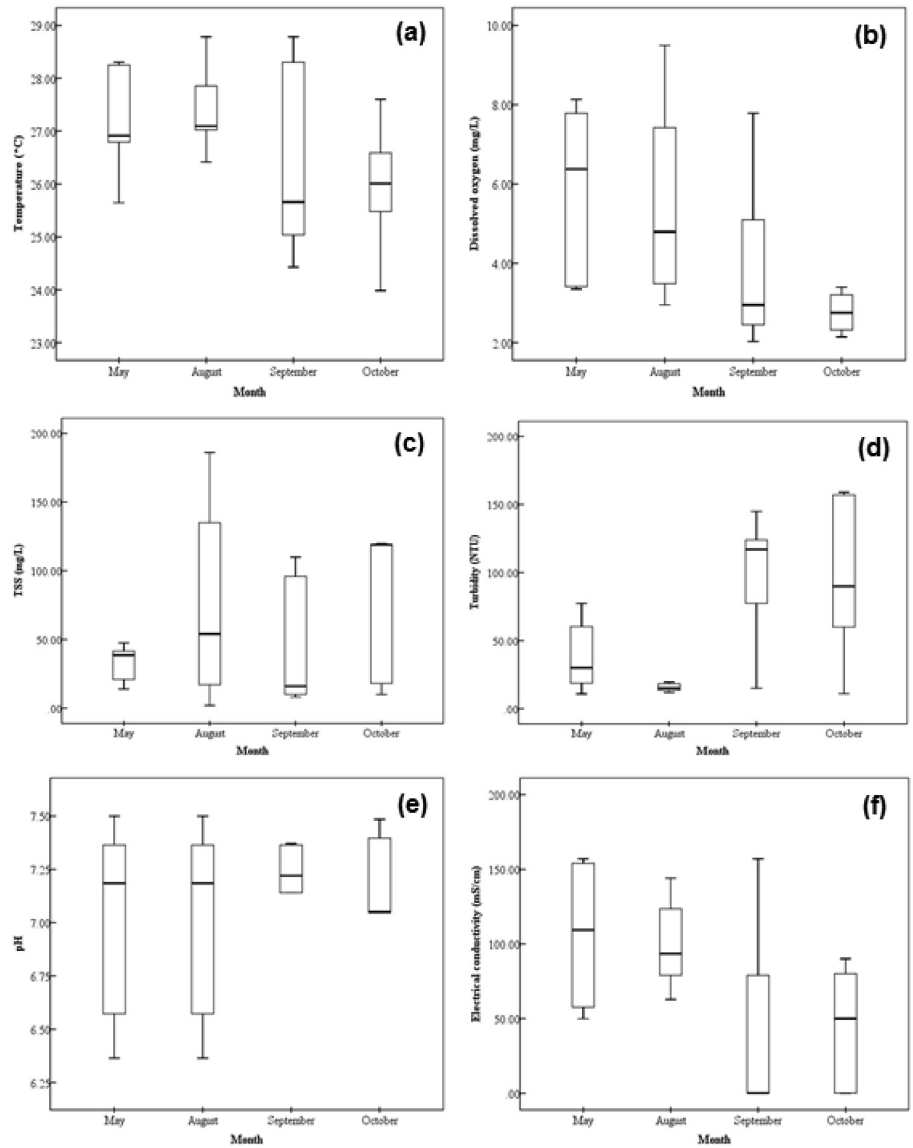

Figure 4 Temporal variations of Temperature (a), Dissolved Oxygen (b), Total Suspended Solid (c), Turbidity (d), pH (e), and Electrical Conductivity (f) of Rui River from May to October 2015

The overall water quality status of Rui River is a combination of different parameters. Four parameters namely pH, temperature, salinity and EC are in Class I of the Interim National Water Quality Standards (INWQS). DO and TSS are in Class III, while turbidity is in Class III and above (not specified in the INWQS). This diversification between water quality parameters illustrated the good health status of river water in Rui River and possible sources of pollution for example tin mining activity.

It was observed from this study that *T. thynnoides* had been avoiding the contaminated upstream nearby the tin mining area. The assumption is that the concentration of contaminants near the tin mining area was not diluted by the Rui River. Tin mining activity affects the water quality of Rui River. One of the identified causes is the in–river water treatment compound at Kepayang River, a tributary of Rui River. According to Saat *et al*. (2014) in a study on the linkage of radionuclides between fish–water–sediment samples in a former tin mining lake in Kampung Gajah, Perak, Malaysia, a high ratio of ^{226}Ra, ^{228}Ra and ^{40}K were found in bighead carp species (*Aristichthys nobilis*), Malayan leaf fish species (*Pristolepis fasciatus*) and giant snakehead species (*Channa micropeltes*) with concentrations of 5.67 ± 0.47 Bq/kg, 4.48 ± 0.63 Bq/kg and 239.7 ± 8.6 Bq/kg, respectively. However, the concentrations of zinc and copper in the muscle of *T. thynnoides* species were low (copper: 0.416 µg/g, zinc: 0.406 µg/g), which were within the acceptable limit stipulated by the Malaysian Food Regulation 1985 (Rasyidah, 2016).

Correlation of Turbidity, Spawning Activities and Fish Condition

Spawning season is determined by the existence of *T. thynnoides* at the upper stream area (S2 and S3) in September and October, while non–spawning season is determined by the absence of this fish species upstream (May and August). There was no significant variation in the overall water quality parameters between spawning and non–spawning seasons, with the exception of turbidity concentration ($F = 13.23$, $P < 0.05$) (Figure 5). Turbidity concentration during spawning season ranged from 11.00 to 159.00 NTU compared to non–spawning season which was 10.87 to 77.37 NTU. *Thnnichthys thynnoides* may prefer turbid water for spawning activity. The probability that *T. thynnoides* juveniles survive and migrate downstream to their refuge habitat is greater, as the turbid water reduces the vision of predators in the water column. The weight of *T. thynnoides* is negatively correlated with the water temperature ($r = –0.512$, $P < 0.05$) (Table 3). At lower temperature, the weight of *T. thynnoides* is heavier. The average weight of *T. thynnoides* is relatively higher as adult fishes migrate upstream during wet season, where the precipitation level is high. High precipitation generally lowers the temperature of water body.

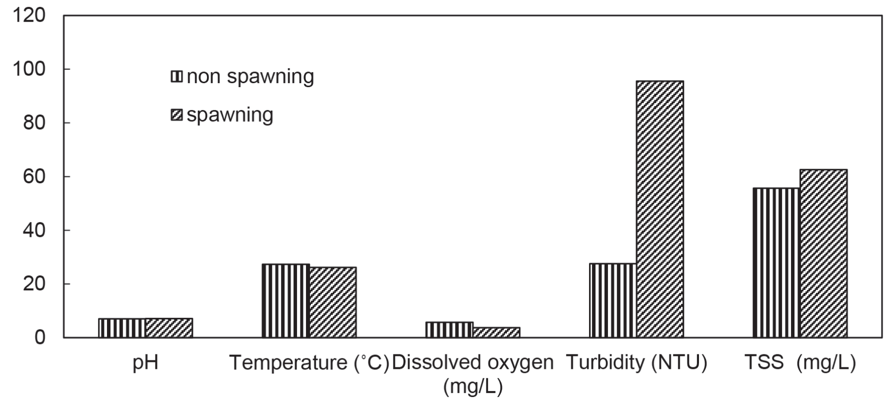

Figure 5 Comparison of water quality parameters between spawning and non–spawning seasons

Table 3 Pearson's correlation matrix for different parameters

	pH	Temperature	Dissolved oxygen	Turbidity	Electrical conductivity	TSS	CPUE (Gill net)	CPUE (Scoop net)	Fish condition	Weight
pH	1									
Temperature	–.194	1								
Dissolved oxygen	.593**	.318	1							
Turbidity	.583**	–.629**	–.149	1						
Electrical conductivity	.267	.004	.130	–.084	1					
TSS	.648**	–.471*	.308	.396	.095	1				
CPUE (Gill net)	–.265	.075	–.099	–.305	.479*	–.219	1			
CPUE (Scoop net)	.055	–.226	–.158	.200	–.077	.310	–.094	1		
Fish condition	.073	–.425	–.109	.208	.469*	–.010	.618**	–.021	1	
Weight	.243	–.512*	–.061	.337	.540*	.108	.325	.006	.924**	1

Note: ** denotes correlation is significant at 0.01 level (2–tailed); * denotes correlation is significant at 0.05 level (2–tailed)

Environmental factors that influence fish migration include variation of river water level, change in turbidity, or the colour of river water, first rainfall after the dry season, variation of discharge volume, and apparition of insects (Baran, 2006). *Thynnichthys thynnoides* prefer turbid water during the spawning season (11.00–159.00 NTU), reflecting higher inputs of silt during the runoff period as well as runoff from the mixed landscape (mining and agricultural) during wet season. Consequently, the species benefit from a high turbidity level that provides protective cover by reducing predation pressure. A similar situation has been observed for young fishes of European perch, *Perca fluviatilis* which prefer 5.00–85.0 NTU during spawning season at coastal areas of the Baltic Sea (Pekcan–Hekim and Lappalainen, 2006). Although the species prefer turbid water, the suspended solid concentration at Rui River needs to be monitored, as higher TSS is known to harm fish directly by reducing their feeding habit and clogging their gills. A similar water quality status was observed in a former tin mining river catchment (Ashraf *et al*., 2012). In the Bestari Jaya catchment, Selangor, the release of acid mine drainage and particulate mine waste (tailings) deposited to the catchment area had caused severe degradation of water quality in the Ayer Hitam River. The migrational timing and behaviour of *T. thynnoides* are also associated with high water level as reported by Ali and Kadir (1996) and Rainboth (1996). In addition, Baran (2006) reported in his study triggers in the Lower Mekong Basin and other tropical freshwater systems that *T. thynnoides* species is very sensitive to the river water level and discharge volume. This species only migrates between 2,500 and 12,500 m^3/s with an optimum range of between 2,000 and 3,000 m^3/s.

CONCLUSION

In general, the population of *T. thynnoides* in Rui River, Gerik, Perak, is in good condition with isometric body growth as compared to Pahang River, Pahang and Chi River, Thailand. This study confirmed that *T. thynnoides* migrate about 52 km to the upper stream until S2 during peak season. The migration upstream starts in August and reaches its peak during September and October despite being highly polluted with suspended particles (*e.g*. TSS and turbidity) at Rui River. In conclusion, the population of *T. thynnoides* is in excellent condition and this species is also dependent on the environmental conditions for migration and spawning. However, the pollution, as well as the overexploitation by fishing suggests that anthropogenic activities are major threats to *T. thynnoides* and, therefore, a proper management system is warranted.

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