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# Length-Weight Relationship and Condition Factor of the Silver Rasbora (*Rasbora argyrotaenia*) from Sungai Batang River, South Kalimantan, Indonesia

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**This study describes the growth pattern, condition factor, length at first capture, length at first maturity, and selection factor (SF) of silver rasbora (*Rasbora argyrotaenia*) in Sungai Batang River, Indonesia. This species is commercially exploited and highly vulnerable to overfishing. The fish samples were purchased periodically once every 2 wk from the gillnet fishermen. A total of 255 specimens consisting of 121 males and 134 females [79.43–85.56 mm total length (TL) and 4.22–5.21 g body weight (W)] were investigated procedurally. Males showed a negative allometric growth (*b* = 2.71), while females exhibited isometric growth (*b* = 3.02). Males had TL, W, BD (body depth), and the mean ratio of W/TL that are significantly higher than those of females. The highest catch fell between 80–89 mm TL (39.67–43.28%) and weighted between 4–6 g (57.02–65.67%). The condition factor values of males and females were 0.80 ± 0.23 and 0.82 ± 0.20, thus indicating that the fish were in good condition. The estimated length at first capture and SF were 80–76 mm TL and 3.99–4.20, thus indicating that the used 0.75-in mesh size of gill net was acceptable for fishing practices. However, empirically, the length at first capture was smaller than the length at first maturity (male = 87.53 mm; female = 84.57 mm), leading to growth overfishing. The output of this study could be useful for baseline information in formulating a sustainable fisheries management strategy since many aspects related to *Rasbora* fishery have not been fully studied.**

Keywords: condition factor, growth pattern, gillnet, *Rasbora argyrotaenia*, selection factor, Sungai Batang River

## INTRODUCTION

*Rasbora* is categorized as schooling fish from the family Cyprinidae, it is widely distributed in freshwater bodies throughout the Indian subcontinent, southern China, and Southeast Asia (Brittan 1954). The genus presently recognized includes some 120 valid species (Kottelat 2012). *Rasbora* was considered the most species-rich genus in the cyprinid subfamily Danioninae (Froese and Pauly 2013) – 45 of them were found in Indonesia and 28 species came from Sumatera (Kottelat *et al*. 1993). In Indonesia, *Rasbora argyrotaenia* is one of the economically important freshwater fish species that beneficially support the culinary business, the fried fish household industries, and the ornamental fish market (Harris 2013; Astuti and Fitrianingsih 2018). Partan *et al*. (2019) recommended eating this fish due to its high level of vitamin D as a new therapeutic modality.

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The Inland fishery of Kalimantan islands is one of the potential areas with the highest diversity of fish species in Asia (Winemiller *et al*. 2008). For decades, however, research related to fish in tropical river waters has lagged behind temperate waters. Therefore, it is a great challenge for us to explore various aspects related to biodiversity studies. *R. argyrotaenia* – locally known as "*seluang*" in Kalimantan, South Sumatera, and Jambi Provinces – is one of the indigenous and omnivore fish species that inhabit the rivers, streams, lakes, and flooding swamps (Arsyad and Syaefudin 2010; Sulistiyarto 2012; Aprilian *et al*. 2016), with most of them caught by the gill nets (Muchlisin *et al.* 2018; Mutiara *et al*. 2019) instead of lift net and fish trap (Dina *et al*. 2019). In the investigated area, the supply and demand of *R. argyrotaenia* are completely dependent on the catch from the wild; meanwhile, the attempt to domesticate and cultivate this species has not yet been performed so far. The relatively expensive selling price of fish is the main factor that drives overfishing. Excessive fishing pressure, water pollution, and degradation of environmental quality have been attributed to the decline in fish population (Zulkurnain *et al*. 2015; Suryani *et al*. 2019) and finally, reflect the socio-economic condition as a whole (Kalita *et al*. 2015; Hanif *et al*. 2019). This issue should be of great concern to the people and the local authority as a whole to manage fish resources properly and to keep the fishery business sustained. Before going further, it is necessary to have deep knowledge and well understanding, particularly of the biological and ecological aspects of this species.

*R. argyrotaenia* spawns continuously throughout the year (Rosadi *et al*. 2014). Lisna (2013) confirmed that female *R. argyrotaenia* was a partial spawner, while the male was a total spawner. According to Ginanjar *et al*. (2014), the best spawning ratio of male to female *R. argyrotaenia* was 2:1 in terms of spawning frequency, egg production, hatching, and fertilization rates. After that, domestication protocol has been locally introduced in Sebangau and Musi Rivers (Augusta 2018; Mutiara *et al*. 2019). The best larval stocking density for *R. argyrotaenia* aquaculture was 20 individuals/L (Budi *et al*. 2020). The addition of Lemuru fish (*Sardinella lemuru*) oil to the pellets can increase protein retention and feed efficiency of *R. argyrotaenia* by 16.95 and 57.93%, respectively (Ayunda *et al*. 2020). Recently, Adawiyah *et al*. (2020) successfully characterized the morphology and morphometric of sperm *R. argyrotaenia* for further research. It is acknowledged that the growth pattern and sex ratio of fish may considerably differ from a specific geographical location; for example, *R. argyrotaenia* in upstream Barito River grew negatively allometric with the sex ratio of 3:1 (Rosadi *et al*. 2014), while *R. argyrotaenia* in downstream Sekadau River was reported to have isometric growth pattern with the sex ratio of 1:1 (Suryani *et al*. 2019).

The length-weight relationship is the most common scientific method used for analyzing growth pattern for an individual species of fish (Plamoottil 2016; Herawati *et al*. 2017), as well as for understanding population structure, maturity, and reproduction in various species from different geographical areas (Sentosa and Djumanto 2010; Sarkar *et al*. 2013; Suryani *et al*. 2019). In fish, the growth was reflected as a function of length and weight (Weatherley and Gill 1987). The heavier fish of a given length was considered healthy and in good shape (Dodds 2002). The fish's health can be seen from its condition factor value (Froese 2006). Studies on the length-weight relationship and condition factor can also be used as baseline information on the management and conservation of threatened and commercially important fish species in natural water bodies. In addition, the changes in fish population structure associated with the life history of fish (*e.g.* stock size and age structures) are greatly influenced by size-selective fishing gear (Hsieh *et al*. 2010; Liang *et al*. 2014). To get a clear picture of *R. argyrotaenia* fishery in this area of study, we started investigating the length-weight relationship, condition factor, length at first capture, length at first maturity, and SF of *R. argyrotaenia* to provide some essential recommendations to maintain the sustainability of the fish in their natural habitat. This is the first morphometric study of *R. argyrotaenia* in this river.

## MATERIALS AND METHODS

### Study Site

The research was conducted in Sungai Batang River, sub-district of Martapura, South Kalimantan Province (Figure 1), located on 03°25'32" S and 114°43'21" E, and determined by GPS-60 (Garmin, Taiwan). This river is an important part of the Martapura River, which connects to the Barito River in Banjarmasin City and the Riam Kanan Lake at Aranio in Banjar District, as well as supporting the local economic activities such as fishery, fish farming (*i.e.* Nile tilapia, carp), agriculture, and irrigation. The water depth in the river reaches 6 m. The dried fish processing business driven by fishermen's women was also available. This fishing village consists mostly of a wetland area with water level fluctuation between 0.5–2 m, which strongly influences nutrient cycles in the aquatic system. The fish production of *R. argyrotaenia* was higher in the rainy season compared to the dry season, which is similar to *R. tawarensis* from Lake Laut Tawar in Aceh Province (Muchlisin *et al*. 2011) and *R. argyrotaenia* from Barito River (Rosadi *et al*. 2014). The dry season starts from June–November, while the rainy season is from December–May, and our study was coincided perfectly with the rain season with a rainfall of 268–326 mm. Water

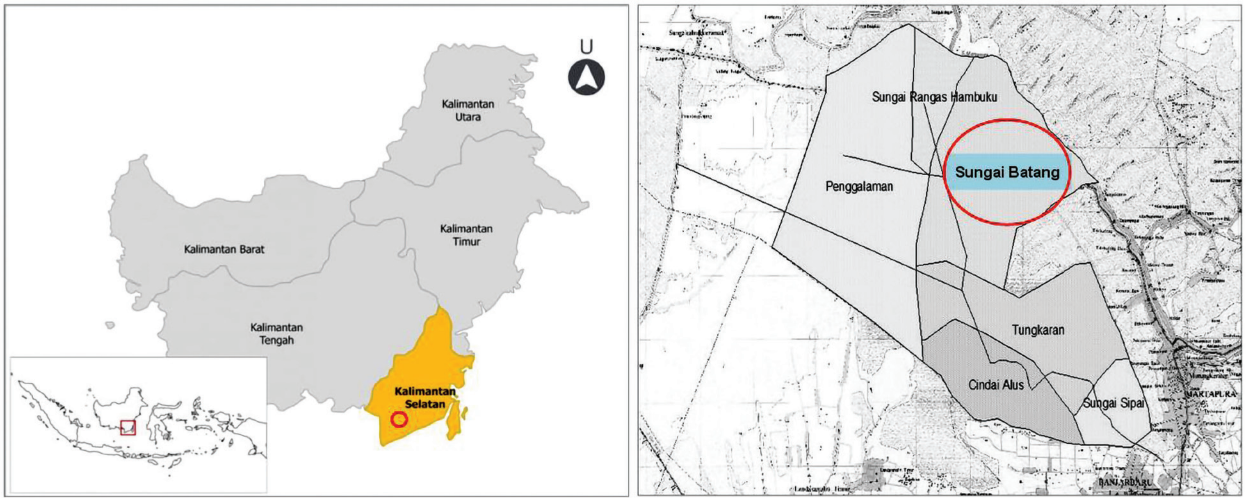


**Figure 1.** The map showing the location of Sungai Batang Village in South Kalimantan Province, Indonesia.

in the dry season is blackish brown-colored, and brownish yellow-colored when the rainy season comes. The river water contains suspended solids ranging from 182–567 mg/L, which is categorized as highly turbid water. The water transparency varied from 55–65 cm with water flow ranging from 0.05–0.22 m/s. The surface water temperature ranged from 26.2–28.6 °C. The pH, dissolved oxygen, and ammonia content were 5.7–6.2, 4–6 ppm, and 0.01–0.02 ppm, respectively – which were within tolerance range for *R. argyrotaenia* to growth and survival.

Using the key of Brittan (1954: 205), Kottelat (2012) characterized *R. argyrotaenia* falls within a group of species *R. rheophila*, *R. myersi*, *R. dusonensis*, and *R. philippina* with the dorso-hypural distance falling in front of the posterior margin of the eye when carried forward, 1 or 1½ scale row between the lateral line, and the origin of the pelvic fin and a continuous dark mid-lateral stripe from the gill opening to the base of the caudal fin and 14 circumpeduncular scale rows (Figure 2). A year later, Ng and Kottelat (2013) redescribed and included *R. tornieri* as a member of *R. argyrotaenia* group. Genetically, Purnama *et al*. (2019) found that species *R. argyrotaenia*, *R. dusonensis*, and *R. borapetensis* have 91% similarity with *R. caudimaculata*. In this river, *R. argyrotaenia* was mostly caught by gillnet with a 0.75-in (19.05 mm) mesh size, which was similarly used for catching *R. argyrotaenia* from Lake Maninjau of West Sumatra (Dina *et al*. 2019). Bamboo stage-trap (*tempirai*) and portable lift net (*hancau*) were also applicable for catching them but in small numbers due to their limited gear functions to reach the fish targeted. We excluded data from these additional fishing gears and were more focused on the catch of gillnet.

### Data Collection

A total of 255 specimens (121 males and 134 females) of different size groups were directly obtained from the gillnet fishermen in the early morning and purchased periodically once every 2 wk during sampling periods (April–May) of rain season. Each individual fish was identified for sex and measured for TL, BD, and W. TL was measured from the tip of the snout (mouth closed) to the end of the caudal fin. BD was measured vertically from the dorsal fin origin to the ventral midline of the body. A standard ruler to the nearest millimeter was used to measure TL and BD of all individual fishes, while a digital scale with an accuracy of 0.01 g (CE, SF-400, China) was used to weigh the W. The ratio of W/TL and BD/TL were empirically determined with a non-dimension number. The length-weight size distribution of fish was set at 10-mm interval class.

This research substantially complied with recognized ethical principles and guidelines for animal care and experiments authorized by the Dean of the Faculty of Marine and Fisheries at Lambung Mangkurat University with the permit number: 455/UN.1.27/AK/2020.

### Length-Weight Relationship

The length-weight relationship of fish was separately estimated for males and females using the standard formula (Froese 2006):

$$W = aL^b \quad (1)$$

where W is the total weight in g, L is the total length in mm, *a* is the constant, showing the initial growth index, and *b* is the slope showing the growth coefficient. According to Bagenal (1978), the *b* value varied between 2.5–3.5 and it is usually used to outline the growth pattern of fish. The

**Figure 2.** A sample of *R. argyrotaenia* taken from Sungai Batang River, Indonesia.

statistical significance of the isometric exponent (*b*) was analyzed by a function (Pauly 1984):

$$t = \left(\frac{\text{SD (x)}}{\text{SD (y)}}\right)\left(\frac{|b-3|}{\sqrt{1-R^2}}\right)\left(\sqrt{n-2}\right) \tag{2}$$

where *t* is the *t* student statistic test value, SD (x) is the standard deviation of log L, SD (y) is the standard deviation of log W, *b* is the slope of the curve, $R^2$ is the coefficient of determination, and *n* is the number of fish sample. The *t*-value was compared with the *t*-table value (0.05) for degrees of freedom at a 95% significance level. If the *t*-value was less than the *t*-table value, the fish grows isometrically ($b = 3$). If the *t*-value was greater than the *t*-table value, fish grows allometrically ($b \neq 3$). The *b* value has an important biological meaning: when $b > 3$, weight increases more than length (positive allometric). When $b < 3$, the length increases more than weight (negative allometric). The coefficient of determination ($R^2$) and the coefficient of regression (r) of the length-weight relationship between males and females were also presented.

### Condition Factor

The condition factor (K) of fish was calculated by the mean of the following formula (Weatherley and Gill 1987):

$$K = 100(W/L^3) \tag{3}$$

where K is Fulton's condition factor, L is the total length in cm, and W is the body weight in g. The factor of 100 is used to bring the K close to unity. The K value is used to determine the health condition of the fish. Relative condition factor (Kn) was further estimated by following Le-Cren (1951) formula:

$$Kn = \frac{W}{\hat{}W} \tag{4}$$

where Kn is the relative condition factor (reflecting "fatness" or well-being of fish), W is the observed weight, and ^W is the calculated weight derived from the length-weight relationship. The higher the Kn value the healthier condition of the fish. Thus, the Kn value is expected to be equal to or close to *1*.

### Estimation of Length at First Capture ($L_{c50}$)

The length at first capture is the TL at which 50% of individuals were captured by gillnets. It also represents 50% of the recruits were under full exploitation. The capture probability was projected by plotting the cumulative frequency distribution of the catch (%) with the TL (mm). It was analyzed using a standard selectivity logistic curve fixed at 50% of the resultant cumulative curve (Sparre and Venema 1992).

### Estimation of Length at First Maturity ($L_{m50}$)

The size at first maturity is the length at which 50% of the fish are mature. This information is necessary for fisheries managers to make sound decisions, particularly for fish stock management and conservation of the fish population (Soares *et al*. 2020). The $L_{m50}$ value was estimated by using the Spearman-Karber formula (Udupa 1986):

$$m = x_k + \frac{X}{2} - (X\,\Sigma P1) \tag{5}$$

$$\text{antilog}\left[m \pm 1.96\sqrt{X^2\,\Sigma\,\{P1 \times q1/n1\text{-}1\}}\right] \tag{6}$$

where $X_k$ is the last log size at which 100% of fish are fully mature, X is the log size increment, P1 is the proportion of fully mature fish in the first size group, and q1 is equal to 1 – P1.

The mean size at first maturity is given by antilog (m) = $L_{m50}$.

In addition, gonadal development can be observed both macroscopically and microscopically. Determination of the gonad maturity level can be seen from the changes in the structure of the eggs, which can be divided into five levels (I-V) following Effendie's (1979) criteria with some modifications, and the results would be elucidated in the future study.

### SF

The SF was the index related to the escapement factor expressing the relation between $L_{c50}$ and the mesh size used. The SF was also known as the coefficient of selectivity. The SF was simply predictable with the formula (Pauly 1984):

$$SF = \frac{Lc50}{\text{Mesh size}} \tag{7}$$

### Statistical Analysis

The analysis of covariance was used to determine whether there were any significant differences in growth patterns between males and females. A two-sample t-test was used to compare means of body size, size ratio, and condition factor between males and females. The chi-squared test ($X^2$) was used to calculate the sex ratio, which deviates from the expected values of 1M:1F (Sokal and Rohlf 1995). All tests were analyzed at the 0.05 level of significance using SPSS-18 software.

## RESULTS

### Length-Weight Relationship and Ratio of Body Size

The estimated values of length-weight relationship parameters, the ratio of body size, and condition factor of *R. argyrotaenia* males and females are shown in Appendix Tables I and II. Male grew negatively allometric (b = 2.71), while female grew isometrically (b = 3.02). The length-weight relationships for male and female were expressed as $W = 0.3 \times 10^{-4}TL^{2.7090}$ and $W = 0.7 \times 10^{-5}TL^{3.0178}$ (Figure 3A). The $R^2$ values ranged from 0.578–0.692, indicating that about 70% of the variability of the weight was explained by the length. The r-value falls between 0.760–0.832, showing that the length-weight relationship was positively correlated. There were significant differences in TL, W, BD, and the W/TL ratio between males and females ($p < 0.001$). The body sizes of males ranged from 65–116 mm TL (85.56 ± 11.86 mm) and 2–15 g W (5.21 ± 2.39 g), while those of females ranged from 65–100 mm TL (79.43 ± 7.40 mm) and 2–8 g W (4.22 ± 1.45 g) – with the male: female ratio at 1.0: 1.1. Males had the mean ratio of W/TL (0.06 ± 0.02) greater than females (0.05 ± 0.01), and the relationship was given by $W/TL = 0.3 \times 10^{-4}TL^{1.7090}$ ($R^2 = 0.472$) for males and $W/TL = 0.7\ \ 10^{-5}TL^{2.0178}$ ($R^2 = 0.3799$) for females (Figure 3B). It was clearly demonstrated that the BD of fish was increasingly proportional to the TL (Figure 3C). Although males had BD (17.21 ± 3.22 mm) considerably higher than females (15.96 ± 2.62); however, their mean ratio of BD/TL was found to be equal (0.20 ± 0.02). The relationship of body size ratios for male and female was expressed as $BD/TL = 0.1535TL^{0.0594}$ and $BD/TL = 0.0445TL^{0.3429}$, respectively (Figure 3D). No significant difference in the sex ratio of males to females (1.0: 1.1) was observed.

### Length-Weight Size Distribution

The fish samples in the present study were mostly distributed in the middle size class. The highest catch percentage falls between 80–89 mm TL, which accounted for males (39.67%) and females (43.28%), followed by the

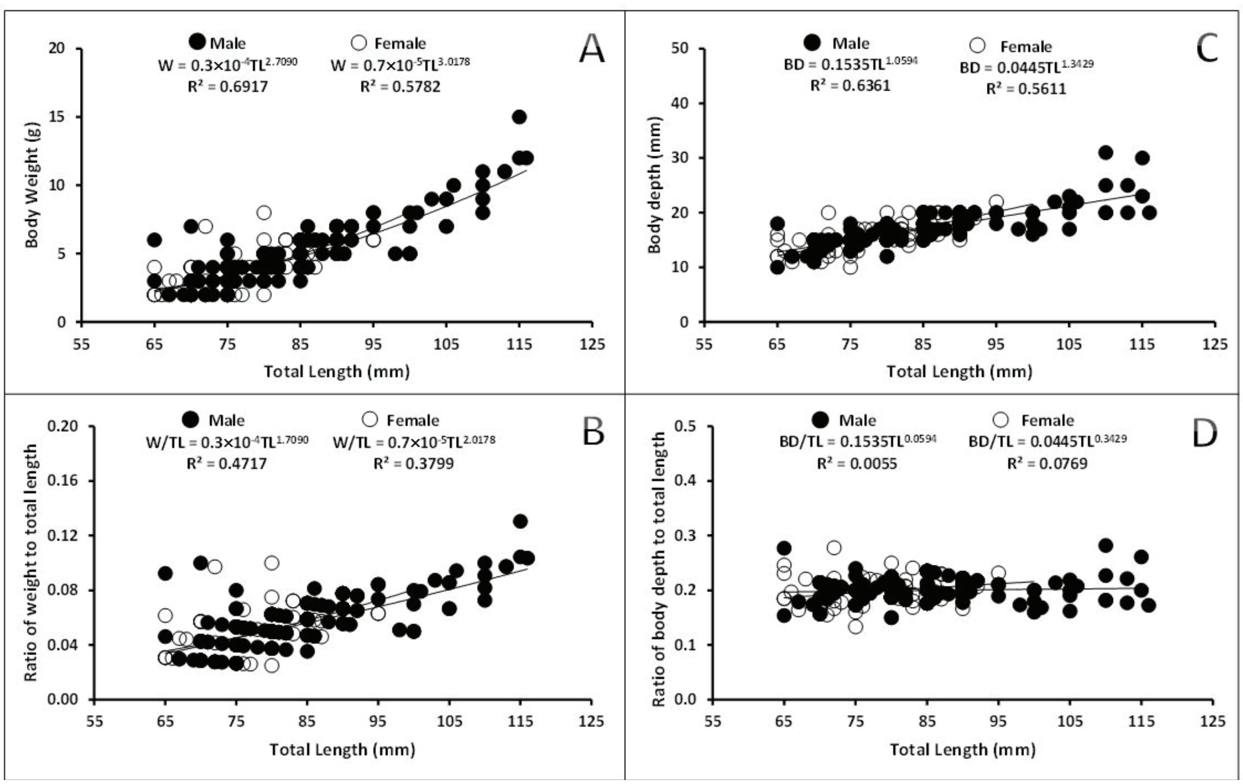


**Figure 3.** [A] The relationship between W and TL of *R. argyrotaenia* taken from Sungai Batang River. [B] The relationship between the mean ratios of W to the TL. [C] The relationship between BD and TL. [D] The relationship between the mean ratios of BD to the TL.

length size of 70–79 mm TL (Figure 4A). Less than 10% of the catch was observed for smaller individuals < 70 mm TL or larger individuals > 99 mm TL (Figure 4A). The heaviest catches of males (57.02%) and females (65.67%) weighted between 4–6 g (Figure 4B). More males than females were caught by the gill nets, particularly individuals with body sizes > 89 mm TL and > 6 g W.

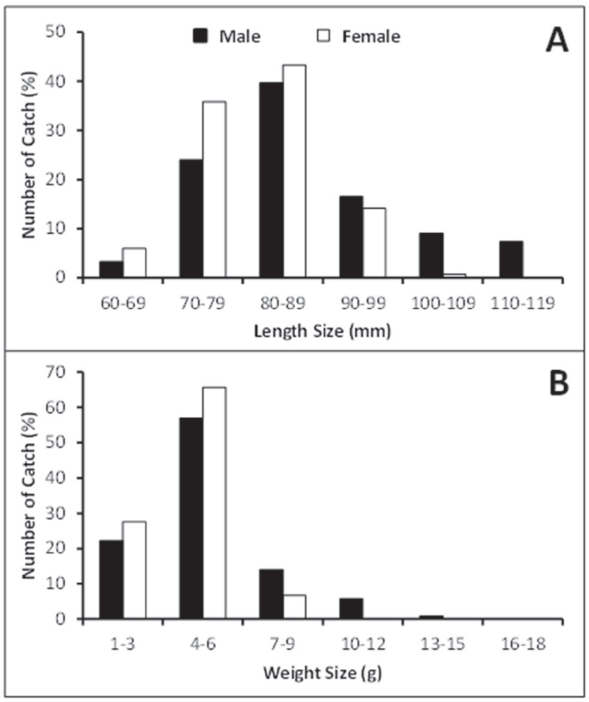


**Figure 4.** The percentages of length size [A] and weight size [B] distribution between male and female of *R. argyrotaenia* from Sungai Batang River.

**Condition Factor**

There was no significant difference in the K value between males and females (Appendix Table III). The mean K values obtained for males and females were 0.80 ± 0.23 and 0.82 ± 0.20, respectively. Nevertheless, the initial growth index of males was greater than that of females. The increase in the ratio of W to TL was corresponding to the condition factor. The relationship was expressed as $W/TL = 0.0418K + 0.0255$ ($R^2 = 0.2527$) for males and $W/TL = 0.0553K + 0.0067$ ($R^2 = 0.5722$) for females (Figure 5). Further analysis obviously revealed that the relative condition factor of females (1.09 ± 0.27) was considerably greater than that of males (0.97 ± 0.27), as shown in Appendix Table III.

**Estimation of Length at First Capture**

The length at first capture ($L_{c50}$) for male and female *R. argyrotaenia* was estimated at 80 and 76 mm respectively, indicating the sizes at which 50% of the catches were

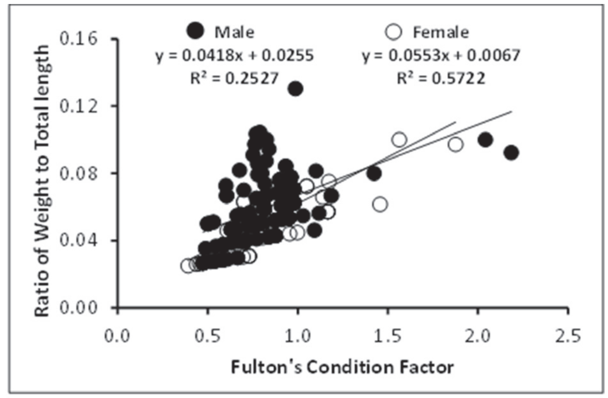


**Figure 5.** The relationship between the ratio of W to TL and the condition factor of *R. argyrotaenia.* The female's condition factor was considerably higher than males.

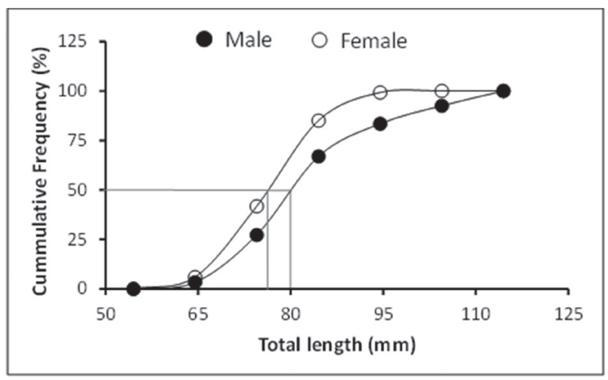


**Figure 6.** The length at first capture ($L_{c50}$) of male and female *R. argyrotaenia* was estimated as 80 and 76 mm, corresponding to the 0.75-in mesh size used.

retained by the gill nets. On the basis of $L_{c50}$, the estimated proportion of smaller and larger individuals of males was 41.79% (< 80 mm) and 35.07% (> 80 mm); for females, the proportion of smaller and larger individuals was 23.14% (< 76 mm) and 75.21% (> 76 mm). The length size of fish was corresponding to the mesh size of gill nets used (Figure 6).

**Estimation of Length at First Maturity**

By using the Spearman-Karber formula, it was clearly found that the size at first maturity for male and female *R. argyrotaenia* was predicted as 85 and 80 mm TL, which were greater than the length at first capture (Figure 7). The proportion of mature individuals by size class distribution was 54.13% for males and 62.31% for females with a sex ratio of 0.8:1. The highest number of mature individuals was found between 83–85 mm TL (31.40%) for males and between 85–87 mm TL (52.96%) for females. Meanwhile, the proportion of sexually immature individuals was estimated as 45.87% for males and 37.69% for females

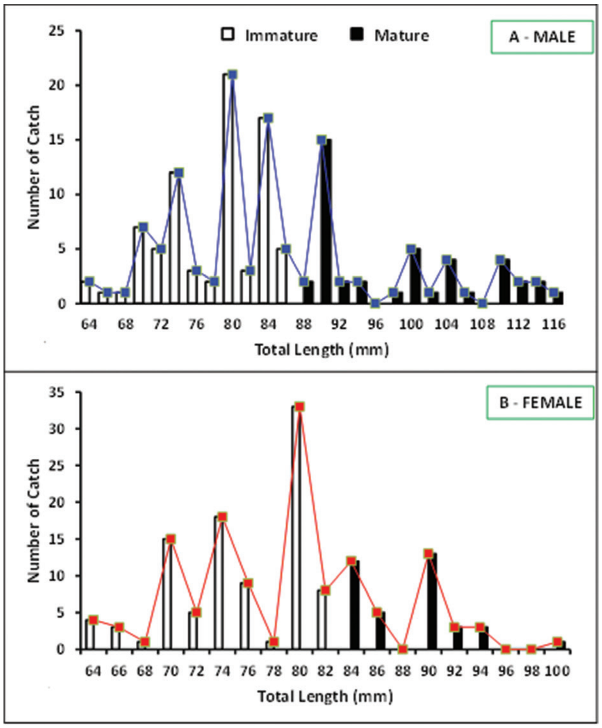


**Figure 7.** The length at first maturity ($L_{m50}$) of *R. argyrotaenia* was estimated as 87.53 mm for males and 84.57 mm for females. The proportions of sexually mature males and females accounted for 54.13 and 62.31% of the allowable biological catch.

with a sex ratio of 1.2:1. The highest number of immature individuals was found between 79–81 mm TL (45.78%) for males and between 85–87 mm TL (52.96%) for females.

### SF

The estimated SF value for males and females was 3.99 and 4.20, respectively. The mesh size used as the main input for calculating the SF value was 0.75 in (19.05 mm) for both males and females. The SF value was directly proportional to the corresponding $L_{c50}$ values (150 mm), but it was inversely proportional to the mesh size used.

## DISCUSSION

The most important result of the present study on the growth pattern of *R. argyrotaenia* was that males grew negatively allometric, while females grew isometrically. The *b* value of females was found to be higher than that of males, indicating that females were capable of utilizing their energy allocation for growth efficiently. Females took advantage of the river environment with nutrient sufficiency originating from the flooded organic matter degradation. This is in line with the results of Newcomer Johnson *et al*. (2016) and Gordon *et al*. (2020), who reported that ecologically functional floodplains and rivers greatly affect the population dynamics of aquatic organisms. Otherwise, males are more physically active than females, *i.e.* males spend more energy for movement in the flowing stream environment rather than used for growth. In other words, males are more adaptable to higher water-flow velocities as compared to females. According to Shukor *et al*. (2008), the population growth and survival of *Rasbora* fish are highly affected by the water current in the river.

*R. argyrotaenia* in the river are very susceptible to predation pressure from snakeheads *Channa striata* (Ansyari *et al*. 2020), while swimming performance is greatly affected by the body morphology of fishes (Veillard *et al*. 2017; Egger *et al*. 2020). Males with a slender shape and narrower body have a greater predator escape response as compared to females with a round shape and deeper body. The body size of male *R. argyrotaenia* was larger than that of the female. This implies that males with a larger relative eye size could improve their visual acuity in detecting predator presence, which is similar to those of other fish studies (Lönnstedt *et al*. 2013; Meuthen *et al*. 2019; Svanbäck and Johansson 2019). Females being less active than males result in greater predation risk, and it was quite reasonable why females tend to avoid predators more frequently than males by swimming in the slow flow stream, resting, and hiding in surrounding vegetation as a rearing habitat away from predation pressure. This observation is principally very closely related to the findings of previous studies (Hockley *et al*. 2013; Welsh *et al*. 2013; del Signore *et al*. 2016).

In nature, predators instinctively prefer not to prey on fish with a deeper body than a narrower body, because a deeper body in fish increases handling times for them. In addition, there was a positive correlation between the relative brain size of prey and predator. Kondoh (2010) reported that prey species had relatively larger brains than predator species. van der Bijl *et al*. (2015) gave empirical evidence that large-brained *Poecilia reticulata* females, but not males, spent less time performing predator inspections that lead to inherently risky behavior for them. Furthermore, Kotrschal *et al*. (2015) confirmed that in the natural environment, small-brained *P. reticulata* females were more vulnerable to the predator attack as compared to large-brained ones – but not males. Besides food availability and predation risk, other factors such as fishing pressure, water quality, and water pollution may also influence the growth rate of *R. argyrotaenia* in Sungai Batang River, which is also naturally experienced by *R. argyrotaenia* living in Siak River in Riau (Zulkurnain *et al*. 2015), Lake Ie Sayang in Aceh (Astuti and Fitrianingsih

2018), and Sekadau River in West Kalimantan (Suryani *et al*. 2019).

Negative allometric growth in males has also been observed for *R. argyrotaenia* from Musi, Kumpeh, Rungan, and Cimanuk Rivers (Arsyad and Syaefudin 2010; Lisna 2013; Sulistiyarto 2012; Herawati *et al*. 2017); *R. tawarensis* from Lake Laut Tawar in Aceh (Muchlisin *et al*. 2011); *R. lateristriata* from Babak River in Lombok (Asrial *et al*. 2017); and *R. daniconius* from Ganga-Gomti-Rapti Rivers and Sharavathi Reservoir in India (Kumar *et al*. 2006; Sarkar *et al*. 2013). However, it was contrary to *R. argyrotaenia* sampled from Kumpeh and Sekadau Rivers (Lisna 2013; Suryani *et al*. 2019) and *R. sumatrana* from Way Tulang Bawang Lampung and Kerian River in Malaysia (Yudha 2011; Zakeyudin *et al*. 2012), which exhibited a positive allometric growth. Similar isometric growth in *R. argyrotaenia* female was also documented in *R. sumatrana* from Hulu Langat in Malaysia (Shukor *et al*. 2008) and *R. lateristriata* from Rawa Jombor and Selaka Rivers in Lombok (Khoirudin *et al*. 2016; Asrial *et al*. 2017). Variation in slope may be attributed to sampling size variation, life stages, seasonal changes, gonad development, sex, change in physiological condition during spawning periods, physicochemical conditions of the environment, and food availability (Lisna 2013; Herawati *et al*. 2017).

The maximum size (116 mm TL) of *R. argyrotaenia* samples in our study was comparatively greater than those of other *Rasbora* species such as *R. ataenia* (112 mm) from Alappuzha Stream in India (Plamoottil 2016), *R. tawarensis* (110 mm) from Lake Laut Tawar in Aceh (Muchlisin *et al*. 2010), *R. lateristriata* (79.8 mm) from Babak River in Lombok (Asrial *et al*. 2017), *R. argyrotaenia* (38 mm) from Kumpeh River (Lisna 2013), *R. daniconius* (95 mm) from Sharavathi Reservoir in India (Kumar *et al*. 2006), *R. Sumatrana* (93 mm) from Hulu Langat in Malaysia (Shukor *et al*. 2008), or *R. argyrotaenia* (79 mm) from Cimanuk River (Herawati *et al*. 2017). However, its size was smaller than that of *R. argyrotaenia* (160 mm) collected from the Barito River (Rosadi *et al*. 2014). It implies that the Sungai Batang River environment was suitable for *R. argyrotaenia* to grow. During fishing season (March–April), it was very likely to collect *R. argyrotaenia* smaller than 65 mm TL using the nets, but fishermen prefer releasing them back to the river rather than selling them for free or at a lower price; conversely, the smaller fish might be untrappable because of fishing gear selectivity (Ahmadi and Rizani 2013). The other way, it was also possible for fishermen to collect larger individuals > 116 mm TL; however, it was beyond our investigation due to the daily transactional selling of fish between fishermen and fish traders was done in the early morning before the fish was transported to the local markets. No record of catches and prices potentially leading to unreported fishing practices. Fishing activity is ongoing throughout the year regardless of seasonal periods, thus resulting in the ratio of the fish growth rate to the exploitation rate in this river still being unpredictable. The output of our research could be a good starting point in formulating a sustainable fisheries management strategy.

In the present study, the estimated values of condition factor (K) for *R. argyrotaenia* (0.39–2.18) were in agreement with those of other *Rasbora* species from different geographical areas (Appendix Table IV) and reconfirmed that the *R. argyrotaenia* in this river was in good condition. Variation in the K values may be attributed to biological interaction involving intraspecific competition for food and space between species – including sex, stages of maturity, state of stomach contents, and availability of food (Sulistiyarto 2012; Morioka *et al*. 2014; Asrial *et al*. 2017). Practically, the K value can be improved by developing the technology of breeding and spawning. The $K_n$ value of females was significantly higher than that of males (Appendix Table III), indicating that females grew faster and heavier than males under natural conditions. For survival and growth increment in *R. argyrotaenia*, Budi *et al*. (2020) recommended using 20 fish/L stocking density for larval hatchery culture practices. Dealing with spawning induction, Ningrum *et al*. (2019) proposed using 0.7 mL/kg ovaprim$^{TM}$ to increase its fecundity and fertilization rate. Yusuf (2016), meanwhile, suggested using temperature within 27–28 ºC to provide the best hatching and survival rates.

Empirically, the gill net was the most common fishing gear used for catching *Rasbora* species from their natural habitats (Appendix Table V). In the present study, fishermen used 0.75-in mesh size to harvest *R. argyrotaenia* in Sungai Batang River – as also frequently used in Lake Maninjau in West Sumatera (Dina *et al*. 2011), Rungai River in Central Kalimantan (Sulistiyarto 2012), and Kumpeh River in Muaro Jambi (Lisna 2013). The larger mesh size (1.18 in) was also applied for collecting *R. argyrotaenia* in Barito River in South Kalimantan, and the catch at the full moon was found two times higher than at dark moon (Rosadi 2014). In other places, the fisher community at Tualang Siak in Riau (Zulkurnain *et al*. 2015), Cimanuk in West Java (Herawati *et al*. 2017), and Sekadau in West Kalimantan (Suryani *et al*. 2019) catching *R. argyrotaenia* by means of 0.20, 0.39, and 0.59 in, respectively. Meanwhile, Muchlisin *et al*. (2010) worked with a 0.39-in mesh size for sampling *R. tawarensis* from the Lake Laut Tawar. These mesh sizes can be adjusted according to the type and size of a targeted species, as well as fish behavior (Banda *et al.* 2019). Optionally, fish traps (*lukah*) had also some success in catching *R. argyrotaenia* (Dina *et al*. 2011).

However, it should not be placed in the tributary paths to the flooding habitat during the spawning season to allow the reproduction process of broodstocks.

None of the studies on the gill nets mentioned above discussed the length at first capture ($L_{c50}$). From the data available, we estimated the $L_{c50}$ for males and females at 80 and 76 mm, respectively (Figure 6). The present gill net that caught small individual females (41.79%) was 1.8 times higher than those for males (23.14%). On the other hand, the estimated larger individuals for males (75.21%) were 2.1 times higher than those for females (35.07%). It implies that the use of 0.75-in mesh size for catching *R. argyrotaenia* in this river was still allowable. However, the empirical evidence showed that the length at first capture was smaller than the length at first maturity ($L_{m50}$), indicating that *R. argyrotaenia* has fewer chances of spawning to maintain the fish population, and this condition was highly unexpected in sustainable fisheries management. Therefore, a precautionary measure is needed to prevent growth overfishing. Since the mesh size of the gillnet was closely related to the size of the fish, the length at fish capture can be adjusted by altering the mesh size appropriately. Thus, the use of a larger mesh size (1 in) was recommended for both commercial and conservation purposes. In the present study, the $L_{m50}$ value of males was higher than that of females, which showed the opposite for *R. argyrotaenia* males sampled from Lake Maninjau in West Sumatera (Dina *et al*. 2011). Variation in length at first maturity is attributable to fishing pressure, biotic interaction, and environmental condition (Lappalainen *et al*. 2016; Souza *et al*. 2019). The SF values vary by species and mesh sizes used. However, the SF value is not always dependent on the size of the fish. In the current study, we found that the SF values for *R. argyrotaenia* males and females were 3.99 and 4.20 by means of the 0.75-in mesh size. On the basis of 1.5-in mesh size, *Kryptopterus palembangensis* was reported to have an SF value of 2.08 (Aryantoni *et al*. 2014), whereas the SF value of 4.41 for *Ompok bimaculatus* corresponding to the 2-in mesh size (Amarasinghe and Pushpalatha 1997) was found relatively higher than that of our finding.

As clearly described in Appendix Table V, gill net with 0.75-in mesh size in the present work was considered female-biased gear – similarly with 0.39, 0.75, and 1 in used for catching *R. argyrotaenia* in Lake Maninjau and Sekadau River (Dina *et al*. 2011; Suryani *et al*. 2019), 0.56 in for *R. tawarensis* in Lake Laut Tawar (Muchlisin *et al*. 2011), or 0.5 in for *R. lateristriata* in Rawa Jombor (Khoirudin *et al*. 2016). Meanwhile, the male-biased gear for *R. argyrotaenia* sampled from Cimanuk, Kumpeh, and Barito Rivers (Herawati *et al*. 2017; Lisna 2013; Rosadi 2014) corresponded to 0.59, 0.75, and 1.18-in mesh size used. Variation in the sex ratio of the fish was closely related to food availability, water temperature, dissolved oxygen, and migration cycle (Rosadi *et al*. 2014; Yusuf 2016). It is not enough to regulate gear selectivity for a certain species or only provide the database information on the length-weight ratio, but the most important thing is that all stakeholders should be directly involved in the fisheries management decision-making process since many aspects related to *Rasbora* fishery have not been fully studied.

## CONCLUSION

The *R. argyrotaenia* males showed negative allometric growth, whereas females exhibited isometric growth and were found to be in good condition. Comparatively, the length at first capture was smaller than the length at first maturity, leading to growth overfishing. The involvement of stakeholders in the decision-making process for better fisheries management is strongly encouraged.

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**Table I.** Total length, weight, and growth pattern of male and female of *R. argyrotaenia* collected from Sungai Batang River (a – constant, b – exponent, $R^2$ – determination coefficient, r – regression coefficient, $A^-$ – negative allometric, and I – isometric).

| Sex | n | Total length (mm) | | | Weight (g) | | | a | b | $R^2$ | r | Growth pattern |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Min. | Max. | Mean ± SD | Min. | Max. | Mean ± SD | | | | | |
| Male | 121 | 65 | 116 | 85.56 ± 11.86 | 2 | 15 | 5.21 ± 2.39 | $0.3 \times 10^{-4}$ | 2.7090 | 0.6917 | 0.8317 | $A^-$ |
| Female | 134 | 65 | 100 | 79.43 ± 7.40 | 2 | 8 | 4.22 ± 1.45 | $0.7 \times 10^{-5}$ | 3.0178 | 0.5782 | 0.7604 | I |

**Table II.** The mean ratio of body sizes of *R. argyrotaenia* sampled from Sungai Batang River (a – constant, b – exponent, $R^2$ – determination coefficient, r – regression coefficient, BD – body depth, W – body weight, and TL – total length).

| Sex | n | BD/TL | a | b | $R^2$ | r | W/TL | a | b | $R^2$ | r |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Male | 121 | 0.20 ± 0.02 | 0.1535 | 0.0594 | 0.0055 | 0.0742 | 0.06 ± 0.02 | $0.3 \times 10^{-4}$ | 1.7090 | 0.4717 | 0.6868 |
| Female | 134 | 0.20 ± 0.02 | 0.0445 | 0.3429 | 0.0769 | 0.2773 | 0.05 ± 0.01 | $0.7 \times 10^{-5}$ | 2.0178 | 0.3799 | 0.6164 |

**Table III.** Statistical descriptive of the parameters observed for *R. argyrotaenia* taken from Sungai Batang River (TL – total length, W – body weight, BD – body depth, K – Fulton's condition factor, and $K_n$ – relative condition factor).

| Parameters observed | Mean ± SD of body sizes | | *t*-test for equality of means | | | |
|---|---|---|---|---|---|---|
| | Male | Female | *t* | df | *P* | SE |
| TL | 85.56 ± 11.86 | 79.43 ± 7.40 | 5.007 | 253 | 0.000 | 1.2256 |
| W | 5.21 ± 2.39 | 4.22 ± 1.45 | 4.045 | 253 | 0.000 | 0.2450 |
| BD | 17.21 ± 3.22 | 15.96 ± 2.62 | 3.421 | 253 | 0.001 | 0.3660 |
| W/TL | 0.06 ± 0.02 | 0.05 ± 0.01 | 3.098 | 253 | 0.002 | 0.0022 |
| BD/TL | 0.20 ± 0.02 | 0.20 ± 0.02 | 0.195 | 253 | 0.845 | 0.0028 |
| K | 0.80 ± 0.23 | 0.82 ± 0.20 | -0.757 | 253 | 0.450 | 0.0274 |
| $K_n$ | 1.09 ± 0.27 | 0.97 ± 0.27 | -3.451 | 253 | 0.001 | 0.0336 |

**Table IV.** Comparative length-weight relationship, condition factor, and growth pattern of Rasbora from different locations.

| Species | Sex | n | TL (mm) | W (g) | b | Growth pattern | K | Locations | Country | References |
|---|---|---|---|---|---|---|---|---|---|---|
| *R. argyrotaenia* | M | 121 | 65–116 | 2–15 | 2.71 | $A^-$ | 0.80 | Sungai Batang River | Indonesia | Present study |
| *R. argyrotaenia* | F | 134 | 65–100 | 2–8 | 3.02 | I | 0.82 | Sungai Batang River | Indonesia | Present study |
| *R. argyrotaenia* | P | 199 | 68–104 | 3.6–13.6 | 2.63 | $A^-$ | 1.18 | Rungan River | Indonesia | Sulistiyarto (2012) |
| *R. argyrotaenia* | M | 1751 | 45–160 | 0.8–35 | 2.86 | $A^-$ | – | Barito River | Indonesia | Rosadi (2014) |
| *R. argyrotaenia* | F | 630 | 47–161 | 1–38 | 2.91 | $A^-$ | – | Barito River | Indonesia | Rosadi (2014) |
| *R. argyrotaenia* | P | 155 | 53–79 | 1.41–4.14 | 2.70 | $A^-$ | 1.20 | Cimanuk River | Indonesia | Herawati *et al.* (2017) |
| *R. argyrotaenia* | M | 107 | 24.02–35.06 | 4.00–11.1 | 2.96 | $A^-$ | – | Kumpeh River | Indonesia | Lisna (2013) |
| *R. argyrotaenia* | F | 80 | 27.09–38.08 | 4.02–13.5 | 3.20 | $A^+$ | – | Kumpeh River | Indonesia | Lisna (2013) |
| *R. argyrotaenia* | M | 58 | 53–113 | 1.40–12.8 | 3.04 | $A^+$ | – | Sekadau River | Indonesia | Suryani *et al.* (2019) |
| *R. argyrotaenia* | F | 69 | 40–130 | 1.39–14.8 | 3.04 | $A^+$ | – | Sekadau River | Indonesia | Suryani *et al.* (2019) |
| *R. tawarensis* | M | 326 | 64.82–98.84 | 2.25–7.32 | 2.59 | $A^-$ | 1.73 | Lake Laut Tawar | Indonesia | Muchlisin *et al.* (2010) |
| *R. tawarensis* | F | 833 | 67.43–109.55 | 2.43–9.40 | 2.57 | $A^-$ | 1.85 | Lake Laut Tawar | Indonesia | Muchlisin *et al.* (2010) |
| *R. lateristriata* | P | 23 | 47.5–78.8 | 4.77–5.53 | 3.47 | I | 1.04 | Selaka River | Indonesia | Asrial *et al.* (2017) |
| *R. lateristriata* | P | 23 | 49.5–79.8 | 3.65–4.20 | 2.65 | $A^-$ | 0.86 | Babak River | Indonesia | Asrial *et al.* (2017) |

| Species | Sex | n | TL (mm) | W (g) | b | Growth pattern | K | Locations | Country | References |
|---|---|---|---|---|---|---|---|---|---|---|
| *R. lateristriata* | M | 314 | 45–87 | 0.77–4.66 | 2.72 | $A^-$ | 1.11 | Rawa Jombor | Indonesia | Khoirudin *et al.* (2016) |
| *R. lateristriata* | F | 977 | 45–95 | 1.08–8.25 | 3.01 | I | 1.50 | Rawa Jombor | Indonesia | Khoirudin *et al.* (2016) |
| *Rasbora* sp. | P | 35 | 10.65 | 11.90 | 2.42 | $A^-$ | 1.71 | Krueng Simpoe | Indonesia | Fuadi *et al.* (2016) |
| *R. daniconius* | M | 52 | 17–60 | 0.21–8.10 | 2.64 | $A^-$ | – | Sharavathi reservoir | India | Kumar *et al.* (2006) |
| *R. daniconius* | F | 18 | 25–95 | 0.05–2.19 | 2.49 | $A^-$ | – | Sharavathi reservoir | India | Kumar *et al.* (2006) |
| *R. daniconius* | P | 40 | 34–85 | 3.29–4.08 | 1.99 | $A^-$ | – | Ganga River | India | Sarkar *et al.* (2013) |
| *R. daniconius* | P | 35 | 35–80 | 2.36–3.05 | 1.90 | $A^-$ | – | Gomti River | India | Sarkar *et al.* (2013) |
| *R. daniconius* | P | 65 | 33–83 | 3.12–3.88 | 1.92 | $A^-$ | – | Rapti River | India | Sarkar *et al.* (2013) |
| *R. Sumatrana* | P | 100 | 40–93 | 1.01–13.6 | 3.05 | I | – | Hulu Langat | Malaysia | Shukor *et al.* (2008) |
| *R. Sumatrana* | P | 92 | 51–116 | 1–16 | 3.64 | $A^+$ | 1.87 | Kerian River | Malaysia | Zakeyudin *et al.* (2012) |
| *R. Sumatrana* | P | 77 | 51–116 | 1–16 | 3.61 | $A^+$ | 1.21 | Kerian River | Malaysia | Isa *et al.* (2010) |
| *R. Sumatrana* | P | 9 | 45–110 | 1–12 | 4.81 | $A^+$ | 1.06 | Way Tulang Bawang | Indonesia | Yudha (2011) |

$A^+$ – positive allometric, $A^-$ – negative allometric, I – isometric, W – weight, TL – total length, K – condition factor, M – male, F – female, P – pooled

**Table V.** Comparative mesh size of gill nets, catch proportion, and sex ratio of *Rasbora* collected from different habitats.

| Mesh size | | Targeted fish | n | Fish size (mm) | | Catch proportion (%) | | Sex ratio M: F | Location | Province | References |
|---|---|---|---|---|---|---|---|---|---|---|---|
| mm | inch | | | Male | Female | Male | Female | | | | |
| 19.05 | 0.75 | *R. argyrotaenia* | 255 | 65–116 | 65–100 | 47.45 | 52.55 | 1.0 : 1.1 | Sungai Batang River | South Kalimantan | Present study |
| 30.00 | 1.18 | *R. argyrotaenia* | 2381 | 45–160 | 47–161 | 73.54 | 26.46 | 2.8 : 1.0 | Barito River | South Kalimantan | Rosadi (2014) |
| 19.10 | 0.75 | *R. argyrotaenia* | 187 | 24–35 | 27–38 | 57.22 | 42.78 | 1.3 : 1.0 | Kumpeh River | Jambi | Lisna (2013) |
| 25.40 | 1.00 | *R. argyrotaenia* | 25 | 103–138 | 103–138 | 4.00 | 96.00 | 1.0 : 24.0 | Lake Maninjau | West Sumatera | Dina *et al.* (2011) |
| 19.05 | 0.75 | *R. argyrotaenia* | 537 | 76–129 | 76–129 | 18.40 | 81.60 | 1.0 : 4.4 | Lake Maninjau | West Sumatera | Dina *et al.* (2011) |
| 15.88 | 0.63 | *R. argyrotaenia* | 72 | 67–102 | 67–102 | 80.60 | 19.40 | 4.2 : 1.0 | Lake Maninjau | West Sumatera | Dina *et al.* (2011) |
| 9.91 | 0.39 | *R. argyrotaenia* | 213 | 53–113 | 40–130 | 45.67 | 54.33 | 1.0 : 1.2 | Sekadau River | West Kalimantan | Suryani *et al.* (2019) |
| 14.99 | 0.59 | *R. argyrotaenia* | 155 | 54–79 | 53–75 | 53.55 | 46.45 | 1.2 : 1.0 | Cimanuk River | West Java | Herawati *et al.* (2017) |
| 9.91 | 0.39 | *R. tawarensis* | 1159 | 65–99 | 67–110 | 28.13 | 71.87 | 1.0 : 2.6 | Lake Laut Tawar | Aceh | Muchlisin *et al.* (2010) |
| 12.70 | 0.50 | *R. lateristriata* | 1291 | 45–87 | 45–95 | 24.32 | 75.68 | 1.0 : 3.1 | Rawa Jombor | Central Java | Khoirudin *et al.* (2016) |