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THE REPRODUCTIVE ASPECT OF TINY SCALE BARB, *Thynnichthys thynnoides* (BLEEKER, 1852) AT RUI RIVER, PERAK, MALAYSIA

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ABSTRACT

This study aims to understand the reproductive biology of *Thynnichthys thynnoides* at Rui River, Perak, Malaysia. A total sample of 175 individuals, including 83 from Kuala Rui (S1) and 92 from Air Ganda (S2), were collected from local artisanal fishers. Fish was caught using gill nets and scoop nets during migration and spawning seasons (i.e., November to December 2018). For each fish individual, the total length (TL), body weight (BW), and ovary weight (OW) were and. A Chi-square test was performed to evaluate the sex ratio of the studied population. Simple linear regression analysis was used to explain the relationship between absolute fecundity (FA) or relative fecundity (FR) with total length, body weight, and ovary weight. For a coefficient of determination (r^2) and correlation coefficient (r), a regression equation was determined. The results showed that the TL of *T. thynnoides* varied from 13.3 to 20.3 cm, with a calculated mean of 16.78 ± 1.1 cm. Body weights ranged from 31.86 to 78.86 g, with an average body weight of 53.81 ± 10.1 g. The FA ranged from 14454 to 29531 (mean = 21112 ± 4612) eggs per fish, and the FR from this study ranged from 211 to 658 (mean = 358 ± 93), where the OW was more significantly correlated with the absolute fecundity (r>0.513; p<0.001) than other body metrics. Negative allometric growth of *T. thynnoides* was observed during this study. The overall ratio of the *T. thynnoides* was 1:0.82 (male: female). In conclusion, this study has shown that the fecundity of the fish population is declining, although the cause is still unclear. The knowledge of this study would help fisheries managers plan necessary regulations for sustainable fishery practice at the Rui and Perak rivers, specifically during the migration and spawning season of *T. thynnoides*.

Key words: Fisheries, Perak River, reproductive, spawning, *Thynnichthys thynnoides*

INTRODUCTION

Several freshwater fish species migrate to different locations from their habitat for spawning purposes. Tiny scale barb, *Thynnichthys thynnoides,* is a freshwater fish classified as a short-distance migrating fish and will naturally initiate migration through streams and flood plains for spawning. Unique mass migration of *T. thynnoides* for spawning begins from their habitat downstream at Perak River to the upstream part of Rui River during the rainy season from early October every year (Ismail *et al*., 2015).

Many fish migrate from downstream to upstream regularly, mainly for feeding and reproduction. Some fishes may spawn upstream of the rivers for other reasons - to ensure that eggs are deposited in areas with improved oxygen supply and to decrease the embryos' predation pressure (Zimmer *et al*., 2010). However, such behavior was not yet determined for *T. thynnoides*. Another question arises whether *T. thynnoides* migration involves a return journey to its refuge habitat after spawning. Most study on fish migration has advanced with new technology, but researchers are not entirely sure how and when the fish migrate and what dictates their migration behavior. In some cases, researchers suggested that some fish use a mix of stimuli, such as sunlight, the earth's magnetic fields, and chemicals. As for *T. thynnoides,* the migration is believed to be triggered by high water discharge and water levels in the river due to heavy rainfall that acts as a cue to spawning (Ismail *et al*., 2015).

The study of the reproduction of fishes is an essential item in fish biology; so far, it has its practical importance in solving some fishery management questions, such as the determination of spawning stock. The availability of data based on reproductive parameters and environmental variation leads to a better understanding of observed fluctuation in reproductive output and enhances our ability to estimate recruitment. Information on fish condition,

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health, and reproductive aspects of *T. thynnoides* will assist the stakeholders' decision-making process while constituting regulation or governance issues on Rui River and fish populations. A sound fisheries management will result in sustainable fisheries by the local community, thus providing improved and sustained life for *T. thynnoides* and its habitats. Unfortunately, reproductive information on *T. thynnoides* is scarce, albeit works were done by Rizky *et al*. (2017), Ismail *et al*. (2015), Tampubolon *et al*. (2008), and Ali & Kadir (1996) indeed help to contribute to setting an ample ground for more studies on the species reproductive aspects. Ali & Kadir (1996) was the only reference that extensively discussed the reproductive aspect of the *T. thynnoides*. A note on the tiny scale barb, *T. thynnoides* migration activity at Rui River done by Ismail *et al*. (2015), briefly discussed the fecundity of the population. Nevertheless, no further attempts were made to discuss the relationship between fecundity and various body metrics (total length, body weight, and ovary weight). Hence, the study examines the reproductive aspect (sex ratio, GSI, & fecundity) of *T. thynnoides* during the spawning season.

MATERIALS AND METHODS

Sampling site

The study area is located at the Rui River, Gerik, Perak, Malaysia. The river flows through six Malay villages located along the upper river area, Kampung Alai, Kampung Baharu, Kampung Plang, and lower river area, including Kampung Kerunai, and finally confluence with the Perak River at Kuala Rui. Rui River is used as the primary source of income by local artisanal fishers, agricultural irrigation, and recreational activities.

One sampling site was chosen for fish sampling in the lower river area, which is Kuala Rui (S1) (5° 27' 34.6" N 101°10' 33.0" E), and the control sampling site is located approximately 16 km further down Perak River, which is at Kampung Air Ganda (S2) (5° 19' 11.1" N 101° 09' 02.3" E) (Figure 1). The S1 was chosen because of its geographical location situated at the intersection between the spawning pathway (Rui River) and the main river (Perak River). The control sampling site was chosen because the location is known as a permanent habitat for the fish where the fishing activity happens all year round. Only these sampling sites can accommodate the objective set up for this study. All the sampling sites are accessible via paved roads. The sampling sites were also chosen based on the availability of the studied species at both locations. The first sampling site, Kuala Rui (S1), is located near a small town that includes schools, shops, and oil palm plantations, and the second site, Kampung Air Ganda (S2), is located downstream of the Perak River.

Sampling and laboratory work

Thynnichthys thynnoides were collected from local artisanal fishers twice within two months span from November to December 2018. Fishers used gill nets during these migration and spawning seasons. However, the scoop nets with a mesh size of two cm were the fisher's most common fishing gear to catch

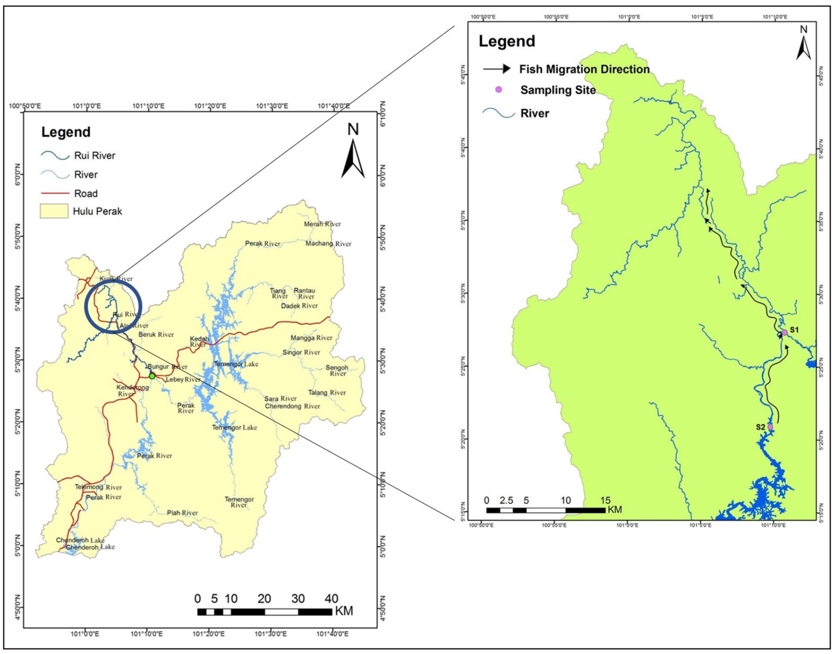

Fig. 1. Location of sampling sites at Rui River, Gerik, Perak. The left map is the Hulu Perak District and the right map shows Kuala Rui (S1) and Kuala Ganda (S2)

T. thynnoides. The fish samples were immediately kept in an icebox with ice cubes and transported to the Aquatic Research Laboratory, Faculty of Forestry and Environment, Universiti Putra Malaysia. At the laboratory, individual samples were cleaned with tap water before the examination. In measuring the total length (TL) to the nearest centimeter, a steel scale was used, and the body weight (BW) of each specimen was recorded using an electronic balance (Smith LT2002, China) with an accuracy of 0.001 g. Then, the fishes were dissected, and the sex of each specimen was identified by examination of the gonads. If ovaries were present, they were taken out carefully, and the moisture was dried up using blotting paper. Ovaries were weighed (OW) and measured individually before being preserved in a 2% buffered formalin solution for this study. Fecundity estimation analysis of preserved specimens was conducted at the Research Laboratory, School of Biological Sciences, Universiti Sains Malaysia.

Length-weight relationships

The length-weight relationships (LWR) was determined using simple linear regression analysis based on the natural-logarithmic transformation of the following equation:

$$W = aL^{B}$$

where, W: Body weight (g); L: Total length (cm); a: Coefficient (indicates body shape); b: Exponent (indicates fish growth)

In this formula, *a* is represents the coefficient of body shape. Therefore, the value obtained from the above analysis implies a specific fish body shape. For example, when the values are around 0.1, the fish is small-sized with a rounded body shape, 0.01 for streamlined-shaped fishes and 0.001 for eel-like shaped fishes (Froese, 2006).

Sex ratio

The proportion of *T. thynnoides* in two sexes relative to one another was used to calculate the sex ratio. First, it was determined based on the number of specimens of each sex sampled obtained at both locations for the entire study period. Then, a Chi-square test (χ^2) was performed to assess the significant deviations from the expected 1:1 sex ratio for male and female *T. thynnoides* in the two sample areas. Finally, the calculation of the Chi-Square statistic is subjected to the following formula:

$$x^2 = \sum \frac{f_o - f_e}{f_e}$$

f_0 = the observed frequency (the observed counts in the cells)

f_e = the expected frequency if NO relationship existed between the variables

Gonadal development and calculation of gonadosomatic index

The gonadal development phase for the males and females is determined based on observation of both macro and microscopic characteristics of the gonads. Examination of gonadal development includes describing and recording morphological characteristics of the gonads, such as the external appearance of the gonad, color, shape, and measurement of eggs diameter. The recorded results were further classified into a few phases of the reproductive cycle. The female fish was categorized into five different phases, and the male fish was divided into four phases. The gonadal classification scheme from Ali & Kadir (1996) was used as the primary reference, and a description of the morphological development of each phase was adapted to fit the study. The samples were sorted into different categories based on the classification, which were underdeveloped (I, II), ripening and running (III, IV), and spent (V).

The gonadosomatic index (GSI) is the ratio of gonad weight to body weight and is used to measure sexual maturity in correlation to gonad development. The GSI of each female fish with mature ovaries was calculated according to Brown-Peterson *et al*. (2011) as follows:

$$\text{Gonadosomatic Index (GSI)} = \frac{\text{Gonad weight}}{\text{Total body weight-Gonad weight}} \times 100$$

Fecundity estimation

In this study, a gravimetric method or weight method was selected for the *T. thynnoides* fecundity estimation, which was done by counting the number of matured eggs from a known weight of mature/ripe ovary. This method offers a lower probability of error than the other methods and better efficiency due to its simple and easy sampling techniques (Bithy *et al*., 2012).

The process started with subsamples, each weighing 300 ± 0.32 mg (weight was acquired using an electronic balance, Smith LT2002, China), obtained from the anterior, middle, and posterior sections of one of the ovaries (Ali & Kadir, 1996) and were placed in a petri dish separately. The subsamples (F_1, F_2, & F_3) were spread evenly on a petri dish, and a few drops of water and methylene blue were added to the subsamples before the counting process. Next, the total number of eggs in each sample was counted and measured carefully under a stereo microscope (SXZ16), and the data was recorded. Finally, the total number of eggs for each subsample was estimated according to the following formula:

$$\text{Subsample } (F_1) = \frac{\text{No. of eggs in the subsample x total ovary weight}}{\text{Weight of subsample}}$$

Then, the absolute fecundity of each female fish was estimated using the calculated mean of the three subsamples fecundity (F_1, F_2, and F_3) using:

$$\text{Absolute fecundity } (F_A) = \frac{F_1 + F_2 + F_3}{3}$$

The relative fecundity was obtained by dividing the absolute fecundity by the total weight of fish:

$$\text{Relative fecundity (FR)} = \frac{\text{Absolute fecundity}}{\text{Body weight}}$$

The relationship between total length and fecundity, weight (body and ovary), and fecundity of *T. thynnoides* were tested using the linear regression analysis based on natural-logarithmic transformations, where a and b were constants, and the correlation coefficient of these variables was determined. The variables include the total length (TL, cm), body weight (BW, g), and ovary weight (OW, g) were plotted as independent variables (X), and absolute fecundity (FA), and relative fecundity (FR) were plotted as dependent variables (Y). The coefficient correlation (r^2) from the regression analysis indicates the strength and direction of the linear relationship between fecundity (FA or FR) and the other variables in this study (TL, BW, & OW).

$$\ln F_A \text{ or } F_R = \ln a + b \times \ln TL$$

$$\ln F_A \text{ or } F_R = \ln a + b \times \ln BW$$

$$\ln F_A \text{ or } F_R = \ln a + b \times \ln OW$$

Statistical analysis

Before any analysis, all data were checked for homogeneity of variance using Levene's test. This test is used to tell whether the variance is equal across the studied groups. When the p>0.05, the equal variance is assumed, and when the p<0.05, the data violate the assumption of equal variance. An independent sample *t*-test was used to compare the mean relative weight, total length, GSI, and absolute and relative fecundity of the two sampled locations, with all statistical analyses, considered significant at 95% (p<0.05). A Chi-square test was performed to evaluate the sex ratio of the studied population. Simple linear regression analysis was conducted for LWR to show the growth of the fish. All data collected were interpreted using SPSS23 and Microsoft ® Excel.

RESULTS AND DISCUSSION

Population

Overall, the 175 samples of the *T. thynnoides* obtained (Figure 2) had an average total length and body weight of 16.78 ± 1.1 cm, and 53.81 ± 10.1 g, respectively. The average total length and weight of *T. thynnoides* at S1 were 17.09 ± 1.0 cm and 57.72 ± 9.50 g, correspondingly. *Thynnichthys thynnoides* from S2 on the other hand, varied in size with an average total length of 16.52 ± 1.03 cm. The sizes of *T. thynnoides* recorded in this study conform to recent studies by Mohamad Radhi *et al*., (2020) and Ismail *et al*., (2015) at Rui River, but it can grow up to 32 cm (Ali & Kadir, 1996).

Thynnichthys thynnoides from S1 and S2 have an approximately similar total length value for both sexes. The individual average weight between the two populations, however, differed significantly (t (173) = -5.16, p=0.0), that the population at S2 was slightly lower compared to S1. The females in both locations were significantly heavier (t (173) =2.724, p=0.007) than the males (S1 =M: 56.62 g, F: 61.73 g; S2= M: 48.84g, F: 51.62 g). The size differences between sexes, within and among different populations could be due to spawning season, environmental conditions, food availability, selective fishing, genetics, genetics-environment interactions, and changes in respective factors over decades (Kenchington, 2003; Bjordal, 2009; Ikhwanuddin *et al*., 2016; Wan Nazwanie *et al*., 2020). Regardless of the changes, *T. thynnoides* can still thrive due to its wide range of diets as described by Kika *et al*. (2017), Hanjavanit & Sangpradub (2012), and Rainboth (1996), of which, the nutritional value may influence fish's growth (Kika *et al*., 2017).

Length-weight relationship

Length-weight relationships from S1, S2, and overall indicated that *T. thynnoides* has negative allometric growth with the *b*-values 2.15, 2.56, and 2.51, respectively (Table 1). These values contradict with *b*-values by Mohamad Radhi *et al*. (2020) that captured the fish from the same locations with 3.02, 3.05 by Ali & Kadir (1996) at Chenderoh Reservoir, and 3.23 by Satrawaha & Pilasamorn (2009) at Chi River, Thailand. These differences may have been influenced by factors such as sex, health, environmental parameters (water temperature, salinity, and seasonal effects), habitat, food, area, degree of stomach fullness, differences in age, stage, and gonad maturity, and differences in the observed length ranges of the specimen caught (Bagenal & Tesch, 1978; Weatherley & Gill, 1987; Wootton, 1990). These external factors, however, were not considered during this study. Hence the leading cause of the negative allometric results could not be thoroughly investigated. Nonetheless, isometric growth is unlikely to happen, especially for wild fish that is highly influenced by various environmental settings or the condition of the fish themselves (Mohamad Radhi *et al*., 2020).

Although *T. thynnoides* in this study were found to have negative allometric growth, samples from S1 were slightly more rounded (0.1301) compared to S2 (0.0375) (Figure 3a, b & c). Mohamad Radhi *et al*. (2020) also reported that the shape of *T. thynnoides* from the exact location was also found to be more rounded during the spawning season. The spawning season indeed caused the shape of the fish to be more rounded due to gonads' maturity compared to the non-spawning season (Satrawaha & Pilasamorn, 2009; Zulkafli *et al*., 2014).

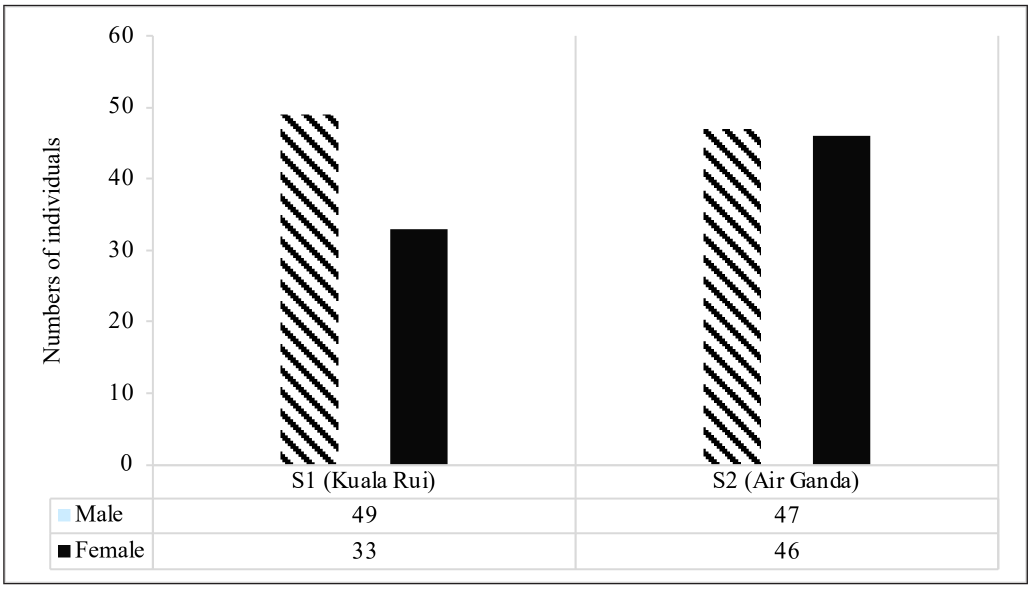

Fig. 2. Several individual samples were captured during the study by location and sex.

Table 1. Summary of LWR component of *T. thynnoides* at the Rui River

Location	n	*a*	*b*	r^2
All samples	175	0.0452	2.5064	0.6945
S1	82	0.1301	2.1436	0.5532
S2	93	0.0375	2.5643	0.7679

Sex ratio

In fishery management practices, estimation of fish sex ratio (i.e., ready-to-mate females to ready-to-mate males or vice versa (de Jong *et al*., 2009; Maskill *et al*., 2017) may assist in determining whether the population is in a standard or abnormal condition. A healthy fish population in its natural habitat usually has a sex ratio of 1:1 (Neves *et al*., 2020). However, biological, environmental, and behavioral changes such as water temperature, water velocity, ecological hazards, competition level, mate selection, migration phase, the vulnerability of females to their predators, and aggression could drive fluctuations in the sex ratio of the fish population (Neves *et al*., 2020). Therefore, the estimated sex ratio would be better understood according to their breeding behavior.

In this study, there were 49 male fish and 33 female fish at S1 and 47 male fish and 46 female fish at S2 (Figure 2). The overall ratio of the *T. thynnoides* in this study was 1:0.82 (male: female), where the Chi-square homogeneity test reveals no significant difference ($\chi 2 = 1.50$, $p>0.05$) in fish compositions between males and females. Nandikeswari *et al.* (2014) showed that the sex ratio of *Terapon jarbua* conformed to the expected ratio of 1:1 except during the peak spawning season when the proportion of males was the highest. This ratio was due to the active male movement for spawning activity, which is also parallel with this study. However, the study on *Hemibagrus menoda* by Jega *et al*. (2018) at the Kangsha River, Netrakona, Bangladesh, found that the sex ratio of the species was female-biased (1.30:0.97), implying the non-existence of seasonality in sex distribution. Laboratory fertilization on *Plagopterus argentissimus*; a small, endangered cyprinid, found that a sex ratio of 1:1, 1:3, or 1:5 (female: male) will likely heighten fertilization success (Maskill *et al*., 2017). Results from respective studies and the Chi-square homogeneity test may suggest that *T. thynnoides* in the studied areas can still thrive.

Gonad development

The studied population exhibited four stages of male gonadal development stages and five stages for females based on the classification by Ali & Kadir (1996). In S1, out of 33 female samples, 97% (*n*= 30) had matured gonads and 3% (*n*=1) had the spent stage. In S2, 41% (*n*=19) females' gonads were underdeveloped, 33% (*n*=15) in spent stage and 26% (*n*=12) matured (Figure 4). These results indicated that S2 is a possible feeding and nursery ground for *T. thynnoides* because the number of underdeveloped gonads is the highest, followed by the spent stage. S2 is a lentic floodplain ecosystem that provides nursery habitats and dependable food sources for many species of riverine fish (Naus & Adams, 2016). The spawning site of the migrating *T. thynnoides* is thought to be located further upstream than S1 in the Rui River because 97% of the females with ripening eggs were captured at the upper stream of Rui River.

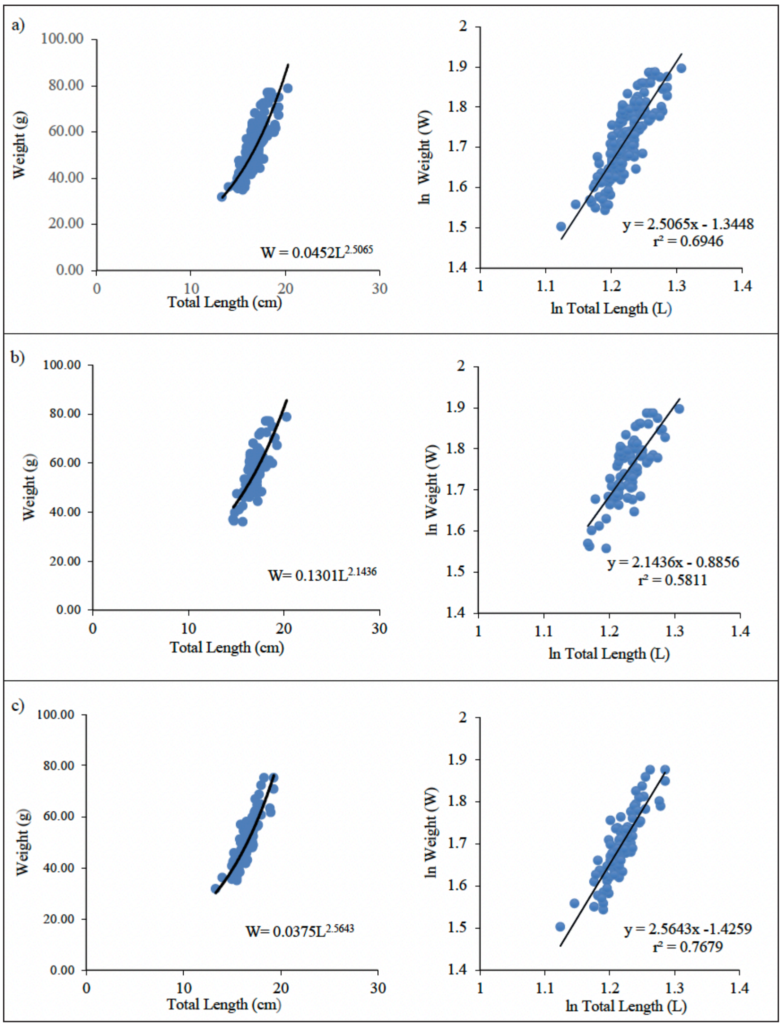

Fig. 3. Length-weight Relationship of *T. thynnoides* at the Rui River. (a) all samples (b) S1 (Kuala Rui) and (c) S2 (Air Ganda). Overall, total length and body weight exhibit *a* positive relationship (r^2=0.6946), and the *b* value indicated that the *T. thynnoides* population at the Rui River experience a negative allometric growth (*b*=2.5065).

Gonadosomatic index

Gonadosomatic index (GSI) is a method indicating maturation and gonad development (Nandikeswari *et al*., 2014). The GSI increases as fish matures and is at maximum at the peak of the maturity period. The *T. thynnoides* GSI averages of this study were 24.9 ± 4.09 for females, and 1.7 ± 0.9 for males (Figure 5) indicating that the GSI value was mostly contributed by the females. The abruption of GSI indicates the beginning of spawning (Nandikeswari *et al*., 2014) as the fish release their eggs and sperm, thus, decreasing the gonads' weight. In this study, there was no significant decrease (*p*=0.416) in the female GSI recorded between S1 and S2 indicating spawning activities have yet to happen at S1, and the *T. thynnoides* spawning area is located further upstream of Rui River. Ismail *et al*. (2015) also had a similar result of *T. thynnoides*' GSI at Kuala Rui with 25.9 ± 6.5, and it was significantly decreased at Kampung Kerunai (GSI value 13.7±3.5), which is located further upstream of Rui River.

Estimation of fecundity and its relationship between total length, body weight, and ovary weight

The absolute fecundity of *T. thynnoides* in this study ranged from 14454 to 29531 (eggs per fish (Table 2). The average fecundity at S1 is 21522 ± 4322 and 21379 ± 4431 at S2. There was no significant difference (t (41) =0.21, *p*=0.84) between S1 and S2 population's fecundity. Relative fecundity in this study ranged from 211 to 658 and it was noted there was a significant difference (t (41) =2.62, *p*=0.01) between the S1 and S2 populations' relative fecundity.

The fecundity of *T. thynnoides* in this study is lower than Ismail *et al*. (2015). The significant decline in fecundity within four years span (p<0.05) is hypothesized to be due to biological or environmental factors (Bagenal & Tesch, 1978; Jonsson & Jonsson, 2006). Biased fecundity estimation can be ruled out since the data from both studies were collected during the spawning season only. A different study on the northwest Atlantic cod (*Gadus morhua*) population with over 20 years of data exhibits a high degree of variability in the fecundity indicating that fish fecundity is unstable over the years. Therefore, the absence of a detailed report on population density and limited fecundity data on *T. thynnoides* makes it implausible to test if the hypothesis is relevant to the decline of fecundity in the current study.

Table 2. Absolute (no. eggs female^{-1}) and relative (no. eggs g^{-1}) fecundity of *T. thynnoides* for different length groups from November to December 2018

Length group (cm)	No. of fish	Mean body weight (g ± s.e)	Absolute fecundity		Relative fecundity	
			Mean ± s.e	Range	Mean ± s.e	Range
15.1-16.0	4	60 ± 9	21060 ± 4784	14454-27398	357 ± 95	271-658
16.1-17.0	22	60 ± 9	21113 ± 4670	13192-31562	360 ± 94	211-489
17.1-18.0	9	63 ±7	21247 ± 4663	15969-29531	337 ± 67	237-460
18.1-19.0	6	60 ± 9	21322 ± 4658	16426 -31106	361± 94	280-420

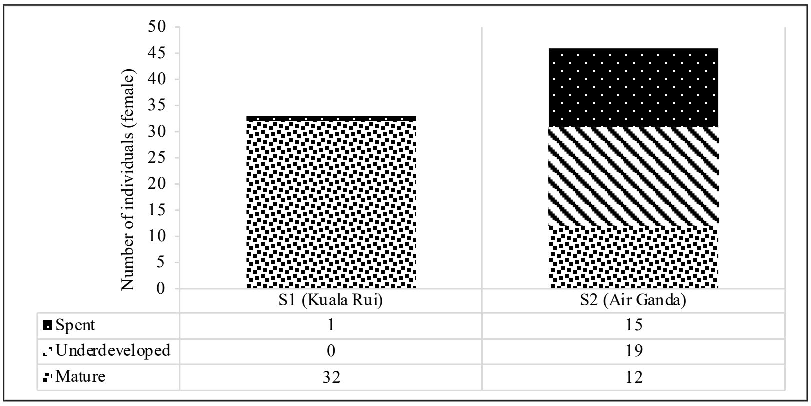

Fig. 4. Total female samples were captured and segregated by location and different stages (underdeveloped (I, II), mature (III, IV), and spent (V) for the study.

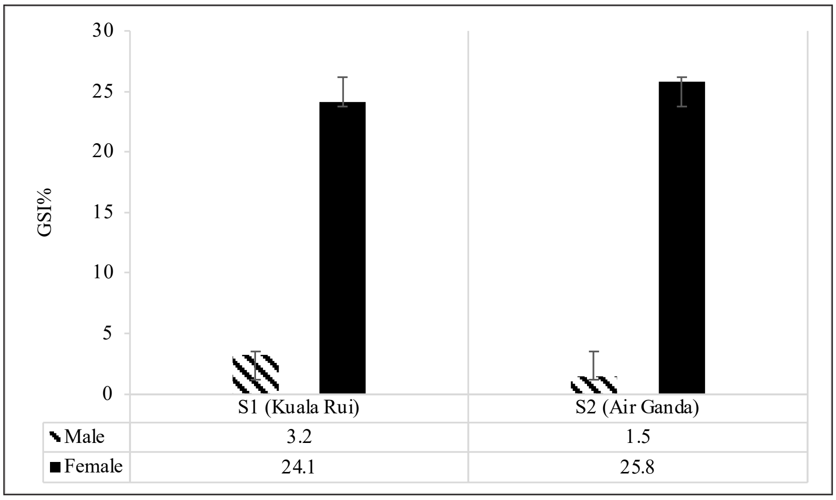

Fig. 5. Gonadosomatic index (GSI) (with SD) of *T. thynnoides* female samples from the study area.

Selective fishing is among the contributing factors and had been discussed in depth by Bjordal (2009), particularly on two traits, which are size-at-age, and age-at-maturation. Bjordal (2009) found that genetic variation traits did affect the presence of fishing activity. Furthermore, selective harvesting has indirectly pressured the slow-growing, early maturing fish to increase reproductive effort at a younger age (Kika *et al*., 2017), and also could lead to changes in fish fecundity. The annual harvesting of *T. thynnoides* during spawning season at certain sites along the migration pathway of the Rui River certainly fits the scenario mentioned above and probably contributes to the declining population's fecundity.

The scatter plot generated from regression analysis of the total length (TL), body weight (BW), and ovary weight (OW) against absolute fecundity (FA) and relative fecundity (FR) is illustrated in Figure 6. Overall, the absolute fecundity (FA) analysis showed a positive log-linear relationship for all independent variables and is supported by various works on fecundity (Kingdom & Allison, 2011; Hossain *et al*., 2012; Nandikeswari *et al*., 2014; Qadri *et al*., 2015; Jega *et al*., 2018). Correlation analysis indicates that ovary weight has the best positive relationship (r=0.513) with absolute fecundity. Overall, relative fecundity (FR) was negatively correlated with *T. thynnoides* population. Absolute fecundity (FA) had the highest R-value. Ovary weight (OW) (r=0.513, p<0.001), is a better fecundity predictor compared to other variables, which is contradictory to the result reported by Ali and Kadir (1996) that total length (TL) and body weight (BW) are better predictors. Nandikeswari *et al*. (2014), who studied the fecundity of *Terapon jarbua* also reported a significant positive linear relationship between fecundity and weight (BW, OW). Therefore, when fecundity increases, the fish's weight, and length also increase.

It is worth noting that this study was conducted towards the end of the spawning *T. thynnoides* season. Therefore, a more extended sampling period could probably give different fecundity correlation coefficient values and better represent the population fecundity.

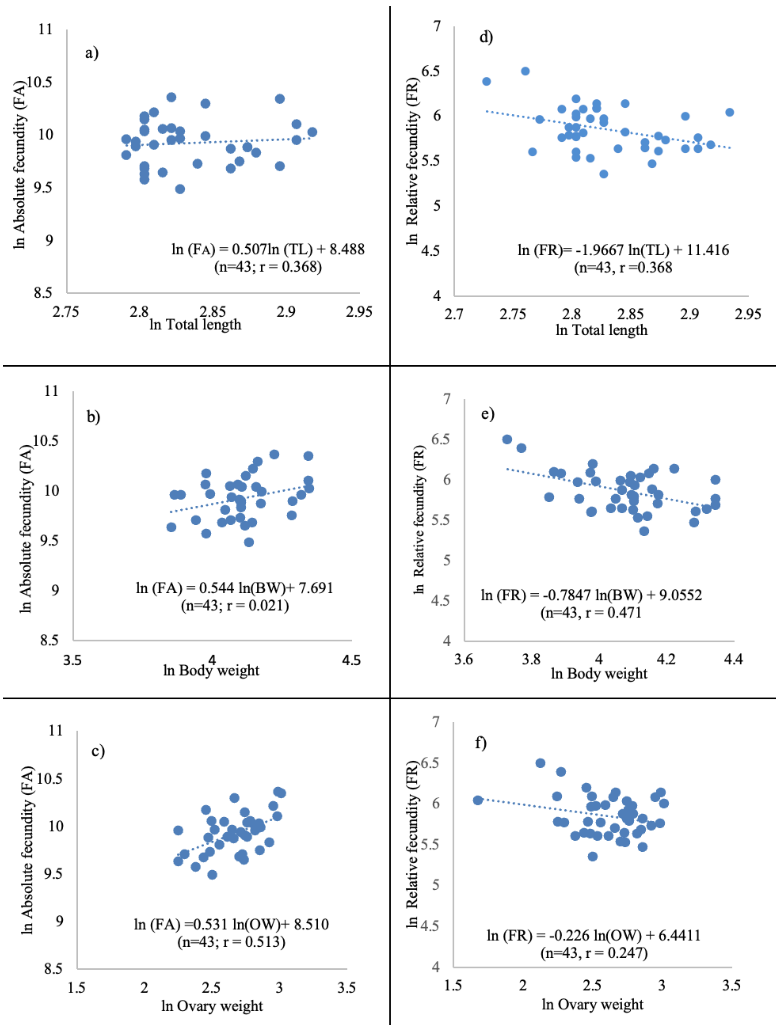

Fig. 6. Relationship between total length (TL), body weight (BW), ovary weight (OW), absolute fecundity (FA), and relative fecundity (FR) of *T. thynnoides* at Rui River, Perak (a. ln (TL *vs* FA) b. ln (BW *vs* FA) c. ln (OW *vs* FA) d. ln (TL *vs* FR) e. ln (BW *vs* FR) and f. ln (OW *vs* FR). In this study, ovary weight (OW) shows a better correlation with absolute fecundity (FA) than other fish body metrics.

CONCLUSION

Overall, this study will contribute to updating the reproductive status of the *T. thynnoides* population of the Rui River. The fecundity of the fish population has declined in four years, compared to past studies in the same area, although the cause is still unclear. Other analyses such as sex ratio and GSI remain unchanged except for the fish population's growth pattern is experiencing negative allometric growth. In this case, it is uncertain whether changes in growth significantly affected the reproduction of the fish, although much literature proved that fecundity varies intensely with fish size and condition. A high degree of variability of fecundity for a fish species is possible even for fish species that had been studied within an extended period, much less for one-shot research, such as this study. Therefore, regular collection of reproductive data of the fish population is encouraged for greater accuracy in the estimation of stock productivity and yield for this critical fishery species while the population stock is still in a healthy state. During the study, it was noticeable that the absence of research in another branch of knowledge for *T. thynnoides* hinders understanding fecundity better. Hence, more studies are suggested to be conducted, particularly regarding ecological and behavioral studies of the fish. Optimistically, the finding from this study would be beneficial specifically for local fisheries management at the Rui River, Perak. It is also recommended that a further study on the diet of *T. thynnoides* in Rui River and Chenderoh Reservoir can be conducted for a thorough understanding of feeding habits.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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