



Reproductive Biology of Mahseer (*Tor tambroides*) from Atu Suasah and Lawe Melang Rivers in Aceh Province to Support Sustainable Fisheries Management

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ABSTRACT

Information on reproductive biology is crucial in formulating policy to manage and conserve mahseer in Atu Suasah and Lawe Melang Rivers, Aceh, Indonesia. This research aimed to analyse and compare of mahseer biology including sex ratio, length and weight relationship, Fulton and relative condition factor and fecundity to estimate the reproductive potential of mahseer in these two rivers. The study was conducted from July to December 2019. Mahseer samples were obtained from fishermen who captured the fish using gillnet with mesh size 1.5-2.0 inch. The specimens collected were placed in a coolbox and transported to the Aquatic Resources Management Department of IPB University in Bogor for further analysis. Regression, chi-square, Mann Whitney test and t-test were applied to analyze reproductive biology parameters. There was no significant between-site difference in the reproductive parameters of mahseer from Atu Suasah and Lawe Melang Rivers. The sex ratio was balanced. The growth pattern was allometric negative and the Fulton condition remained stable over the six month study period. Mahseer in the 610-710 mm length class made the largest contribution to total egg production. Management and conservation of this fish should include the designation of a reservation area to maintain larval production as the source of recruits.

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Authors' Contribution

TFH, MSN and FA presented the concept. TFH, ES, DR planned the methodology. TFH, ES, KN, THP, RYV and TB did sample collection and laboratorium analysis. TFH, MSN, ES and DR performed data analysis. FA, KN, W, THP, TB, RYV wrote the manuscript.

Key words

Mahseer, Sex ratio, Length and weight relationship, Fecundity, Aceh.

INTRODUCTION

Mahseer (*Tor tambroides*) is the fish commonly found in freshwater system in the south, east and south east of Asia Continent. Their habitat is characterised by fast or slowing moving water with high water clarity, high dissolved oxygen content with a preference for sand and gravel as substrates (Khare *et al.*, 2014; Ambili *et al.*, 2014; Pinder *et al.*, 2019). The fish are abundant in intact water, especially in tropical regions of Indonesia, Malaysia, Thailand and India (Yadav *et al.*, 2012; Hoang *et al.*, 2015). In particular, Mahseer are found in freshwater riverine systems in Aceh, where they are one of the fishes exploited by local residents.

Four mahseer species are found in Aceh, *Tor soro*,

Tor tambra, *Tor douronensis* and *Tor tambroides*. Based on body size, *Tor tambroides* is the biggest mahseer of Indonesia (Haryono *et al.*, 2009). Among the four species *Tor tambra* population is the most abundant (Maghfiriadi *et al.*, 2019). Local people usually refer to this fish as kereuling or jurong. This fish is highly appreciated by locals for the delicacy of its meat (Muchlisin *et al.*, 2015; Wibowo and Dwirastina, 2016). Mahseer also have cultural value and are used in many cultural ceremonies (Kristanto *et al.*, 2007; Haryono, 2017).

Mahseer are rare in Java Island, whilst in Kalimantan and Sumatera the populations of these fish are also reported to be declining due to overexploitation and ecosystem degradation, especially in places where the fish spawn (Haryono, 2006; Gupta *et al.*, 2014; Sarkar *et al.*, 2015; Roesma *et al.*, 2017). Hence, management and conservation efforts are needed to sustain mahseer populations.

Information on reproductive biology is required

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to devise policies on management and conservation of mahseer but is still scarce. Previous studies have reported progress with respect to biological information on mahseer including taxonomy (Zulfahmi *et al.*, 2018), growth performance (Muchlisin *et al.*, 2016), morphology (Akmal *et al.*, 2018) and genetics (Arifin *et al.*, 2015). However, there is a lack of information on aspects such as sex ratio, condition factor, fecundity and reproductive potential. Therefore, this study aimed to assess this gap through analysing and comparing these aspects of mahseer reproductive biology in Atu Suasah and Lawe Melang Rivers, in Aceh Province, Indonesia.

MATERIALS AND METHODS

The study was conducted from July to December 2019 in the Atu Suasah and Lawe Melang Rivers, Aceh Province, Indonesia (Fig. 1).

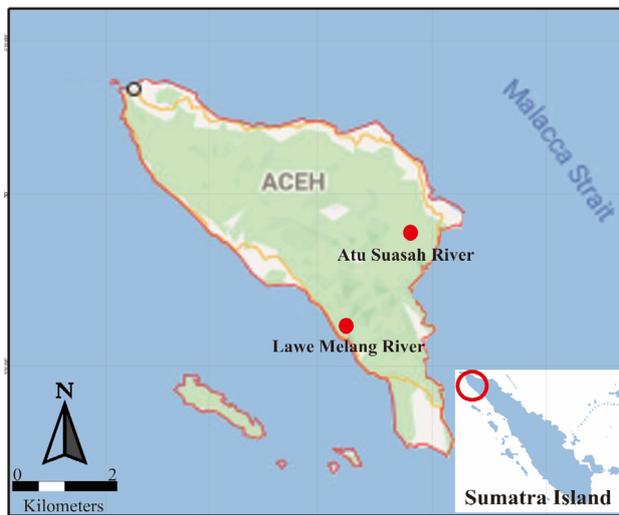


Fig. 1. Map of Aceh Province in Indonesia showing the study sites.

Mahseer samples were obtained from fishermen who captured the fish using gillnet with mesh size 1.5-2.0 inch. On one trip, the fishermen usually operated gill nets 10-15 m in length. The nets were set up at upstream and at the downhill in each of the two rivers. One trip is equaled to 16 h of fishing activity counting when the operation of gillnet at 16.00 in the afternoon and the lift-up of gillnet at 08.00 am. In total 146 mahseer specimens were collected, consisting of 74 fish from Atu Suasah and 72 from Lawe Melang River. The specimens collected were placed in a coolbox and transported to the Aquatic Resources Management Department of IPB University in Bogor for further analysis. The total length (mm) and

weight (g) of each specimen were measured, and the sex was determined. Weight was obtained from digital scale with 0.1 g accuracy whilst total length was measured using ruler with 1 mm accuracy. Three parts of each eggs from anterior, middle, and posterior parts were subsampled to counted fecundity. The eggs subsamples were immersed in Gilson solution for 24 h to dissolved the outer membrane therefore makes it easier to count. Fecundity was estimated using a gravimetric method (Bagenal, 1968) by counting the eggs in the subsamples under a microscope.

Sex ratio was determined by dividing the number of male with the number of females. Chi-square (Zar, 2010) was used to estimate sex ratio difference between the two populations following formula:

$$\chi^2 = \sum_{i=1} \frac{(O_i - E_i)^2}{E_i}$$

where O_i is the observed value and E_i is the expected value of the i^{th} variable.

The length-weight relationship was calculated using the equation in Le Cren (1951):

$$W = aL^b$$

where W is the weight (g) and L is the total length (mm); a is the intercept and b is the slope of the log-transformed regression of weight against length.

The relative condition factor (Wr) and Fulton condition factor (K) were used to evaluate condition factor of each individual. Relative condition factor was computed refer to Rypel and Richter (2008):

$$Wr = \frac{W}{W_s} \times 100$$

where Wr is the relative condition factor, W is weight of the specimen and W_s is the predicted standard weight for that same fish as calculated from a composite of length-weight regressions throughout the range of the species.

A value of the relative condition factor < 100 indicates low food availability while $Wr > 100$ suggests abundant or surplus food availability (Anderson and Neumann, 1996).

The Fulton condition factor was calculated using the following equation (Froese, 2006).

$$CF = \frac{W}{aL^b}$$

CF is the Fulton condition factor; W is the weight (g) of the specimen; L is the total length (mm) of the specimen; a and b are the constants from the length-weight regression model.

The average difference between male and female condition factor was obtained using the Mann-Whitney test (Wilks, 1995):

$$Z = \frac{U - \frac{n_1 n_2}{2}}{\sqrt{\frac{n_1 n_2 (n_1 + n_2 + 1)}{12}}}$$

Z is the statistics, U is the smallest value of U_1 and U_2 ; n_1 and n_2 are sample size.

Fecundity was estimated following gravimetric protocol with formula:

$$F = \frac{W_g}{W_s} F_s$$

where F is fecundity, F_s is the number of eggs counted in the gonad sub-sample, W_g is total gonad weight, and W_s is the weight of the gonad sub-sample.

The between-population difference in mahseer total fecundity was analysed using the t-test (Zar, 2010), where t was calculated using the equation:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}$$

where \bar{x}_1 is the mean fecundity of specimens sampled from population 1, \bar{x}_2 is the mean fecundity of specimens sampled from population 2, S_1^2 is the sample variance from population 1, S_2^2 is the sample variance from population 2, n_1 and n_2 are the sample sizes of the two populations.

Reproductive potential was calculated using the following formula (Tuwo, 1993):

$$RP = \sum \text{number of individuals per size class} \times \text{mean fecundity for size class}$$

RESULTS

The mahseer (*Tor tambroides*) specimens from the Atu Suasah River consisted of 51.35% male and 48.65% female, with a male to female sex ratio of 1.61:1. While the mahseer specimens from Lawe Melang River consisted of 56.94% male and 43.06% female (1.31:1). Chi-square analysis results ($\chi^2=0.054$; $df=1$; $P>0.05$ in Atu Suasah River and $\chi^2=2$; $df=1$; $P>0.05$ in Lawe Melang River) suggest that the sex ratio is not significantly different from 1 in either river.

The length and weight relationship regression analysis showed that the four fish groups have a negative allometric ($b<3$) growth pattern (Table I). This indicates that these fish generally grow faster in length than in weight. The coefficient of determination shows that length explains a higher proportion of weight gain in female mahseer compared to males in both Atu Suasah River and Lawe Melang River.

The mean values and range of the Fulton condition factor were similar for male and female mahseer sampled

from the Atu Suasah River (1.03 ± 0.23 , 1.04 ± 0.30) and Lawe Melang River (1.02 ± 0.30 and $1.06\pm 0.27s$) with mean values slightly greater than 1 (Fig. 2). The relative condition factor was greater than 100 for all groups. The Mann Whitney-test showed no significant difference ($P>0.05$) in either condition factor between male and female fish or between the two study sites. The results also suggest that male and female fish condition remained similar throughout the six month sampling period.

Table I. Length and weight relationship of mahseer in Atu Suasah and Lawe Melang River.

Parameter	Atu Suasah River		Lawe Melang River	
	Male	Female	Male	Female
Growth model	$W=1.72L^{1.56}$	$W=0.41L^{1.12}$	$W=1.15L^{1.76}$	$W=0.34L^{1.10}$
R^2	0.65	0.82	0.56	0.74
Type of growth	Negative allometry			

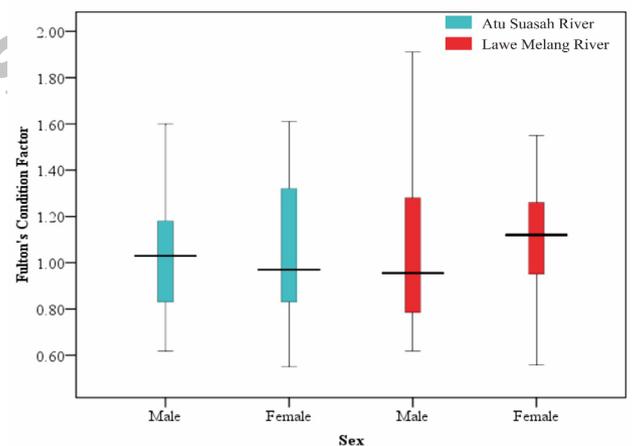


Fig. 2. Fulton condition factor for mahseer (*Tor tambroides*) from two rivers in Aceh, Indonesia.

Mahseer fecundity ranged from 3,600 to 5,466 eggs (average $4,476\pm 911$ eggs) in the Atu Suasah River and 2,433 to 4,203 eggs (average $3,212\pm 631$ eggs) in Lawe Melang River. The student t-test showed no significant between-site difference in fecundity ($P>0.05$). Mean reproductive potential was estimated at $10,444\pm 4,404$ in the Atu Suasah River and $4,818\pm 3,870$ in the Lawe Melang River (Table II).

DISCUSSION

Theoretically, a balanced sex ratio (1:1) is ideal to

maintain a population (Ball and Rao, 1984). Studies on mahseer from several localities, report a female-biased sex ratio; e.g. a study on *Tor putitora* in India (Joshi *et al.*, 2018), and a study in Kalimantan (Haryono, 2006) where the male to female sex ratio was 1:2. Bhatt *et al.* (2004) and Wibowo and Kaban (2014) found that male mahseer are mostly young fish while females are predominately adult fish. The proportion of young fish in the samples collected from the Atu Suasah and Lawe Melang Rivers was 57.14% from and 47.22%, respectively. Therefore, the balanced sex ratio of fish in this study related to the balance between young and adult fish in the samples collected such what had been found in Manna River and Tarusan River (Wibowo and Kaban, 2014).

Table II. Average fecundity and reproductive potential of mahseer in Atu Suasah River and Lawe Melang River.

Size class (mm)	Quantity (fish)	Mean fecundity (eggs)	Reproductive potential
Atu Suasah River			
410-500	2	3,362	6,723
510-600	2	4,652	9,303
610-700	3	5,102	15,306
Lawe Melang River			
410-500	1	2,433	2,433
510-600	1	2,943	2,943
610-700	3	3,533	10,599
710-800	1	3,297	3,297

Mahseer are pelagic fish which swim actively due to their habitat in fast flowing foothills streams with high-water quality (Dinesh *et al.*, 2010; Ambili *et al.*, 2014; Raghavan *et al.*, 2017). Actively swimming fish which live in fast flowing water usually have a value of $b < 3$ because more energy is allocated for swimming than for growth in terms of weight gain (Shukor *et al.*, 2008; Muchlisin *et al.*, 2010; 2015). The same phenomenon was observed in the mahseer populations at both study sites.

However, growth patterns of mahseer reported in previous studies are varied (Tabel III). Muchlisin *et al.* (2015) also found that *Tor tambra* in Nagan and Sikundo Rivers had an allometric negative growth pattern. *Tor putitora* found in their spawning ground (Himalayan foothills) in Pakistan also had an allometric negative growth pattern (Naeem *et al.*, 2011). On the other hand, Ali *et al.* (2014) who also studied *Tor putitora* in four different locations in the Indian Himalayan report an isometric growth pattern. The variability in fish growth patterns is usually closely related to the environment, including the biological and geographical condition of the habitat (Froese, 2006; Pervais *et al.*, 2012).

Aside from food availability, biotic and abiotic factors, age, and length (size class) can also affect the fish condition factor (Le Cren, 1951; Blackwell *et al.*, 2000). The Fulton condition factor of male and female mahseer was relatively stable over the sampling period. The value of relative weight exceeded 100 which indicates good food availability for the fish in both rivers. Mahseer in Atu Suasah and Lawe Melang are considered as omnivores with a tendency towards being predominantly herbivorous. While the main food sources of these fish are aquatic plants and algae, they also occasionally prey on insects (Pervais *et al.*, 2012; Nautiyal, 2014; Mohapatra *et al.*, 2017). Sulastri *et al.* (1985) suggested that, apart from relying on videoreceptor capability in searching for food, mahseer also use their barbels as mechanoreceptors.

Fecundity is considered the most reliable indicator to estimate fish reproductive potential (Bhatt and Pandit, 2015; Achmad *et al.*, 2020). The estimates of mahseer fecundity in this research fall within the range of mahseer fecundity reported from other studies (Table IV). The highest fecundity was found in the Nayar River population (India) (Nautiyal and Lal, 1985). The lowest fecundity was found in Manna River population, West Sumatera Indonesia (Wibowo and Kaban, 2014). The fecundity found in this study is lower than that of mahseer found in Barito (Haryono, 2006), but higher compared to that reported from the Manna River. These variabilities may happens due to variabilities of fish size among populations.

Table III. Comparison of mahseer growth pattern from several locations.

No	Species	Location	b Value	Reference
1	<i>Tor tambroides</i>	Atu Suasah River, Aceh, Indonesia	1.12	This study
2	<i>Tor tambroides</i>	Lawe Melang River, Aceh, Indonesia	1.10	
3	<i>Tor tambra</i>	Nagan River, Aceh Indonesia	2.84	Muchlisin <i>et al.</i> , 2015
4	<i>Tor tambra</i>	Sikundo River, Aceh Indonesia	2.63	
5	<i>Tor putitora</i>	Himalayan foothills, Pakistan	2.85	Naeem <i>et al.</i> , 2011
6	<i>Tor putitora</i>	Indian Himalayan	3.10	Ali <i>et al.</i> , 2014

Table IV. Comparison of mahseer fecundity from several locations.

No	Species	Location	Fecundity (eggs)	Reference
1	<i>Tor tambroides</i>	Atu Suasah River, Aceh, Indonesia	3,600-5,466	This study
2	<i>Tor tambroides</i>	Lawe Melang River, Aceh, Indonesia	2,433-4,203	
3	<i>Tor putitora</i>	Lesser Himalayan, India	4,217-8,365	Joshi <i>et al.</i> , 2018
4	<i>Tor tambroides</i>	Barito River, Indonesia	3,125-8,201	Haryono, 2006
5	<i>Tor tambroides</i>	West Sumatera, Indonesia	2,508	Wibowo and Kaban, 2014
6	<i>Tor tambroides</i>	Nayar River, India	26,997-98,583	Nautiyal and Lal, 1985
7	<i>Tor putitora</i>	Pong Dam, India	15,504	Johal and Negi, 2003
8	<i>Tor putitora</i>	Bhimtal, India	7,076-18,525	Pathani, 1981

Table IV shows that the fecundity of mahseer populations can be different even they come from the same or similar species within the genus *Tor*. Bagenal (1971) argued that length and weight of fish tend to increase linearly. Additionally, variability in fish mahseer fecundity can be affected by species, spawning pattern, and estimating techniques (gravimetry and volumetry) (Pathani, 1981; Johal and Negi, 2003).

Mahseer from the 610-700 mm length class contributed the most to overall egg production. This size class was also the most abundant (42.86% and 50% of the total number of females within the two river population samples). Female mahseer with a length more than 710-800 mm had the lowest fecundity and only comprised 16.67% of the females sampled from the populations. Therefore, this group appears to make a relatively low contribution to total egg production.

Mahseer exploitation in the Atu Suasah and Lawe Melang Rivers is highly intensive due to excessive demand for the fish. To protect the fish populations, spawning grounds of the fish must be determined and protected. Establishing a reservation area in each of the two rivers could improve larval production through protection for the source of new recruits. This approach could also affect fisher incomes therefore its implementation must be accompanied by education for the local fishermen.

CONCLUSION

There was no significant between-site difference in sex ratio, length and weight relationship, condition factor or fecundity between mahseer captured in the Atu Suasah and Lawe Melang Rivers. The sex ratio was balanced and the growth pattern was negative allometric. Fish condition factor remained stable throughout the sampling period. Mahseer from the length class 610 – 700 mm made the largest contribution to total egg production. To improve new recruitment, priority should be given to the protection

of mahseer spawning grounds by establishing a reservation (protected area) in order to maintain egg production.

Statement of conflict of interest

The authors have declared no conflict of interest.

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