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Research Article

Reproductive biology of silver barb, *Barbonymus gonionotus* (Bleeker, 1850), in Lake Tempe, Indonesia

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Abstract

Information about the reproductive biology of the silver barb is essential for conservation and domestication purposes. This study aims to analyze the reproductive biology of the silver barb in Lake Tempe, South Sulawesi, Indonesia. The aspects of reproductive biology analyzed include length-weight structure, sex ratio, length-weight relationship, condition factor, first gonadal maturity size (L50), gonadal maturity, and fecundity. This study used primary data, with silver barb fish being caught using gill nets every week from January to July 2023. The total length of the fish was measured using an ichthyometer with an accuracy of 0.1 cm, and the weight was measured using a digital scale with an accuracy of 0.01 g. The gonads were preserved in a 4% formalin solution, and fecundity was calculated using the gravimetric method. The length structure of male ranged from 8.9 to 22.9 cm, and females ranged from 8.9 to 28.5 cm. Males had weights between 21.2 and 183.2 g, and females 21.2 and 312.8 g. The overall sex ratio of males to females was 1:1, while the sex ratio during spawning was 1:3 (polygamy). The length-weight relationship for males and females was $W = 0.0234L^{2.7349}$ and $W = 0.0172L^{2.8766}$, respectively. The condition factor for both males and females was 1.02. The first gonadal maturity size for females was 18.3 cm and 19.9 cm for males. Spawning was partial, with fecundity ranging from 253 to 13,398 eggs.

Introduction

Silver barb, *Barbonymus gonionotus* (Bleeker, 1850), is an economically important freshwater fish in several countries such as Indonesia, Malaysia, Thailand, Myanmar, Bangladesh, India, and China. This fish has a delicious taste and is relatively inexpensive, making it a primary food source for communities, especially in certain regions of Indonesia. Its production largely relies on wild capture, leading to increasing fishing pressure.

Lake Tempe has a diverse range of fish species, consisting of native fish, introduced fish, and migratory marine fish. According to Dina *et al*. (2019), the native fish of Lake Tempe include *Monopterus albus*, *Anabas testudineus*, *Glossogobius aureus*, and *Channa striata*. The introduced fish species are *Barbonymus gonionotus*, *Clarias batrachus*, *Trichopodus pectoralis*, *Pangasianodon hypophthalmus*, *Osteochilus vittatus*, *Oreochromis niloticus*, *Helostoma temminckii*, and *Cyprinus carpio* (Yanuarita *et al.,* 2020). The migratory marine fish species include *Megalops cyprinoides*, *Stenogobius gymnopomus*, *Anguilla marmorata*, and *Caranx sexfasciatus*. The introduction of these species was carried out to enhance fishery production to meet increasing demand, optimize water productivity, sustainably boost production, and increase biodiversity (Yanuarita *et al.,* 2020; FAO, 2022).

Lake Tempe is currently facing environmental issues, including eutrophication (Aisyah and Nomosatryo, 2016). Eutrophication is suspected to be caused by nutrient loads originating from human activities, plantations, and livestock farming, which are prevalent around the lake's edge. Nitrate and phosphate nutrients in the water range from 0.1063-0.2620 mg/L and 0.0245-0.0655 mg/L, respectively (Samuel *et al.,* 2012). This condition triggers the growth of aquatic weeds such as *Ipomoea aquatica* and *Eichhornia crassipes*. *E. crassipes* is the most dominant plant, with its population estimated to cover about 30-40% of the lake's surface. According to Yani *et al*. (2019), Lake Tempe has experienced moderate to severe pollution in several parameters, including turbidity, total suspended solids, biological oxygen demand, nitrate, and phosphate levels.

Another issue is overfishing and the use of non-environmentally friendly fishing gear (Nasution, 2012). A more serious problem is the presence of invasive fish species, specifically *Pterygoplichthys* spp. (Hasnidar *et al.,* 2021). The high population of *Pterygoplichthys* spp. has led to a decrease in the catch of target fish by fishermen (Hasrianti *et al.,* 2020). The presence of *Pterygoplichthys* spp. impacts the lake ecosystem through habitat competition, feeding patterns, and even predation on native and endemic fish, as well as being vectors for various diseases. This can alter species composition and fish community structure, leading to the dominance and possible elimination of native and endemic fish (Syafei and Sudinno, 2018).

Silver barb, *B. gonionotus*, was introduced to Lake Tempe in 1937 (Dina *et al.,* 2019; Yanuarita *et al.,* 2020). Although an introduced species, silver barb has adapted well to the lake environment. The rich aquatic vegetation of Lake Tempe allows them to thrive. Silver barb are herbivores, with phytoplankton (Chlorophycea) being their primary food source (Ain *et al.,* 2021); their diet also includes aquatic plants (80%), detritus (12%), and phytoplankton (8.5%) (Aida, 2018; Pratiwi *et al.*, 2021). Silver barb fish are considered beneficial in controlling excessive vegetation in lake waters. Despite their successful adaptation to Lake Tempe, the declining environmental conditions of the lake inevitably impact the production of this fish.

The production of silver barb has fluctuated in recent years, likely due to overfishing, environmental conditions, and high natural mortality (Sukarman, 2022). The high natural mortality is suspected to be caused by the presence of *Pterygoplichthys* spp. as an invasive species (Hasnidar *et al.*, 2021). Two fish species that are still being caught in large numbers are the silver barb and bloso (*Glossogobius* sp.). As a result, these two species are under very high fishing pressure. Conservation and domestication efforts will continue, but these efforts require up-to-date information, including the reproductive biology of silver barb, for future management. The research aims to analyze the reproductive biology of silver barb, covering size distribution, sex ratio, length-weight relationship, condition factor, gonad maturity, first gonad maturity size, and fecundity.

Materials and methods

The study was conducted from January to July 2023 in Lake Tempe, Wajo Regency, South Sulawesi Province, Indonesia (Fig. 1). Fish sampling was collected every week for six months, using a gill net response tool. Fish samples caught were cleaned, put in a cooler box, and given ice cubes. Sample observations were carried out at the Biota and Environmental Engineering Laboratory, Faculty of Fisheries and Marine Science, Universitas Muslim Indonesia (UMI) Makassar.

The total length (Lt) of the silver barb was measured using an ichthyometer (Vernier caliper, Mitutoyo) with an accuracy of 0.1 cm. Body and gonad weights (g) were measured using a digital scale (electric digital scale, DIGI DS880) with an accuracy of 0.01 g. The parameters analyzed were:

Length and Weight Structure

The length and weight size structure is determined as follows: determining the number of classes; setting the length class interval at 1 cm and the weight class interval at 1 g. The fish sample was placed into the predetermined class. The size structure is determined within the same class intervals and then plotted on a graph.

Sex Ratio

The sex of silver barb is determined morphologically and anatomically by dissecting the fish to observe whether the gonads have developed into testes or ovaries. The determination of the male-to-female sex ratio is carried out by counting the number of male and female fish caught using the formula (Oliveira *et al.,* 2012):

$$SR = \frac{number\ of\ male\ of\ famale}{total\ number\ of\ fish\ observed} \times 100$$

Next, sex ratio variability was tested using the Chi-square test (Oliveira *et al.,* 2012):

$$X^2 = \frac{\sum(\mathrm{oi} - ei)^2}{\mathrm{ei}}$$

Where, X^2 = Value for a random

variable whose sampling distribution approximates the Chi-square distribution oi=Observed frequencies of male and female fish ei=Expected frequencies of male and female fish.

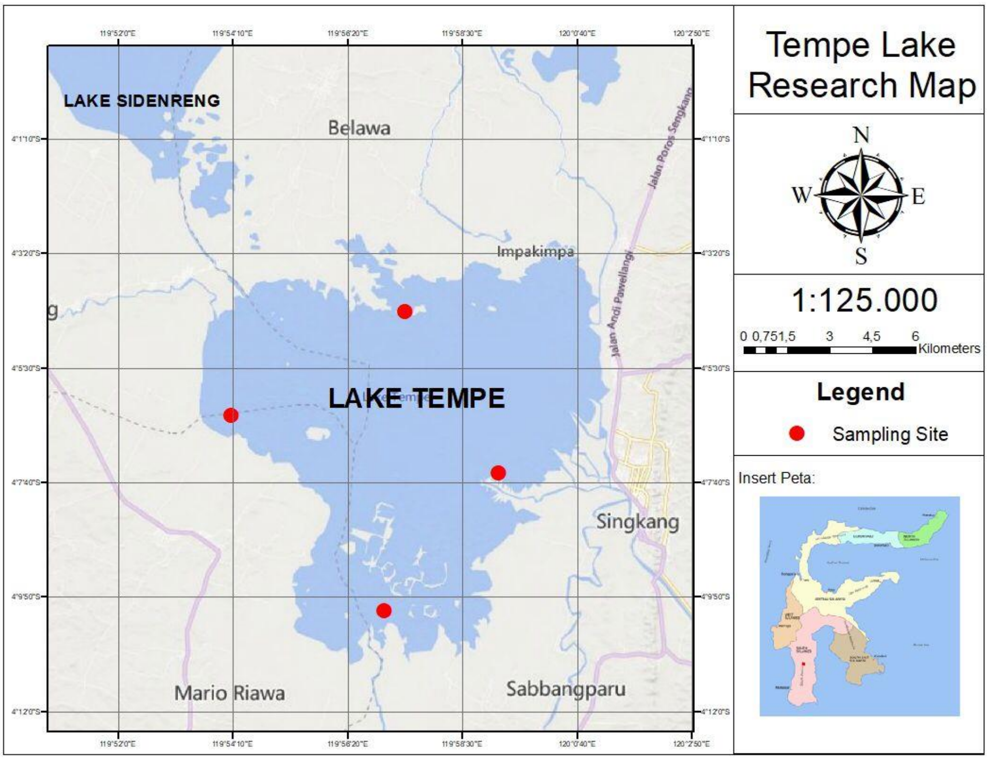


Figure 1: The sampling points for silver barb were located in Tempe Lake, Wajo Regency, South Sulawesi, Indonesia.

Length-weight Relationship

The relationship between length and weight was analyzed using the formula (Le Cren, 1951):

$W = aL^b$

Where, W: Body weight (g), L: Total length (cm), a: Coefficient of determination, b: Exponent that indicates isometric or allometric.

To make the equation, the values of W and L were transformed into logarithms (base 10) as follows:

$W = \log a + b \log L$

The obtained b value is used to estimate the length-weight) parameters, with the following hypotheses: 1) b = 3 indicates isometric growth, 2) b ≠ 3 indicates allometric growth, a) b>3: weight increases more rapidly (positive allometric), b) b<3: length increases more rapidly (negative allometric).

Condition Factor (CF)

Because the growth pattern of silver barb in this study is negative allometric (b ≠ 3), the formulation (Le Cren, 1951) is:

$$CF = \frac{W}{a\,L^{\,b}}$$

Where, CF: Condition factor, W: Fish body weight (g), L: Total length of fish (cm), a: Intercept, b: slope

Size at first gonadal maturity (L50)

The size of the first time the fish matures gonads is obtained by finding the value of L50 by plotting the cumulative percentage of gonadal mature fish with the size of the fish body length, this will yield a standard logistic curve, and the intersection point between the curve and the 50% cumulative frequency represents the length at which 50% of the fish first mature gonadally.

Gonad Maturity Stage

The stages of gonad maturity are observed macroscopically. The observation procedure involves dissecting the fish sample to open the visceral cavity, and then observing the morphology of the gonad, including its shape, color, size, and position within the visceral (abdominal) cavity. The stages of gonad maturity are classified according to Brown-Peterson *et al*. (2011) and modified according to the gonadal condition of silver barb, as follows: Stage I (Immature); II (Developing); III (Maturing); IV (Mature); and V (Spent). For fish samples with gonads at maturity Stage IV, the egg diameter is measured. The gonad is taken from three parts: posterior, middle, and anterior. From each part of the gonad sample, 30 eggs are collected for egg diameter measurement. The egg diameter is measured using an ocular micrometer (0.01 mm) of the UYCP-12 brand.

Fecundity

Fecundity is determined by weighing the total gonad (WG), then taking a sub-part from the posterior, middle, and anterior parts of the gonad and weighing it (Ws). The weight of the sub-part gonad is then preserved in a 4% formalin solution to facilitate counting the number of eggs (n). Fecundity is observed at maturity stage IV and is calculated using the gravimetric method (Hasan *et al*., 2020):

$$F = \frac{Weight\ of\ the\ total\ gonad\ (WG)}{Weight\ sub{-}part\ gonad\ (Ws)} \times \text{number of eggs in sub-part gonad (n)}$$

The relationship between fecundity and total length and body weight using the formulation Hasan *et al*. (2020) is:

$F = a\,L^b \quad and \quad F = a\,W + b$

Where, F: Fecundity (egg), L: Total length (cm), W: Body weight (g), a: Intercept, b: slope

Results

Length and weight structure

The results of the length structure analysis of the male silver barb ranged from 8.9 to 22.9 cm, and females ranged from 8.9 to 28.5 cm, with the largest proportion caught at 14.5 cm for both males and females. The weight structure for males ranged from 21.2 to 183.2 g, and for females, from 21.2 to 312.8 g, with the largest proportion caught at 21.2 g for both males and females (Fig. 2a, b).

Sex Ratio

The total number of Silver barb caught was 1,637, consisting of 824 males (50%) and 813 females (50%). Thus, the sex ratio of male to female fish is 1:1 (Fig. 3a). Furthermore, the number of fish caught in a mature condition (stage IV) was 110, consisting of 27 males (25%) and 83 females (75%). Based on this data, the sex ratio of mature male to female fish is 1:3, indicating that 1 male pairs with 3 females for spawning activities (Fig. 3b).

Length-weight relationship

The results of the length-weight relationship analysis for males are $W = 0.0234\ L^{2.7349}$, for females $W = 0.0172\ L^{2.8766}$, and for the combined group (males and females) $W = 0.0183\ L^{2.8415}$ (Fig. 4 a, b, c). The t-test results show that the b values for male, female, and combined silver barb fish are different from 3 ($b \neq 3$), indicating that the growth pattern is allometric. Since the b value is less than 3 ($b<3$), it indicates negative allometric growth, meaning that length increases faster than weight.

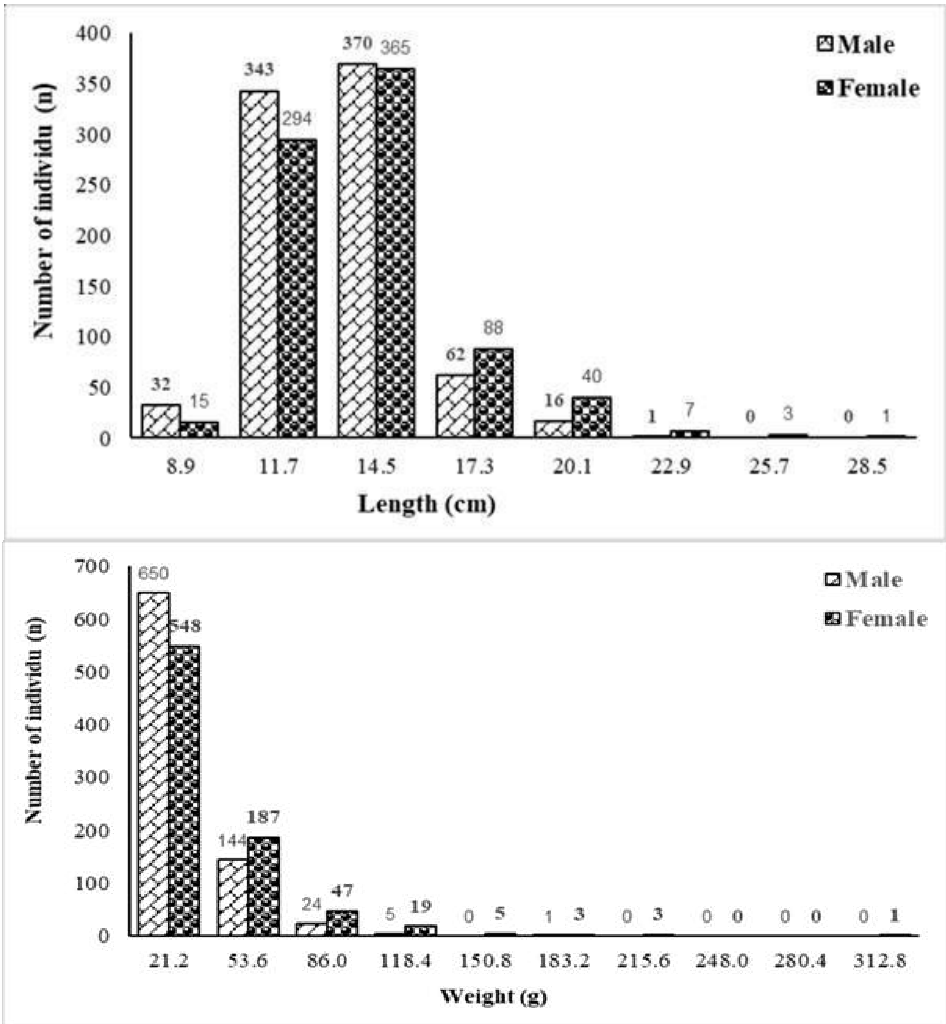


Figure 2: Length (a) and weight (b) structure of silver barb.

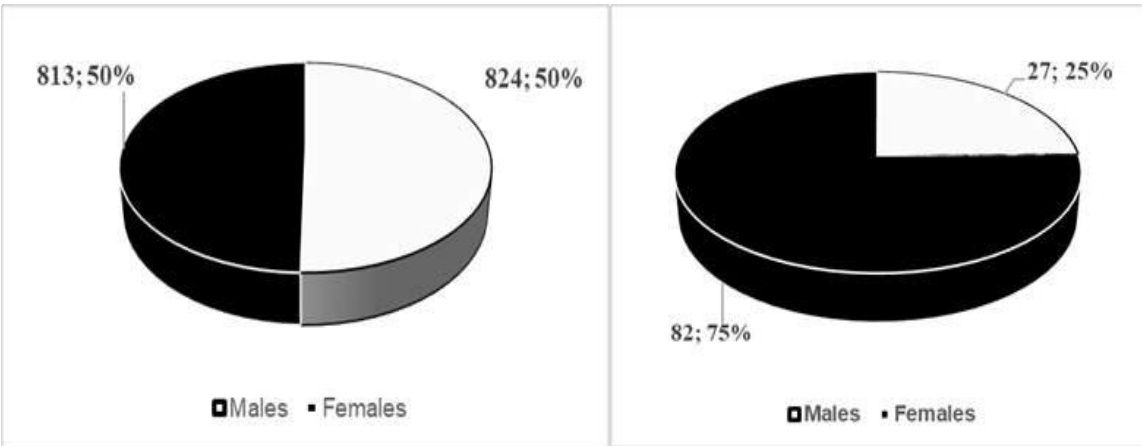
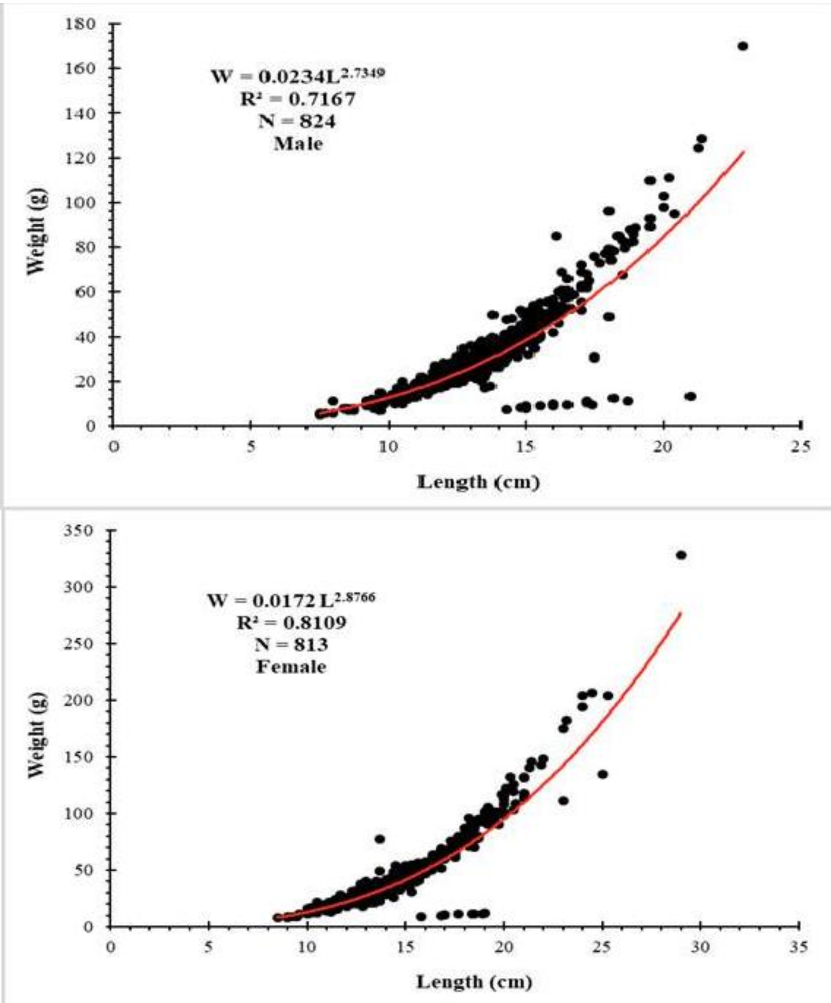


Figure 3: The sex ratio of male to female silver barb (a) and the sex ratio of male to female that have reached gonadal maturity (b).



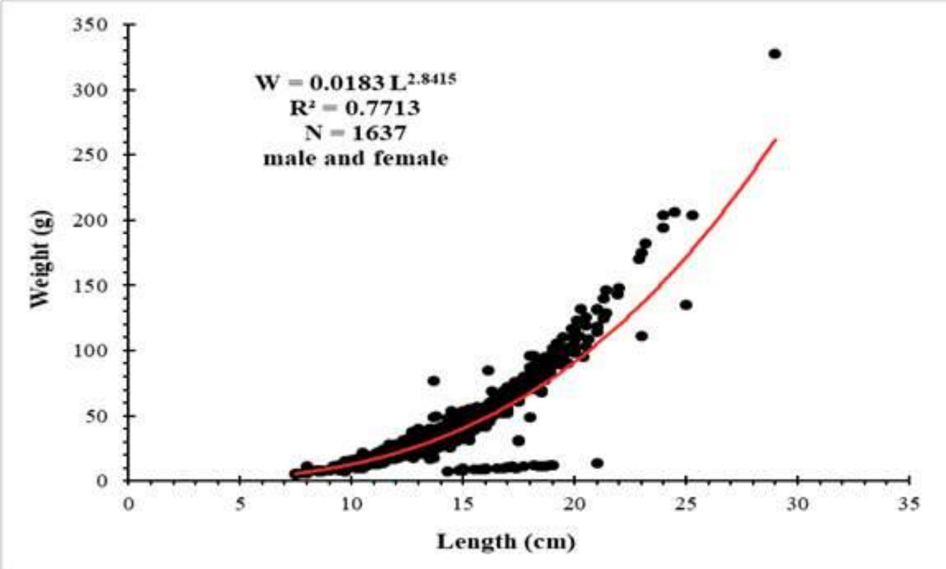


Figure 4: Length-weight relationship of male (a), female (b) and combined (male and female) (c).

Condition Factor (CF)

The condition factor for male and female silver barb is 1.0243±0.0061 and 1.0181±0.0054, respectively.

Size at First Gonad Maturity (L50)

The analysis results for the size at first gonad maturity (L_{50}) show that male fish have an L_{50} of 19.9 cm, while female fish have an L_{50} of 18.3 cm. This data indicates that female mature faster than male fish.

Gonad Maturity Stage

The determination of gonad maturity level criteria was conducted macroscopically by observing the morphology, size, color, and position of the gonads within the abdominal cavity. The development stages of the gonads (ovaries and testes) of the silver barb were classified into five levels according to the guidelines of Hasnidar *et al*. (2022) and the condition of the silver barb gonads. The morphological characteristics of male and female gonads based on their maturity stages can be seen in Table 1.

Fecundity

There are 82 mature female fish (stage IV) with a length range of 7.5 to 17.5 cm and a weight range of 7 to 82 g, with gonad weights ranging from 1.25 to 10.11 g. The fecundity of silver barb obtained in this study ranged from 253 to 13,398 eggs with an average value of 2,571 eggs. The fecundity of silver barb obtained from the results of this study ranged from 253 to 13,398 eggs with an average value of 2,571 eggs. The relationship between fecundity and total length is $F=4.6297\ L^{2.958}$ (R^2=0.3526), fecundity with body weight is a linear relationship that is F=444.66W+1489.3 (R^2=0.5145) (Fig. 5a, b).

Table 1: Gonad maturity stage of female and male silver barb.

Maturity Stage	Note	Female	Male
I	immature	Ovary is very small, extending from the anterior to the posterior in the dorsal part of the abdominal cavity, filled with white fluid, eggs are not visible, estimated to occupy less than 15% of the abdominal cavity	Testis is very small and thin, extending from the anterior to the posterior of the abdominal cavity, containing clear white fluid
II	Developing	Ovary is larger than at maturity stage I, white in color, with visible egg grains, estimated to occupy 20-30% of the abdominal cavity. The average egg diameter is 0.20 – 0.425 mm	Testis enlarges, larger than at maturity stage I, containing white fluid
III	Maturing	Ovary enlarges, containing white egg grains, but the egg grains are still difficult to separate. It is estimated to occupy 30%-60% of the abdominal cavity. The average egg diameter is 0.450 - 0.750 mm	Testis further enlarges from maturity stage II, with grooves visible on the surface. Contains thick white fluid
IV	Mature	Ovary continues to enlarge, occupying about 60-80% of the abdominal cavity. The ovary contains yellowish-green eggs, with an average egg diameter of 0.800 - 1.25 mm	Testis enlarges further from maturity stage III, with grooves visible on the surface. Contains thick milky white fluid
V	Spent	Ovary shrinks, wrinkles, with thick and lobed walls, yellowish-green in color, containing residual eggs that were not spawned	Testis size decreases, edges become wrinkled

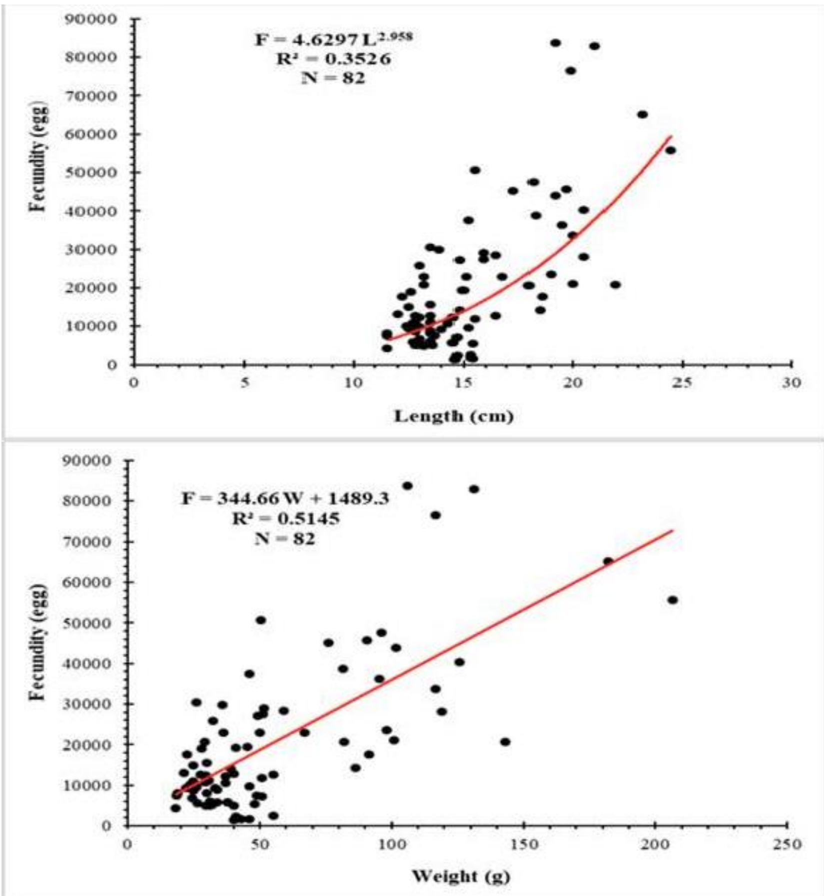


Figure 5: Fecundity-length (a) and fecundity-weight (b) relationships of silver barb.

Discussion

The length structure of male and female silver barb ranged from 8.9 to 28.5 cm, with the most frequently caught size being 14.5 cm. Similarly, the weight structure ranged from 21.2 to 312.8 g, with the largest proportion of catches at 21.2 g. This data indicates that the length and weight structure of the silver barb caught is predominantly small in size.

The length and weight structure of the silver barb from these waters shows lower values compared to those caught in Tchang Reservoir, Thailand, which measure 45 cm in length and 2,100 g in weight (Chheng *et al.*, 2005). This data suggests that fishing for silver barb, particularly in Lake Tempe, is very intensive, even excessively exploited (Sukarman, 2022). The silver barb does not have the opportunity to grow large due to intensive fishing. Additionally, suboptimal environmental conditions in the lake, the presence of predators or competitors, and the limited ability of swimming larvae to escape environmental factors are suspected to affect their survival and growth. According to Arevalo *et al*. (2023), 99% of the mortality in many fish species occurs during the early life stages. The high mortality rate is believed to influence the size variation of the silver barb population.

The overall sex ratio of male and female silver barb fish is 1:1, indicating a balanced number of male and female fish. This sex ratio is consistent with that reported by Maknuu (2016) for the silver barb from the Brantas River, Jombang Regency, West Java, Indonesia, which also has a ratio of 1:1. Similarly, silver barb from the Padma River in Bangladesh has a ratio of 1:1.27 (Jasmine and Begum, 2016); from the rivers in Ogan Komering Ilir Regency, South Sumatra, Indonesia, a ratio of 1:2 (Ardelia *et al.*, 2023); and from the Nagan River, Aceh Province, Indonesia, a ratio of 4:1 (Efizon *et al.*, 2021). The sex ratio can vary among the same species because sex determination is influenced not only by genetic factors but also by environmental factors (Capel, 2017). A 1:1 sex ratio is considered ideal because it ensures that both male and female fish have an equal opportunity to sustain their species. Although silver barb fish experience high exploitation pressure, the sex ratio data indicate that the species still has a strong ability to maintain its population.

Furthermore, the sex ratio of mature gonad males to females is 1:3, meaning that in spawning activities, 1 male and 3 females are needed (polygamy). The sex ratio in spawning is related to the interaction and synchronization between male and female fish (Mylonas *et al.*, 2010), as well as the efficiency of using the number of males or females in spawning. Each fish species has an optimal sex ratio for spawning, for example, climbing perch, *Anabas testudineus*, it is 1:2 (Hasnidar *et al.*, 2022); sailfin molly, *Poecilia latipinna*, it is 1:10 (Tamsil and Hasnidar, 2019); and silver barb, *Barbonymus* sp., it is 6:1 (Efizon *et al.*, 2021).

The length-weight relationship model for silver barb resulted in $W=0.0234\ L^{2.7349}$ for males, $W=0.0172\ L^{2.8766}$ for females, and $W=0.0183\ L^{2.8415}$ for the combined (males and females). The t-test results showed that the b values for male, female, and combined silver barb were different from 3 ($b\neq3$), indicating that the growth pattern is allometric. Since the b value is less than 3 (b<3), it is classified as negative allometric growth. Several studies on the length-weight relationship of silver barb fish in various water bodies have reported similar findings. For instance, in the Jatiluhur Reservoir, Indonesia, the relationship was W=0.0413 $L^{2.231}$ for males and females (Hardjamulia, *et al.*, 1988; Chheng *et al.*, 2005). Similarly, in the Brantas River, Kesamben Subdistrict, Jombang Regency, East Java, Indonesia, the relationship was W=0.024 $L^{2.770}$ for males and W=0.021 $L^{2.850}$ for females (Maknuu, 2016). In Gajah Mungkur Reservoir, Central Java Province, Indonesia, the relationship was W=0.020 $L^{2.880}$ for males and W=0.001 $L^{3.140}$ for females (Aida, 2018). In the Bengawan Solo River, Lamongan Regency, Indonesia, the relationship was W=0.037 $L^{2.641}$ for males and W=0.029 $L^{2.782}$ for females (Buwono *et al.*, 2019). In Cipanas Reservoir, West Java Province, Indonesia, the relationship was W=0.006 $L^{3.169}$ (Syaiful *et al.*, 2019). The differences in the growth patterns of silver barb are caused by variations in water conditions. An important factor influencing fish growth in tropical regions is the availability of food (Froese, 2006). Therefore, the same species of fish in different locations will exhibit different growth patterns due to this factor. In addition to food, other factors include the stage of gonad development, the physicochemical properties of the water, fish health conditions, seasons, sampling time, and techniques (Sheridan, 2011; Mehanna and Farouk, 2021). In this study, 1,637 fish were caught, of which only 110 fish, or 6.7%, were in the mature gonad (stage IV), which is suspected to be the cause of the negative allometric growth pattern.

The condition factor is a value that reflects the influence of environmental factors on the physiological condition of fish (Faradonbeh *et al.*, 2015). A favorable environment, including the availability of food, supports good growth, resulting in higher fish weight and a CF≥1. Conversely, an unsuitable environment and limited food availability lead to smaller weight gain and a CF<1 (Dirican and Cilek, 2012). The CF values in this study ranged from 1.024 to 1.018. These values indicate that the fish are in a lean condition, consistent with their negative allometric growth pattern, where length increases faster than weight. Condition factors for silver barb from several previous studies ranged from 0.84 to 1.4 (Buwono *et al.*, 2019), 1.05 to 3.17 (Sidik *et al.*, 2020), 1.01 to 1.02 (Dwirastina and Marson, 2021), 0.82 to 1.10 (Syaiful *et al.*, 2019), 0.76 to 2.27 (Laila, 2018), and 1.145 to 1.328 (Maknuu, 2016). The variation in CF is caused by differences in the aquatic environment, density, food availability, and physiological conditions such as the fish's reproductive cycle. A higher CF value indicates a better adaptation of the fish to its environment.

The macroscopic analysis of gonad maturity stages showed that at each level of gonad maturity, there were differences in the size, color, and volume of the gonads in the abdominal cavity. In the ovaries, the higher the maturity stage, the larger the oocyte diameter tends to be however, there is variation in oocyte diameter at the same maturity stage. Similarly, histological observations revealed differences in oocyte diameter (Efizon *et al.*, 2021). This data indicates that silver barb exhibit batch spawning, meaning they do not release all their eggs at once during spawning. Batch spawning results in a prolonged spawning season. The spawning season of silver barb in Lake Tempe is estimated to last throughout the year, as adult fish (stage IV) were found during each monthly observation from January to June, with a peak in January. In contrast, the spawning season for silver barb in the Padma River, Bangladesh, occurs from April to July, with a peak in June (Jasmine and Begum, 2016).

The size at first gonad maturity (L50) is the size at which 50% of individuals in a group have reproduced at least once (Barzotto and Mateus, 2017). The L50 for males is 19.9 cm, and for females, it is 18.3 cm. The L50 values found in this study are larger than those of silver barb from the Nagan River, Aceh Province, Indonesia, where the L50 for males is 7.3 cm, and for females, it is 8.5 cm (Efizon *et al.*, 2021). The size at first gonad maturity can vary due to competition and predation, fishing pressure, and environmental conditions (de Souza *et al.*, 2019). Fish will undergo first maturity in a shorter time frame to reduce the risk of death before reproduction if environmental conditions are unfavorable (Barzotto and Mateus, 2017). Based on the L50 values for males and females in relation to the dominant length of silver barb caught in this study, approximately 90% of the captured fish were not yet mature.

The silver barb identified at maturity stage IV in this study totaled 82 individuals, with a length range of 12.2 to 21.28 cm (average±15.0 cm) and a body weight range of 21.0 to 124.4 g (average±41 g), producing fecundity ranging from 1,443 to 83,822 eggs (average=20,239 eggs). Fecundity data for silver barb in various water bodies are presented in Table 2.

Table 2: Fecundity of Silver Barb in Various Water Bodies.

Water Body	Fecundity	Reference
Lake Tempe	1,443 – 83,822 eggs (average = 20,239 eggs)	This study
Nagan River, Aceh Province, Indonesia	656 – 5,725 eggs (average 2,663 eggs)	Efizon *et al.*, 2021
Upper Serayu River, Central Java, Indonesia	2,760 - 50,085 eggs (average 17,347 eggs)	Haryono *et al.*, 2015
Padma River, Bangladesh	13,192 – 98,325 eggs (average 58,660 eggs)	Jasmine and Begum, 2016
Bangladesh	18,001 – 42,034 eggs (average 24,959 eggs)	Bhuiyan *et al.*, 2000

The coefficient of determination (R^2) for the relationship between fecundity and length (F-L) is R^2=35.3%, and for fecundity and weight (F-W) it is R^2=51.5%. This result indicates that 35.3% of the variation in fecundity is due to variation in the total length of the fish, and 51.5% of the variation in fecundity is due to variations in body weight. A similar observation was made for silver barb from the Nagan River, Aceh Province, Indonesia, where the coefficients of determination (R^2) for F-L and F-W were 51% and 24.2%, respectively (Efizon *et al.*, 2021). This means that the fecundity of silver barb increases with the increase in total length and body weight. Larger fish not only have a bigger visceral cavity to hold a greater number of oocytes, but also have sufficient energy for reproductive activities (Jonsson and Jonsson, 1999). Factors influencing fish fecundity include internal factors such as genetics, age, and size (Hunter *et al.*, 1992), while external factors include food availability and environmental conditions (Bryan *et al.*, 2007).

Conclusions

The length and weight structure of female fish are higher than that of male fish. The dominant length and weight of the catch are 14.5 cm and 21.2 g. The growth pattern is negatively allometric, and the condition factor is 1.02. The overall male-to-female ratio is 1:1, while the sex ratio during spawning is 1:3; meaning one male fish pairs with three female fish during spawning. The size at first gonad maturity is faster for females, at 18.3 cm, compared to males at 19.9 cm. Fecundity ranges from 253 to 13,398 eggs (average 2,571 eggs). The variation in fecundity is more influenced by body weight variation than by the total length variation of the silver barb.

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Conflicts of interest

We declare that this research was conducted without any conflict of interest with any party.

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