# Reproductive biology of *Cyclocheilichthys armatus* in Diatas Lake, Solok, West Sumatra, Indonesia

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**Abstract**. The study was conducted from November 2018 to October 2019 in Diatas Lake, Solok, West Sumatra, Indonesia. This study aimed to determine some aspects of the reproductive biology of *Cyclocheilichthys armatus,* based on the observation of 882 male and 844 female specimens. The results showed that the sex ratio of *C. armatus* was well balanced (1.05:1). This species is a total spawner and it spawned twice a year at the end of the rainy season. The peak of spawn occurred in December 2018 and June 2019. The total lengths of gonads at first maturity in *C. armatus* were 165.5±0.003 mm (males) and 128.7±0.004 mm (females). The absolute fecundity varied between the gonadal maturity stages (GMS), ranging from 11,601 to 15,773 eggs individual$^{-1}$ (GMS III) and from 10,801 to 12,293 eggs individual$^{-1}$ (GMS IV) and the relative fecundity ranged from 133-154 eggs g$^{-1}$ bodyweight (GMS III) and 75-91 eggs g$^{-1}$ bodyweight (GMS IV). The *C. armatus* fecundity had a positive correlation with the total length of fish, bodyweight and gonadal weight.

**Key Words**: sex ratio, gonad maturity stage, gonadosomatic index, fecundity, spawning season.

**Introduction**. *Cyclocheilichthys armatus* is considered a highly commercial fish. There are six species of *Cyclocheilichthys* spp. found in Indonesia, including *C. apogon*, *C. armatus*, *C. enoplos*, *C. heteronema*, *C. janthochir*, *C. dzwani*, and *C. repasson*, native to Sumatra, Java, and Borneo (Kottelat et al 1993), and two of them, *C. apogon* and *C. armatus*, are found in the Diatas Lake (Roesma 2011). *C. armatus* belongs to the order Cypriniformes, the Cyprinidae family (Weber 1916; Kottelat et al 1993), locally known as Catua, Minyak, and Hihgfin barb. *C. armatus* is one of the two species of Cyclocheilichthys which is dominantly found in the Diatas Lake, Solok.

The population of *C. armatus* in the Diatas Lake is in decline in the last five years (based on interviews with fishermen and community leaders), due to the high fishing frequency and the pressure of changes in the lake's environment. Diatas Lake is used by the community for daily needs, such as fishing, bathing, washing, and the surroundings are used by the community as crops, accumulating residual washing of agricultural wastes, such as fertilizers, pesticides, and chalk into the waters of the lake. The water quality decreases and further threatens the fish population, fish having a sensitive and vulnerable organism to environmental changes (Alonso et al 2011). Environmental changes such as physical, chemical, and biological factors in aquatic communities greatly affect members of the aquatic community (Kigbu et al 2014; Zakaria et al 2016; Zeswita et al 2016). One of the physiological activities of fish that will be disturbed is the reproductive pattern (Grossman et al 1998; Humpl & Pivnicka 2006; Munir et al 2016).

Sustainable fisheries resource management and domestication efforts in inland water, especially in the Diatas Lake, need to be done to prevent a decline in the *C. armatus* population. The basic information needed for management and domestication efforts is the study of aspects of fish reproduction biology related to changes in habitat conditions. Biological information about *C. armatus* is still lacking and limited to distribution and taxonomic information (Weber 1916; Kottelat et al 1993; Pasco-Viel et al 2012; Kottelat 2013a,b; Sukmono & Margaretha 2017; Akhirianti & Gustomi 2018) and cytogenetic (Chaiyasan et al 2018). There is no information regarding the reproductive aspects of *C. armatus*.

Studies of reproductive biology are a basic requirement for planning fisheries management efforts and conservation strategies (Ali & Kadir 1996; Muchlisin et al 2010; Muchlisin 2014). Moreover, it is also important information for the development of aquacultural cultivation and in the selection of potential target fish from natural populations that will diversify in the aquaculture industry (Muchlisin 2014). One of the important reproductive aspects in fisheries management and in the evaluation of the commercial potential of fisheries culture is fecundity (Lagler et al 1956; Zin et al 2011).

Fecundity values determine the reproductive potential of fish species in aquaculture and fish population management (Zin et al 2011) and can predict species differences between different populations (Bagenal 1978). The joint fecundity of the gonadosomatic index (GSI) and the hepatosomatic index (HSI) were used to determine the status and reproductive season of fish (Arruda et al 1993). GSI values were also used to determine the season and frequency of egg-laying (Islam et al 2008; Ghaffari et al 2011; Sadekarpawar & Parikh 2013; Jan et al 2014). Size of gonads at first maturity is a variable of the reproductive strategy in fish, apart from sex ratio, spawning period and type, oocyte development, and fecundity (Gomiero et al 2008), and it is important in realizing stock management, because it can correctly identify the minimum catch size and the size of the nets used for fishing (Hilborn & Walter 1992).

The size at early maturity of male fish gonads can be used as criteria for controlling and managing fishing time and activities so that juvenile fish are protected and can reach sexual maturity (Suzuki et al 2004; Fauzi et al 2016) and to determine the size of the mesh used for fishing (Omar et al 2011). Understanding the spawning period is also an important factor in fisheries management efforts (Claramunt et al 2014). This study aimed to determine the reproductive biology of *C. armatus*, including sex ratio, gonad maturity stage, gonadosomatic index, fecundity, egg diameter, spawning season, size of gonad at first maturity, biotic and abiotic factors of water, and the relationship between fecundity at GMS IV and GSI with total length, body weight, gonad weight, abiotic and biotic factors. This research provides basic information in the management and domestication of *C. armatus* in the Diatas Lake.

## Material and Method

***Description of the study sites***. Diatas Lake is a tectonic lake located in Alahan Panjang, Solok, West Sumatra, Indonesia. Diatas Lake has an area of 12.3 $m^2$, a depth of 44 m, and is located at an altitude of 1,531 m above the sea level (Nakano et al 1987). The research was conducted in lake waters at six observation stations (Figure 1). Six stations were placed at six locations around the lake, i.e. Dermaga (St. 1: 1° 03'24.43"S; 100°46'21.46"E), Taluak Dalam (St. 2: 1°03'47.76"S; 100°45'23.11"E), Muara (St. 3: 1°04'38.19"S; 100°46'31.24"E), Batanghari (S.t 4: 1°05'25.19"S; 100° 46'25.48"E), Middle Lake (St. 5: 1°05'00.95"S; 100°45'48.52"E), and Taluak Kinari (St. 6 : 1°04'50.81" S; 100°44'38.10"E).

***Sampling method***. The specimens of *C. armatus were* collected twice a month, in the dark and the bright moon from November 2018 until October 2019. Specimens were taken by fishermen using gillnets with mesh sizes ranging from 1.25 to 2.5 cm. The specimen was preserved with 5% formaldehyde and stored in a cool box for identification and measurement in the laboratory. The total number of samples was 1,726, consisting of 882 males and 844 females.

Physical and chemical variables measured included temperature, brightness (Secchi disc), pH (pH meter), DO and $CO_2$ dissolved (titration), hardness, phosphate, nitrate, and ammonia (following the water analysis procedure of the Health Laboratory, West Sumatra). The data regarding temperature, pH, DO and CO2 were taken every month in situ and data concerning hardness, phosphate, nitrate, and ammonia were taken four times, namely twice in the rainy season (November 2018 and May 2019) and twice in the dry season (February 2019 and August 2019), measurements being performed at the Health Laboratory, West Sumatra.

Figure 1. Map of the study area, and observation stations.

***Reproductive studies***. The study was carried out in the laboratory. For each specimen the total length (L) was measured with a digital caliper to the nearest 0.01 (for sizes ≤150 mm) and ruler to nearest 0.1 cm (for sizes >150 mm), body weight (W) was weighed with a digital balance to an accuracy of 0.01 g and gonad weight ($W_g$) with an electric digital balance to an accuracy of 0.001 g. Total length, body weight, and gonadal weight were recorded to calculate the gonadosomatic index ($GSI=100\ W_g/W$) (Effendie 2002; Afonso-Dias et al 2005) and then the GSI provided information about the spawning period. The gonad maturity stage (GMS) was determined morphologically, including color, shape, and size of gonads according to Effendie 1979. Determination of sex was based on the study of primary and secondary sexual characteristics of male and female fish from the Cyprinidae family (Lagler et al 1956; Effendie 2002; Haryono 2006). The sex ratio (SR) was determined by comparing the number of individual males to females during the observation period (November 2018-October 2019) at each station.

Oocyte diameter was measured in 30 oocytes from the anterior, middle, and posterior gonads in the subsample for each ovary. All oocyte samples were measured under a stereomicroscope using an optilab to the accuracy of 1 μm. The rhythm of oocytes experiencing ovulation describes the types of spawning patterns, namely synchronous ovulatory (total spawners) or asynchronous ovulatory (batch spawners) (Tyler & Sumpter 1996). Species with total spawners release their eggs in a single episode in each breeding season, whereas in batch spawners, eggs are released in groups over a period that can last days or months (Murua & Saborido-Rey 2003). The spawning period is estimated from GSI values and variations in the diameter of sample eggs every month (Lagler 1956). The spawning period was determined in the month with the highest GSI value (Zhang et al 2009; Olele 2010).

Fecundity was calculated by the combined method of direct counting and gravimetric methods (Effendie 2002; Al Mukhtar et al 2006). Fecundity was calculated on eggs at GMS III and IV (220 individuals). The fish were dissected to obtain the gonads, then the gonads were weighed using a digital scale which was then expressed as the weight of the whole gonad. The whole gonad was cut into 3 parts, namely anterior, middle, and posterior, 0.5 g of gonad samples were taken in each part and the sub-sample was immersed in Gilson's solution to harden the egg and release the egg from the ovarian tissue. Eggs were counted directly manually using a counter in each sample and then the average was taken from all parts. Absolute fecundity (Fa) was calculated using the formula: Fa=(gonad weight X number of eggs in the sub-sample)/sub-sample weight (Yeldan & Avsar 2000; Effendie 2002). The relative fecundity (Fr) was expressed by dividing the absolute fecundity (Fa) with the body weight, and the result was the number of eggs $g^{-1}$ of body weight.

***Data analysis***. The sex ratio was expressed as the number of males/number of both sexes combined. A Chi-square test ($X^2$) at a level of significance of 0.05 was used to verify whether the proportion of males and females differed from the expected ratio 1:1 (Walpole 1992), using Microsoft SPSS version 26. Fecundity relationships with L, W, and $W_g$ were determined by linear regressions analysis (Hossain et al 2012), using Microsoft SPSS version 26. The spawning type was determined by analyzing the frequency distribution of the oocyte diameter of the gonads at the GMS IV. The grouping of the oocyte diameter of the left and right ovaries was carried out based on normal distribution through the Bhattacharya method, using Microsoft SPSS version 26.

The size of the gonad at first maturity was calculated based on the Spearman-Karber method using the cumulative percentage frequency curve of adult fish in the sample. 50% of sample fish had ripe gonads (Udupa 1986). The size of the gonads at first maturity (mm) is calculated using the formula (Udupa 1986):

$$m = Xk + \frac{X}{2} - \left(X \sum Pi\right)$$

Where:
*Xk*-log size where 100% of fish are fully mature;
*X*-difference in mean log size from the median logarithmic;
*Pi*-proportion of fully adult fish in the group size-i.
The minimum and maximum size of gonads at the first maturity (significance level ɑ=0.05, confidence level = 95%) were calculated using the formula (Udupa 1986):

$$antilog\ [m \pm 1{,}96 \sqrt{X^2 \times \sum \left\{\frac{p_i\ x\ q_i}{n_i - 1}\right\}}]$$

Where:
m-the mean size at first maturity;
Xk-last log size at which 100% of fish are fully mature;
$p_i$ -proportion of fully mature fish in the group size-I;
$q_i$ 1 - $p_i$;
$n_i$-the number of fish in class-i.

**Results and Discussion**. The overall number of male and female fish was almost the same with a ratio of 1.05:1. This ratio was found to vary with the GMS and month (Figure 2; Table 1 and Table 2). Based on the Chi-Square Test, for the total sex ratio *C. armatus* was 1.05:1 male to females, which was non-significant with the expected 1:1 (p>0.05), indicating that the sex ratio is 1:1 and is in a balanced condition. Ball & Rao (1984) stated that to maintain the survival rate in a population, the ratio of male and female fish is expected to be in a balanced condition.

The same has been observed in other freshwater fish: *C. apogon* in Cambodia (Rainboth 1999), in the Musi river (Hedianto et al 2010), and in the Menduk River, Bangka (Suhendra et al 2017); *Thynnichthys thynoides* in the Chenderoh River, Malaysia (Ali & Kadir 1996), and in the Kampar Kiri River, Riau (Tampubolon et al 2008); *Puntioplites bulu* in the Siak River, Riau (Pulungan 2013); *Labiobarbus ocellatus* in the Tulang Bawang River, Lampung (Yudha et al 2016), and *Lagusia micracanthus*in Towuti Lake, South Sulawesi (Omar et al 2015).

The number of males caught each month was generally more than females. This was also observed in the case of *C. apogon* in the Menduk river, Bangka (Suhendra et al 2017), *Telmatherina celebensis* in Towuti lake (Nasution et al 2007), *Thynnichthys polylepis* in the Kampar Kiri river (Bakhris et al 2007), *Thynnichthys thynoides* in the Chinderoh reservoir, Malaysia (Ali & Kadir 1996), and in the Kampar Kiri river (Tampubolon et al 2008), *Rasbora aprotaenia* in several rivers in Mt. Halimun (Dewantoro & Rachmatika 2004), *Capoeta umbla* in Karasu, Turkey (Turkmen et al 2002), *Cyprinion macrostomum* in the Tigris drainage (Langroudi & Sabet 2018).

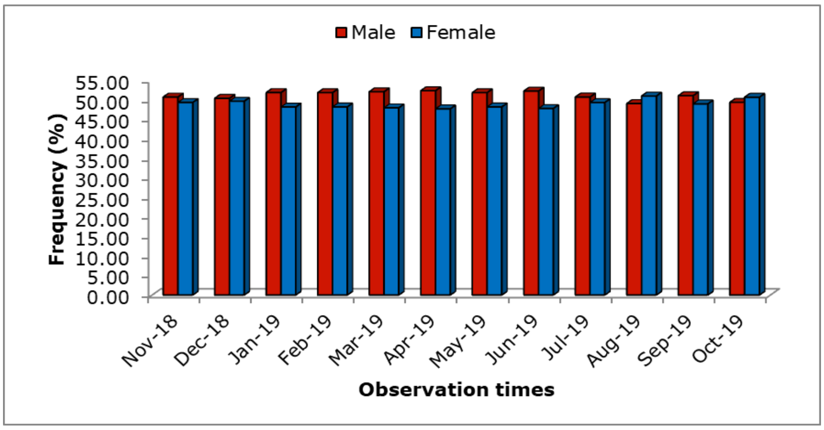


Figure 2. The frequency distribution of the sampled males and females of *Cyclocheilichthys armatus*.

Fish sex ratios can change before, during, and after the spawning period. The sex ratio can change due to many factors and the change in ratio from 1:1 is caused by changes in temperature, predation of females by predators, natural risks, also, the migration phase of the female parent population is different from that of males (Nikolsky 1980).

Table 1

Sex ratio of *Cyclocheilichthys armatus* based on the sampling time

| *Months* | *Number of fish examined* | | *Sex ratio* | *p-value** |
|---|---|---|---|---|
| | *Male* | *Female* | | |
| November 2018 | 73 | 71 | 1.042:1 | 0.028 |
| December 2018 | 66 | 65 | 1.015:1 | 0.008 |
| January 2019 | 56 | 52 | 1.077:1 | 0.148 |
| February 2019 | 71 | 66 | 1.076:1 | 0.182 |
| March 2019 | 76 | 70 | 1.086:1 | 0.247 |
| April 2019 | 90 | 82 | 1.098:1 | 0.372 |
| May 2019 | 71 | 66 | 1.076:1 | 0.182 |
| June 2019 | 82 | 75 | 1.093:1 | 0.312 |
| July 2019 | 72 | 70 | 1.029:1 | 0.324 |
| August 2019 | 77 | 77 | 0.963:1 | 0.057 |
| September 2019 | 73 | 70 | 1.043:1 | 0.063 |
| October 2019 | 75 | 77 | 0.974:1 | 0.026 |
| Total | 882 | 844 | 1.050:1 | 0.360 |

p-value* < 3.841 p-value$_{(0.05;1)}$

Table 2

Sex ratio of *Cyclocheilichthys armatus* sample based on GMS

| *GMS* | *Male fish* | *Female fish* | *Ratio* | *p-value* * |
|---|---|---|---|---|
| I | 248 | 263 | | |
| II | 373 | 354 | 1.05:1 | 0.497 |
| III | 215 | 185 | 1.16:1 | 2.250 |
| IV | 39 | 37 | 1.05:1 | 0.053 |
| V | 7 | 7 | 1:1 | 0 |

p value* < 3.841 p $value_{(0.05;1)}$

The development stage of *C. armatus* gonads consists of 5 stages (GMS I-V) (Figure 3).

| *Female* | | *Male* | |
|---|---|---|---|
| GMS I | | | |
|  | Ovaries shape like a thread up to the body cavity, clear color, and slippery surface. |  | Testes shaped like a thread, shorter and visible ends in the body cavity, and looks clear. |
| GSM II | | | |
|  | Ovary appears larger, the color reddish and transparent, with lots of blood capillaries, eggs are still not visible to naked eyes. |  | Testes appear larger, milky white color, and still transparent, the shape is clearer than at stage I. |
| GMS III | | | |
|  | Gonad mass fills ½ of the body cavity, yellowish red and eggs are visible to naked eyes. |  | The testes's surface looks jagged, the color wshiten and the size appears larger. |
| GMS IV | | | |
|  | The ovary is getting bigger, eggs are yellow, easily separated, filling ½-¾ of the body cavity and the intestines pushed away. |  | Testes appear similar to stage III, white, clearer, and solidified. |
| GMS V | | | |
|  | Ovary crumpled, wall thickened. There are remaining egg drops present near the genital pore, and many eggs like stage II. |  | The backside of the testes flattens and the side near the genital pore is still filled. |

Figure 3. Description of the gonad morphology of *Cyclocheilichthys armatus* male and female.

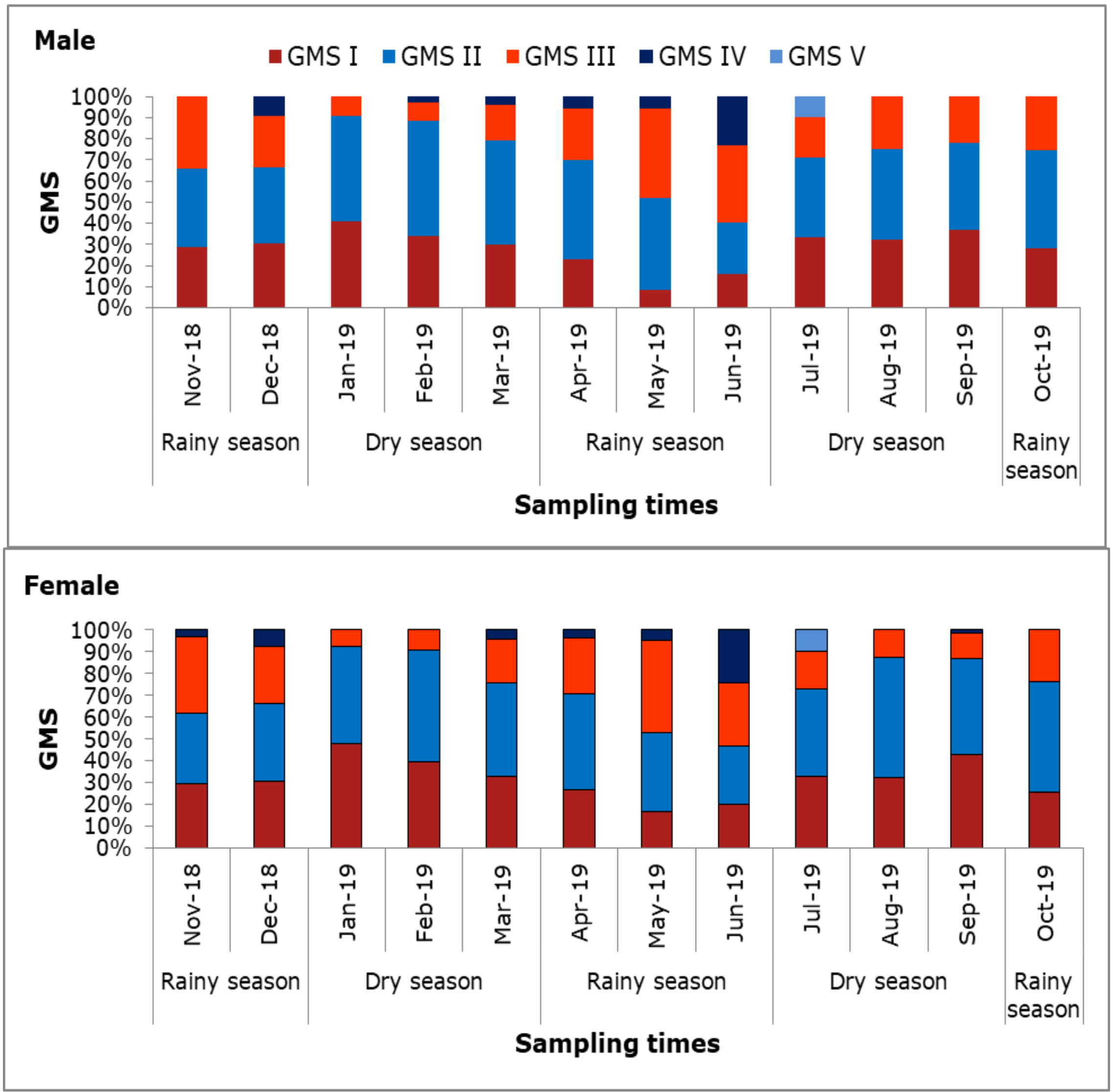

Figure 4. Monthly changes in the frequency of GMS of *Cyclocheilichthys armatus* sample.

Changes in the frequency distribution of GMS in male and female fish showed the same pattern (Figure 4). The development of male and female gonads is determined as follows: the development stage takes place from January to May, spawning (June), and spent (July), and then the development starts again from August to November and the re-spawning period is in December. The dominance of frequency distribution of GMS III and IV was found twice a year, namely, in June and December, this indicated that *C. armatus* had two spawning periods in one year, in June and December with the spawning peak in June, with the highest frequency of GMS IV. The first GMS IV of males was found in February and of females in March. The mean percentage of GMS III and IV during the gonad development period from March to May was higher in the case of males (39.68%) than that of females (38.52%) (Figure 4). It is suspected that male gonads develop and reach maturity earlier than females. This was also observed at *C. apogon* in the Menduk River (Suhendra et al 2017), *T. polylepis* in the Kampar Kiri River (Bakhris et al 2007).

Rainfall in the two districts of the Diatas Lake ranged between 62.5-168 mm month$^{-1}$ (January-March), 134-268 mm month$^{-1}$ (April-June), 28-134.9 mm month$^{-1}$ (July-September), and 140-563 mm month$^{-1}$ (October-December) (Central Statistics Agency 2020). Based on rainfall data and referring to the potential evapotranspiration (PET) value from the Penmar Nonteth method (Giarno et al 2012), rainfall >150 mm month$^{-1}$ is defined as the rainy season and <150 mm month$^{-1}$ as the dry season. Diatas Lake is classified an area with two dry and rainy seasons in one year. Based on the month when the maximum GMS IV and GSI are achieved, the spawning period of *C. armatus* occurs at the end of the rainy season, from June to December. Fish spawning in tropical areas takes place in the rainy season from September to December (Makmur & Prasetyo 2006; Tampubolon et al 2008). The same pattern was noticed at *C. apogon*, *C. armatus*, *and C. enoplos* in Cambodia (Rainboth 1999).

Monthly changes of GSI at GMS III and IV are presented in Table 3. The maximum average GSI for both, male and female fish, was achieved in June and December (Figure 5), indicating that the spawning period of *C. armatus* occurs twice a year, namely in June and December. The average GSI of GMS III and IV ranged between 4.281-6.291% (male) and 4.669-6.630% (female) (Table 3 and Table 4). The average GSI at *C. armatus* is less than 20%, so it is classified as a fish that spawns more than once a year (Bagenal 1978). The variation in the maturity stage of the gonads is influenced by temperature and food (Burhanuddin 2010). The optimal temperature for fish and other aquatic organisms is in the range of 25-30°C. In general, female GSI is higher than male, this indicates that the weight of male gonads is smaller than that of females. Female gonad weight ranges between 10-20% of the body mass and males 10-15% (Effendie 2002) or 5-10% (Affandi & Tang 2002).

Table 3

Average GSI at GMS III and IV

| *Month* | *Average GSI (%)±SD* | | | |
|---|---|---|---|---|
| | *GMS III* | | *GMS IV* | |
| | *Male* | *Female* | *Male* | *Female* |
| November 2018 | 4.281±0.17 | 4.971±0.28 | | 6.630±0.04 |
| December 2018 | 4.907±0.12 | 4.968±0.45 | 5.915±0.11 | 6.542±0.56 |
| January 2019 | 4.569±0.24 | 4.771±0.47 | | |
| February 2019 | 4.416±0.16 | 5.200±0.18 | 5.660±0.00 | |
| March 2019 | 4.322±0.18 | 5.110±0.02 | 5.660±0.02 | 6.067±0.55 |
| April 2019 | 4.345±0.17 | 5.077±0.23 | 5.602±0.15 | 6.074±0.65 |
| May 201 | 4.361±0.21 | 4.669±0.54 | 5.525±0.08 | 6.351±0.15 |
| June 2019 | 5.155±0.22 | 5.034±0.45 | 6.291±0.14 | 6.433±0.70 |
| July 2019 | 4.339±0.15 | 5.049±0.14 | | |
| August 2019 | 4.338±0.18 | 4.813±0.23 | | |
| September 2019 | 4.365±0.16 | 4.824±0.34 | | 5.700±0.0 |
| October 2019 | 4.331±0.15 | 5.044±0.28 | | 6.630±0.04 |

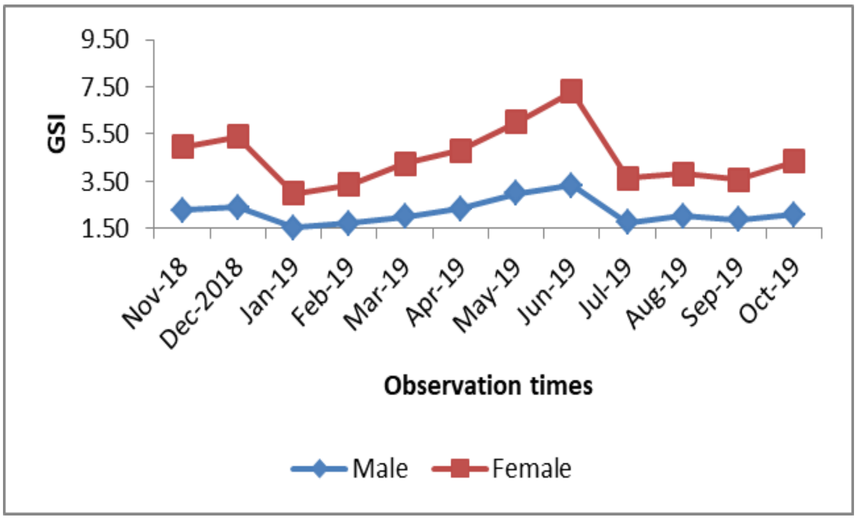


Figure 5. Monthly change of GSI average *Cyclocheilichthys armatus* from November until October 2019.

Table 4

Monthly change of GSI at *Cyclocheilichthys armatus* based on GMS and gender

| *Gender* | *GMS* | *N* | *Body weight (g)* | *Gonad weight (g)* | *GSI (%)* | *Average ±SD* |
|---|---|---|---|---|---|---|
| Male | I | 248 | 24.47–58.04 | 0.124–0.333 | 0.507–0.602 | 0.547±0.02 |
| | II | 373 | 36.25-80.37 | 0.624–1.532 | 1.701–1.941 | 1.791±0.04 |
| | III | 215 | 58.97–109.62 | 2.182–5.213 | 3.946–5.666 | 4.500±0.35 |
| | IV | 39 | 96.15–140.17 | 5.942–7.812 | 5.340–6.504 | 5.986±0.34 |
| | V | 7 | 80.42–88.26 | 0.604–0.664 | 0.705–0.826 | 0.728±0.04 |
| Female | I | 263 | 23.04–61.04 | 0.122–0.373 | 0.509–0.752 | 0.550±0.03 |
| | II | 354 | 39.78–88.26 | 0.702–1.962 | 1.714–3.076 | 1.849±0.08 |
| | III | 185 | 69.31–144.70 | 3.253–7.689 | 4.101–7.043 | 5.120±0.55 |
| | IV | 35 | 91.65–180.32 | 5.411–15.445 | 5.321–8.633 | 6.829±0.73 |
| | V | 7 | 115.95–150.42 | 0.987–1.070 | 0.745–1.070 | 0.858±0.11 |

The male and female samples at GMS IV were mostly caught in Station VI (Taluak Kinari). The condition of the water in the Taluak Kinari area is relatively calm and there is more aquatic vegetation than in the other stations, making it suitable for the mothers to lay eggs and young fish take shelter and forage. Cyprinidae is classified as phytophil fish that do not make nests during spawning, but spread their eggs in the aquatic vegetation in spawning sites (Lagler et al 1956). In addition, in the post-larvae period (after 1-4 days of age) of Cyprinidae, the yolk reserves carried by the fish run out, the larvae start feeding (Woynarovich & Horvath 1980). Also, at Station VI the possible pressures from environmental damage and pollution are lower than in the other stations, due to the sharp elevation angle of the land area around the lake, being unsuitable for agricultural activities.

GSI, both male and female, positively and linearly correlated with the total length (L), weight (W), and gonad weight ($W_g$) (Figure 6) and the value of $R^2$ showed a dominant influence from the weight of the gonads. For the same bodyweight, the greater the weight of gonads, the higher the GSI value (Sembiring et al 2014). The GSI value continues to grow and reaches a maximum at GMS IV, then decreases when entering GMS V (Effendie 2002).

The spawning season of *C. armatus* showed a tendency to adapt to the environmental conditions and changes. Young fish can take advantage of the variety of food and shelter available during the transition period from the rainy to the dry season. This showed the harmony between the end of the maturation period of the gonads with the end of the rainy season, when the carrying capacity of the environment increases, with regard to the reproduction processes. This can be seen from the results of the analysis of the relationship between environmental factors and the gonad weight of female fish at GMS IV (Table 7).

Environmental factors that are positively related to gonad weight are temperature, nitrate, dissolved oxygen, and plankton. These four factors were found to gradually increase from the end of the rainy season to the dry season. A similar situation was noticed at *Capoeta umbla* in Karasu River, Turkey (Türkmen et al 2002), at some cyprinid fish in the Mekong River, such as *Barbonymus gonionotus*, *C. enoplos*, *Mekongina erythrospila*, and *Paralaubuca typus* (Baran 2006), *T. polylepis* in the Kampar Kiri River (Bakhris et al 2007), and *Pristolepis grootii* in the Musi river (Ernawati et al 2009).

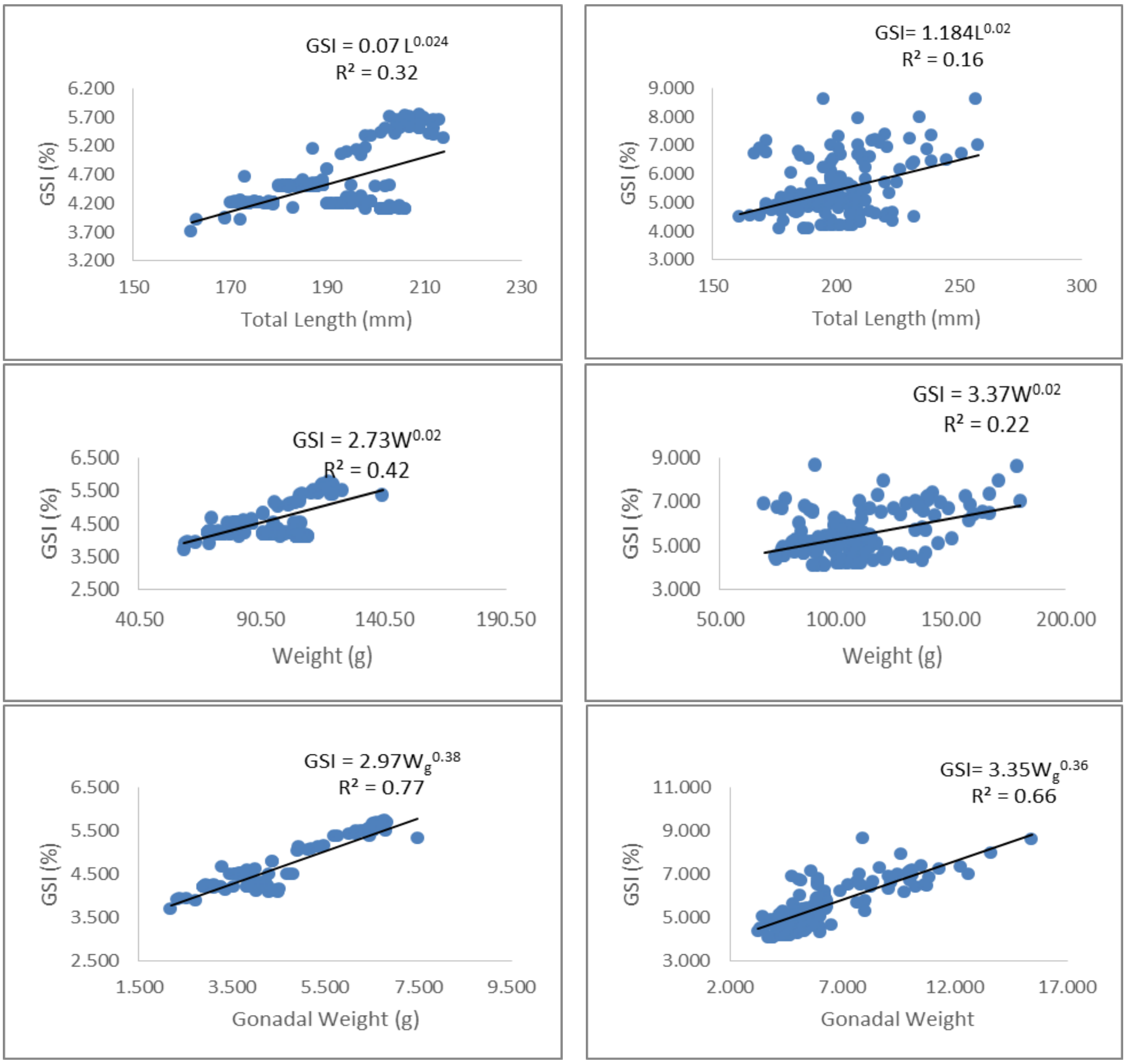


Figure 6. Relationship between GSI and total length (L), body weight (W) and gonadal weight (Wg).

The fecundity for the 220 observed *C. armatus* samples ranged between 13,448 and 14,521 eggs individual$^{-1}$, with an absolute mean of 14,082, for GMS III females and between 11,251 and 11,549 eggs individual$^{-1}$, with an absolute mean of 11,369, for GSM IV females (Table 5). The average relative fecundity of *C. armatus* was 143 eggs g$^{-1}$ of body weight (GMS III) with a range of 133-154 eggs g$^{-1}$ and 86 eggs g$^{-1}$ of bodyweight (GMS IV) with a range of 75-91 eggs g$^{-1}$ (Table 5).

Fecundity at GMS IV was found to be less than at GMS III, being caused by the larger diameter of the oocyte GMS IV (Table 5) and by the experimentally observed atresia presence in the oocytes. The number of atresia oocyte increases during pre-spawning and spawning, which is an essential criterion for the reproductive success of females. Atresia events are related to the compatibility with the reproductive environment and can occur at all levels of oogenesis, predicting the amount of oocyte potential for the reproductive process (Mañaños et al 2009).

Table 5

The average of absolute and relative fecundity of *Cyclocheilichthys armatus* on GMS III and IV

| *Month* | *GMS* | *N* | *L Average ±sd (mm)* | *W Average ±sd (g)* | *$W_g$ Average ±sd (g)* | *$F_a$ Average ±sd (eggs)* | *$F_r$ Average ±sd (eggs $g^{-1}$)* |
|---|---|---|---|---|---|---|---|
| November 2018 | III | 25 | 190.7±15.3 | 96.37±15.60 | 4.792±0.79 | 13,448±995 | 148±26 |
| | IV | 2 | 211.5±3.54 | 131.99±9.29 | 8.749±0.56 | 11,337±123 | 91±7 |
| December 2018 | III | 17 | 196.1±9.96 | 99.90±11.72 | 4.971±0.78 | 13,571±958 | 139±22 |
| | IV | 5 | 217.6±15.92 | 136.68±31.20 | 8.898±2.06 | 11,385±288 | 91±26 |
| January 2019 | III | 4 | 183.8±11.32 | 105.20±28.15 | 4.086±0.78 | 14,332±849 | 143±49 |
| | IV | | | | | | |
| February 2019 | III | 6 | 188.3±6.06 | 91.67± 6.57 | 4.776±0.51 | 14,072±559 | 154±16 |
| | IV | | | | | | |
| March 2019 | III | 14 | 196.6±8.27 | 101.77±10.63 | 5.202±0.55 | 13,952±920 | 137±17 |
| | IV | 3 | 229.3±19.86 | 142.32±6.33 | 8.657±1.18 | 11,270±372 | 82±2 |
| April 2019 | III | 21 | 196.3±11.83 | 101.92±14.85 | 5.164±0.68 | 14,114±930 | 139±24 |
| | IV | 3 | 233.0±11.53 | 158.42±6.77 | 9.651±1.42 | 11,255±361 | 75±3 |
| May 2019 | III | 28 | 197.8±10.13 | 102.05±9.07 | 4.763±0.68 | 13,794±943 | 133±24 |
| | IV | 3 | 218.0±11.27 | 125.03±16.34 | 7.944±1.08 | 11,251±345 | 91±8 |
| June 2109 | III | 22 | 194.8±14.04 | 100.02±13.42 | 5.022±0.74 | 14,068±868 | 137±28 |
| | IV | 18 | 219.1±19.66 | 142.48±21.98 | 9.234±2.21 | 11,534±390 | 85±18 |
| July 2019 | III | 12 | 189.8±10.56 | 93.52± 12.32 | 4.728±0.69 | 14,306±479 | 145±21 |
| | IV | | | | | | |
| August 2019 | III | 10 | 191.0±11.33 | 94.97± 13.69 | 4.548±0.48 | 14,521±503 | 150±16 |
| | IV | | | | | | |
| September 2019 | III | 8 | 195.4±13.28 | 101.82±16.49 | 4.885±0.63 | 14,432±362 | 140±20 |
| | IV | 1 | 220±0.0 | 134.89±0.0 | 7.689±0.0 | 11,549±0.0 | 86±0 |
| October 2109 | III | 18 | 190.1±9.40 | 90.34±9.23 | 4.863±0.57 | 14,369±507 | 146±14 |
| | IV | | | | | 13,448±995 | |

GMS-gonadal maturing stage; N-number of individuals; L-total length; W-body weight; Wg-gonadal weight; F-fecundity.

Fecundity of *C. armatus* in GMS IV showed a positive and linear correlation with the total length (L), body weight (W), and gonad weight ($W_g$), according to the following expressions: $F=9,112L^{11:23}$ ($R^2$=0.27), $F=10,015W^{11:18}$ ($R^2$=0.41), and $F=10,152W_g^{149.34}$ ($R^2$=0.58), respectively (Figure 7).

The value of $F>F_{(0.05)}$ indicates that the fecundity of linear and positively correlated with total length, body weight, and gonad weight. The value of $R^2$=0.58>0.50 shows a strong relationship between fecundity and gonad weight. The same situation was observed for *T. thintynus* in Towuti Lake (Nasution et al 2007) and for *T. olylepis* in the swamps of the Kampar Kiri River (Bakhris et al 2007). Thus, these three factors can be used to estimate fecundity. By looking at the total length of *C. armatus* females at the time of maturation of the first gonads, namely 127.4±0.004 mm, it is estimated that the fish already had an oocyte number of 4.223.

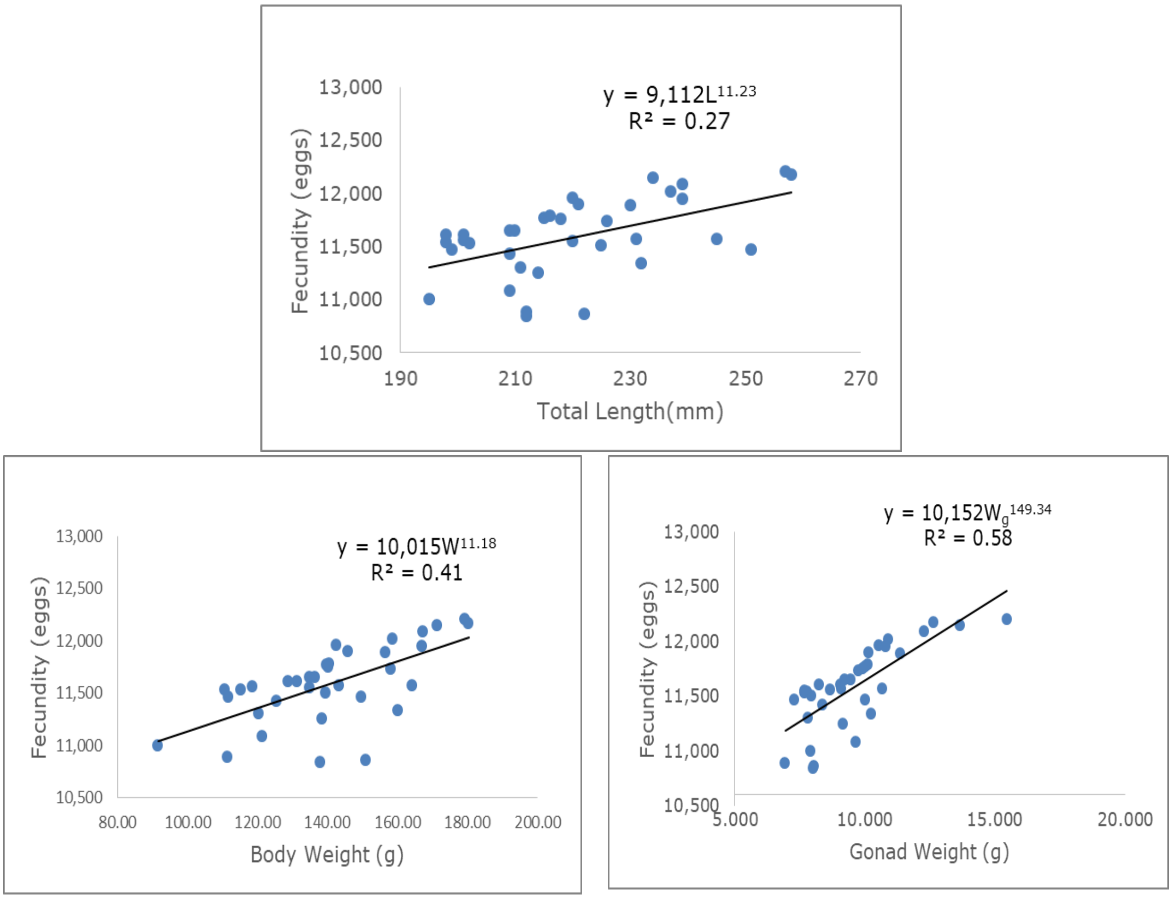


Figure 7. Relationship fecundity *Cyclocheilichthys armatus* with total length (L), body weight (W), and gonadal weight ($W_g$).

The total length of fish samples ranged between 121 and 220 mm for males (882 fish) and between 123-272 mm (844 fish) for females. The total samples that had ripe gonads were 261 male fish (30%) and 228 female fish (27%), as shown in Figure 8.

The immature gonad sizes ranged from 121 to 150 mm in males and from 123 to 152 mm in females. Mature gonads sized from 151 to 200 mm in males and from 153 to 272 mm in females (Figure 9). The size difference for one sex in a population is due to differences in growth patterns, early maturity of gonads and changes in new fish populations of existing species (Nikolsky 1963). The total length of fish caught ranged from 121 to 214 mm (mean 162.9±21.6 mm) for males and from 123 to 258 mm (mean 164.2±25.6 mm) for females.

The average total length of the captured male fish is less than the total length of the male specimens with gonads at first maturity, but in the female population this pattern is reversed. This condition indicates that there are symptoms of recruitment overfishing in male fish, meaning that the *C. armatus* male did not have the opportunity to spawn before being caught.

According to Saputra et al (2009), the catch was dominated by specimens with a size larger than the size of the fish with gonads at first maturity, meaning that these fish species were still safe from recruitment overfishing. Recruitment overfishing occurs when most of the fish caught have unripe gonads.

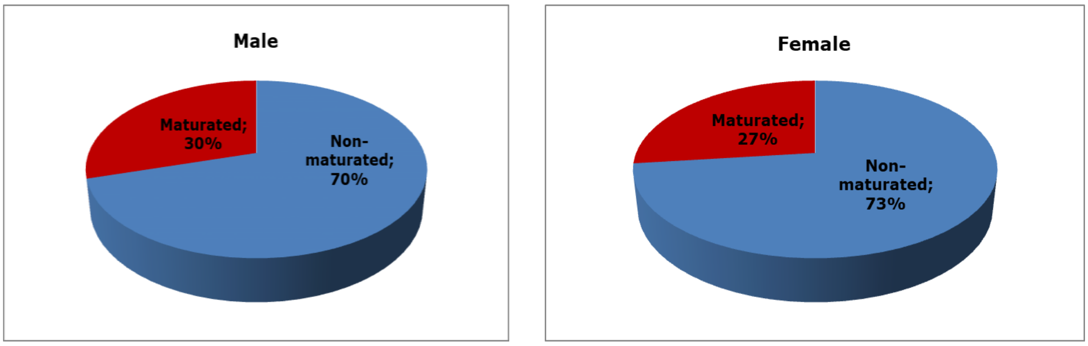


Figure 8. Percentage of gonadal maturity of *Cyclocheilichthys armatus* male and female for one year (November 2018 until October 2019).

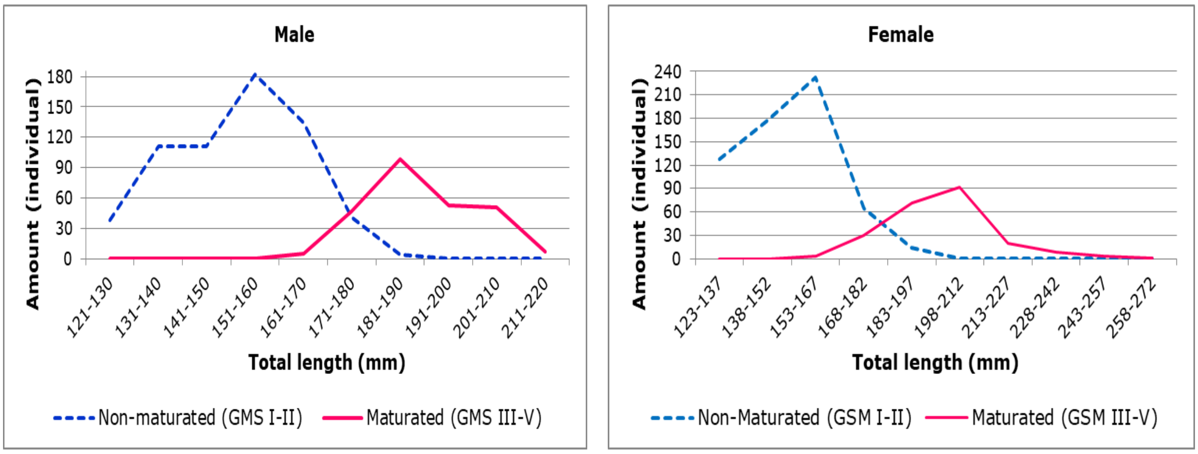


Figure 9. Frequency distribution of *Cyclocheilichthys armatus* total length (L) based on gonadal maturity from November 2018 until October 2019.

Based on the results of the analysis using the Spearmen-Karber method (Udupa 1986), it was found that the range of gonad ripe sizes for males was 164.4-166.7 mm, with an average of 165.5 mm, and of 127.4-129.9 mm for females, with a mean of 128.9 mm (Table 6). The size of gonads at first maturity is greater for males than for females, showing that the growth rate of males is faster than in female fish. This was also observed in *Paratheria striata* populations from Towuti Lake (Nasution et al 2007; Omar et al 2011). The size of the gonad at first maturation is influenced by the abundance and availability of food, temperature, light period (photoperiod), and environmental factors of the habitat (Mendoza et al 2005).

Table 6

Total length (L) of *Cyclocheilichthys armatus* gonads at first maturation

| *Gender* | *Total length of gonads at first maturation* | | | | |
|---|---|---|---|---|---|
| | *Log M* | *Log M±SD* | *M* | $M_{min}$ | $M_{max}$ |
| Male | 2.2188 | 2.2188±0.003 | 165.5 | 164.4 | 166.7 |
| Female | 2.1094 | 2.1094±0.004 | 128.7 | 127.4 | 129.9 |

Distribution of oocytes diameter collected from the 185 females at GMS III varied between 0.44-0.52 mm, and for the 35 females at GMS IV it varied between 1.51-1.63 mm, with a normal distribution of the ovaries diameters variations (Figure 10). The result of normality test obtained p-value<p-value $_{(0.05;4)}$, indicating that the oocytes diameter is relatively similar between the anterior, middle, and posterior part in both the left and right ovaries, it varied between 1.80-2.08 mm. The diameter distribution shows the tendency of the oocyte to form a group that has the same relative size (Figure 11). This indicates that *C. armatus* is a total spawner. The same aspect was noticed for *C. apogon* in the Menduk River (Suhendra et al 2017). Judging from the spawning time and the percentage of achievement of GMS IV in terms of total spawner fish, at the end of the rainy season or at the transition from the rainy season to the dry season, it is estimated that *C. armatus* has a strategy to take advantage of the upcoming dry season by maximizing the number of offspring produced. The oocyte is entirely ovulated to produce juveniles under the influence of the favorable environmental conditions. The availability of food (plankton) tends to increase in the dry season because the lake water is clear and light intensity stimulates the photosynthetic rate, l which increases the dissolved oxygen (DO). In addition, low rainfall during the dry season will reduce the rate of agricultural surface runoffs. The most determinant factors for the number of eggs produced by females are: fertility, frequency of spawning, parental care, egg size, environmental conditions, and population density (Moyle & Cech 2004).

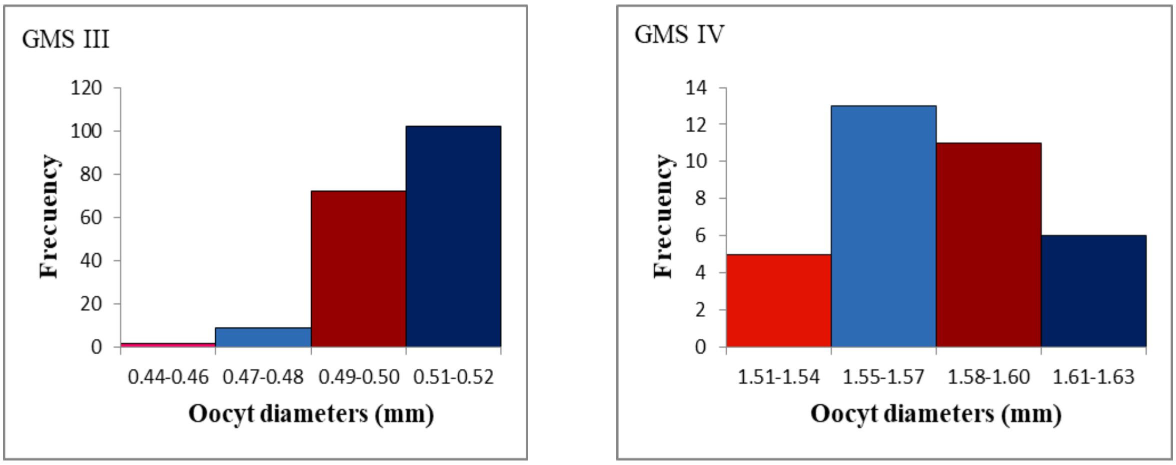


Figure 10. Frequency distribution of oocyte diameter's (GMS IV) from left and right ovaries.

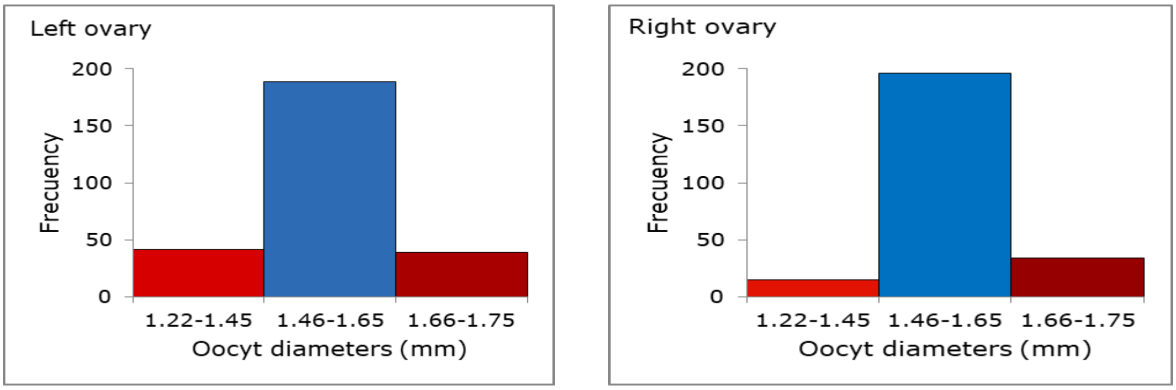


Figure 11. Frequency distribution of oocyte diameter's (GMS IV) from left and right ovaries.

Most of the water variables do not show significant fluctuations between the rainy season and the dry season (Table 7), with the exception of temperature, hardness, nitrate, $O_2$ dissolved and plankton. The relationship between the gonad weights of females at GMS IV with water variables is presented in the following regression equation:

$$logy = 3.687x_1 - 0.292x_2 - 0.006x_3 + 0.096x_4 - 0.579x_5 - 0.0203x_6 + 0.0307x_7 - 1.811x_8 - 0.463x_9 + 0.023x_{10}$$

Where:
y-gonadal weight;
$X_1$-temperature;
$X_2$-brigtness;
$X_3$-hardness;
$X_4$-nitrate;
$X_5$-phosphate;
$X_6$-ammonia;
$X_7$-disolved oxygen;
$X_8$-disolved carbon dioxcid;
$X_9$-partial hydrogen;
$X_{10}$-plankton.

Table 7
Average of water variables in the rainy and dry season in Diatas Lake from November 2018 to October 2019

| *Variable* | *Rainy season I* | *Dry season I* | *Rainy season II* | *Dry season II* |
|---|---|---|---|---|
| | | Physical | | |
| Temperature (℃) ($X_1$) | 20.5-22.5 | 22.1-22.8 | 20.5-22.8 | 21.9-23.1 |
| Water transparency (m) ($X_2$) | 4.3-5.3 | 5.0-6.0 | 4.2-5.2 | 5.3-6.0 |
| | | Chemical | | |
| Hardness ($CaCO_3$) (mg $L^{-1}$) ($X_3$) | 49-53 | 50.56 | 53.0-63.2 | 52.0-66.0 |
| Nitrate ($NO_3$-N) (mg $L^{-1}$) ($X_4$) | 0.010-1.329 | 0.010-1.473 | 0.245-0.792 | 0.010-1.294 |
| Phosphate ($PO_4$-P (mg $L^{-1}$) ($X_{5)}$ | 0.026-0.034 | 0.034-0.047 | 0.022-0.102 | 0.001-0.0.57 |
| Ammonia ($NH_3$-N) (mg $L^{-1}$) ($X_6$) | 0.001 | 0.001-0.035 | 0.016-0.246 | 0.001-0.032 |
| Dissolved $O_2$ (mg $L^{-1}$) ($X_7$) | 6.04-6.59 | 6.24-7.32 | 6.02-7.05 | 6.22-7.35 |
| Dissolved $CO_2$ (mg $L^{-1}$) ($X_8$) | 1.72-1.80 | 1.73-1.83 | 1.68-1.78 | 1.72-1.79 |
| pH ($x_{9)}$ | 7.9-8.2 | 7.5-8.2 | 7.8-8.1 | 7.6-8.1 |
| | | Biological | | |
| Plankton ($X_{10}$) | 37.00-55.25 | 59.13-65.13 | 35.13-48.75 | 40.63-163.75 |
| Gonadal weight (g) (Y) | 20.5-22.5 | 22.1-22.8 | 20.5-22.8 | 21.9-23.1 |

Rainy season I: October-December; Dry season I: January-March; Rainy season II: April-June; Dry season II: July-September.

Variables that show a positive relationship with the development of gonad weight in female fish GMS IV are temperature, nitrate, dissolved $O_2$ and plankton abundance. All water variables from the observation locations are generally still in a suitable range to support the aquatic biota (Effendi 2014).

**Conclusions**. *C. armatus* is a total spawning type of fish species. It spawns twice a year at the end of the rainy season. The peak of spawning takes place at the end of the rainy season in June and December. During the life and the spawning period, the sex ratio of *C. armatus* is 1:1. The size of the first mature gonads in *C. armatus* was 165.5±0.003 mm for males and 128.7±0.004 mm for females. The absolute fecundity ranged from 11.601 to 15.773 eggs per individual at GMS III and from 10.801 to12.293 eggs individual$^{-1}$ at GMS IV. Relative fecundity ranged from 133-154 eggs g$^{-1}$ of body weight at GMS III, and 75-91 eggs g$^{-1}$ of body weight at GMS IV. The *C. armatus* fecundity was positively correlated with the total length of fish ($F=9{,}112L^{11.23}$), bodyweight ($F=10{,}015W^{11.18}$), and gonad weight ($F=10{,}152W_g^{149.34}$).

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