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Allometric growth pattern and reproductive biology of Channa striata (Bloch, 1793) from Lake Mainit, Philippines

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Key words: Allometric growth pattern, Condition factor, Gonadosomatic index, Hepatosomatic index, Sex ratio

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Abstract

A research based fishery management would lead to more sustainable fishery resources. This study aimed to provide biological and reproductive data of *Channa striata* from Lake Mainit Philippines. Length-weight relationship, condition factor, gonadosomatic and hepatosomatic indices were determined in this study. Results revealed that snakeheads showed a significant difference in terms of body weight and gonad weight. Females weighed heavier than males. Female gonads were heavier than males as it had high percentage of mature stage (53.13%) in terms of gonadal development compared to male which were in maturing stage (47.83%). Female snakeheads preponderated the males in terms of sex ratio (1:0.72). The length - weight relationship revealed an allometric growth pattern. Female snakehead demonstrated positive allometric pattern (b=3.3143) while male snakehead showed negative allometric growth pattern (b=1.7267). The values for the condition factor in both sexes of snakehead were less than 3, indicative of a poor condition which may be attributed to the threatened environmental condition of the lake. The GSI values in both sexes are high and greater than 1, implying of their fecundity as revealed and consistent to the observed stages of gonadal development. The HSI values for female and male snakehead were minimal, suggestive of low hepatic activity. An inverse relationship between GSI and HIS has been shown in this study. The values on the body parameters and reproductive biology of *C. striata* from Lake Mainit, Philippines are vital baseline information for rational fishery management in the lake. A study on temporal and spatial distribution of *C. striata* caught from this lake and its tributaries may be conducted to elaborate further its reproductive biology particularly on its spawning season to provide significant knowledge in the promotion of *C. striata* utilization and capture production as well as in the restoration of Lake Mainit fishery resources to sustainability.

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Introduction

Channa striata (Bloch, 1793) or snakehead murrel, locally known as haruan or haluan, is an air-breathing fish species which inhabits commonly in freshwater plains like lakes, rivers, streams and ponds preferably with slow - moving to stagnant water and muddy substrates (Menon, 1999). It is freshwater fish rich in high nutrition and health benefits (Mustafa *et al.,* 2012) and largely used for food, biomedical and pharmacological therapeutic purposes (Rahman *et al.,* 2018). It has an economic potential on both captures and cultures in Southern and Southeastern Asia (Vidthayanon, 2002). It is one of the main food dishes in Thailand, Indochina and Malaysia (Davidson, 1975). In 1999, the global catch for this species was 32, 938t with Thailand (27, 500t) and Philippines (5, 438t) as the countries with largest catches (FAO, 2006).

In the Philippines, *C. striata* is caught in the wild from one of its wetland ecosystems, the lake Mainit - the deepest, fourth largest lake and one of the Key Biodiversity Area (KBA) in the country. This 87, 072 ha oligotrophic lake encompassing the provinces of Surigao del Norte, and Agusan del Norte (LMDA, 2005) is a home to a total of 41 fish species including *C. striata*. However, despite of its biodiversity and productivity, this wetland ecosystem suffers typical condition of threatened fishery resources brought by environmental and anthropogenic activities like biodiversity loss, declining water quality, unsustainable fishing practices, high fishing pressures and laxity in the enforcement of fishery policies (De Guzman *et al*., 2015). All these factors resulted to a drastic decline in the annual fish catch from 15, 108 t in 1980-81 to about 831.50 t in 2007 - 08, about 5.5% of production level 26 years ago (Biña - de Guzman *et al*., 2013). Several fish species were caught in increasingly smaller sizes resulting to lower economic value thus giving marginal or meager income to fishery - dependent locals or communities for livelihood. *C. striata,* as one of the fish species in this lake is not exempted from this scenario. Hence, a study on its reproductive biology is deemed appropriate and necessary for fishery management and sustainability.

For a rational fishery resource management, an in - depth knowledge on the quantitative aspects of fish biology such as length - weight relationships, gonadosomatic and hepatosomatic indices, sex ratio and condition factor are considered essential (Dumalagan *et al*., 2017). Length - weight relationships (LWR) is used to determine the population size status of fish species as weight can be estimated from length measurement obtained from production valuation (Pauly, 1993).

Gonadosomatic index (GSI) is used to determine the fish spawning season hence, considered vital in evaluating the fish stocks for commercial potentialities (Roy *et al*., 2014). Hepatosomatic index (HSI) determines the energy reserves in the liver and is related with GSI due to the process of vitellogenesis, where vitellogenin in fish is synthesized and is considered a yolk precursor (Cerda *et al*., 1996). Condition factor is used to determine the 'well-being' of fish which ascertains ecological condition of its habitat relative to species growth indicated by its length and weight (Le Cren, 1951).

Despite of the economic and medical importance as recognized in other countries like Thailand, Bangladesh and Malaysia, there is still paucity of the biological and zoological data of *C. striata* from Lake Mainit, Philippines. To date, only a little to no detailed information on its reproductive biology. Hence, this study is conducted to determine the sex ratio, length - weight relationship, condition factor and the gonadosomatic and hepatosomatic indices to provide baseline information for the development of sound fishery management policies in promoting its capture production as well as conservation in restoring Lake Mainit fishery resources to sustainability.

Materials and methods

Study site

A total of 55 *C. striata* (32 females and 23 males) were collected at Lake Mainit (Fig. 1) from January to May 2021. Lake Mainit is a home to many freshwater fish species, and one of those is *C. striata*. The fish samples were caught by local fishermen using gill nets and cast nets of various mesh sizes. Collected samples were placed in an iced bucket and brought in the laboratory for further analysis.

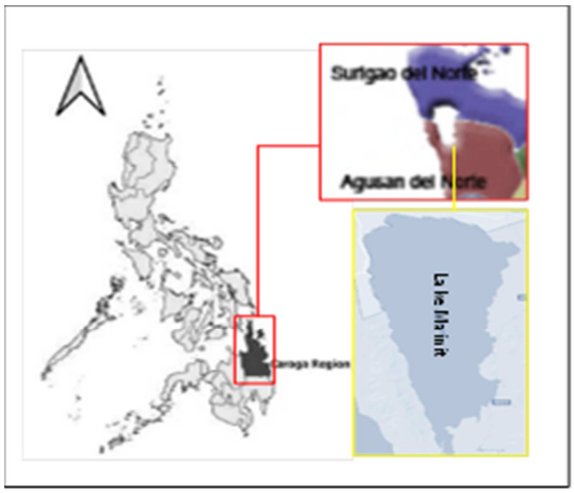


Fig. 1. Study site-Lake Mainit, Surigao del Norte, Philippines

Data collection

The total length (TL), i.e., from tip of the snout to the tip of caudal fin, was measured using a measuring tape with a 0.1cm precision. Each fish was wiped with paper towel to remove excess water before being weighed for its total weight (TW) using a digital weighing balance (KERN EW) at 0.01g accuracy. Sex determination for each *C. striata* was determined macroscopically through dissection. Gonadal maturation stages were identified using maturity keys designed for fishery purposes and descriptively analyzed based on color, shape and texture following the descriptions from Nikolsky, (1963) and Nunez & Duponchelle (2009) (Table 1).

Table 1. Macroscopic gonadal maturation stages classified by Nikolsky, (1963) and Nunez & Duponchelle (2009).

Stages of Gonad	Ovary (Female)	Testis (Male)
Stage I (Immature)	Ovary appears small, thin, transparent, soft texture and blood vessels not visible yet. Oocytes not visible through the ovary wall.	Testes appear very tiny and translucent containing many spermatogonia. Few spermatocytes thinly scattered macroscopically. Flat, transparent white and notched testicles.
Stage II (Maturing)	Ovary appears elongated and only few oocytes. Blood vessels look unclear.	Testes appeared larger than the immature stage. More abundant spermatocytes and spermatids.
Stage III (Mature)	The ovary size is bigger. Yellowish oocytes and blood vessels continue to develop well. Round eggs with rough surfaces, no ovulation yet. The blood vessels combine to form larger capillaries on the external surface of the ovarian wall. Oocytes clearly visible through the reddish yellow ovary wall, filling the half of the abdominal cavity.	Testes show largest volume with a pinkish white color. The testicles getting bigger and squiggly and creamy white in color. Dominance of secondary and tertiary spermatocytes while few primary spermatocytes.
Stage IV (Spent/Recovering)	Ovary appears large with a thin and transparent membrane. Ovaries are larger, yellow, or orange, fill the abdominal cavity. Oocyte grains separate from each other. Clear central and peripheral blood vessels.	Testes are darker, opaque, and flaccid. The testicles widen and appear springy, but some are soft and very squiggly. Blood vessels are thick.

Data Analysis

The relationship of length and weight of *C. striata* was computed using the equation (Ricker, 1971): $W = aL^b$. The constant values of *a* and *b* were determined from the log transformed values of length and weight using the linear regression equation: log BW = log *a* + *b* log TL, where *a*, intercept of y -axis; *b*, exponent between 2 and 4 (Bagenal & Tesch, 1978); BW, total weight in grams and TL for total length in centimeters. When *b* value is equal to 3 (*b*=3), the growth pattern is isometric, that is, an increase in length follows an increase in weight.

When *b* is unequal to 3, an allometric growth patter occurs which may be either negative (*b*<3) or positive (*b*>3). A negative allometric growth implies that fish becomes lean or slim as it gains weight while a positive allometric growth suggests a stouter length as weight increases. Sex ratio was determined by the total number of males over the total number of females (Sex ratio = Σmales/Σfemales). The gonadosomatic index (GSI) was computed as a percentage of gonad weight over body weight as expressed in the equation (Lagler, 1971): GSI = GW/BW x 100. GW and BW refers to the gonad weight and body weight for both sexes, respectively. A GSI higher than 1 indicates that fish is fecund or can produce abundant offspring (Amyatz *et al*., 2013).

The hepatosomatic index (HSI) was calculated as a percentage of the liver weight over the total weight as expressed in the equation: HSI = LW/BW x 100, where LW and BW refers to liver weight and body weight for female and male, respectively. Condition factor (K), as a measure of fish 'well-being', was determined following the equation of Bagenal (1971): K = 100 BW/ TL ^3, where BW is the individual weight of the fish in grams and TL is the total weight in centimeter. Fish is considered in good condition when K value is greater than 3 (Wooton, 1992). Means for relationship between length and were carried out using correlation and regression analysis. Significant difference in the LWR, GSI, HSI and K were determined using Student's t - test at 0.05 level of significance. All these data analyses were done using Microsoft Excel 2016 and JASP software application.

Results and discussion

Morphological Measurements of Channa striata from Lake Mainit, Philippines

Table 1 presents the means on the morphological measurements of *C. striata*. The total length of female *C. striata* had a mean of 35.13±2.18cm while males had 34.23±1.95cm. In terms of body weight, females had a mean of 469.45±108.38g while males had 408.44±78.23g. As to gonad weight, females had mean weight of 16.45±2.93g while males had 0.53±0.34g. For the liver weight, male livers weighed higher with a mean of 3.33 ± 3.05g compared to female livers with a mean of 2.49±0.98g. Pooled sexes resulted to a mean of 34.75±2.12cm for TL, 443.94±100.79g for BW, 9.79±8.23g for GW and 2.84±3.05 for LW. Among the morphological parameters, results revealed a significant difference between female and male *C. striata* in terms of body weight and gonad weight at 0.05 significance level.

This result conformed with the study of Dumalagan *et al.* (2017) on the same fish species from Lake Kilobidan, Agusan Marsh, Philippines where females weighed heavier than males. It was also found out in the study of Boonkusol *et al.* (2020) on *C. striata* from Mae La River, Thailand that the number of oocytes was directly proportional to the weight of the fish and increased progressively with the ovarian weight. According to Al Mahmud *et al.* (2016) as the gonad matures, it increases with weight which adds the total weight of the fish reflective of its reproductive cycle.

Table 1. Mean Morphological Measurements of *C. striata* from Lake Mainit, Philippines

Sex	n	%	Total Length (cm) (Mean±SD)	Total Weight(g) (Mean±SD)	Gonad Weight(g) (Mean±SD)	Liver Weight (g) (Mean±SD)	Sex Ratio
Female	32	58.18%	35.13±2.18	469.45±108.38*	16.45±2.93*	2.49±0.98	
Male	23	41.82%	34.23±1.95	408.44±78.23*	0.53±0.34*	3.33±3.05	1:0.72
Pooled	55	100%	34.75±2.12	443.94±100.79	9.79±8.23	2.84±3.05	

p≤0.05 significance level

Sex ratio, Total Length and Body Weight Frequency Distribution of C. striata from Lake Mainit

As to sex ratio, this study revealed that females preponderated males. This result was similar to the triple population increase of females over males of *C. striata* from Bantimurung River, Maros Regency on the study of Irmawati *et al.* (2017) which contradicted to the findings of Makmur *et al.* (2003) where a balanced sex ratio between male and female snakehead population from Musi River Basin, Indonesia.

These findings showed that sex ratio of females and a male greatly varies. This variation may be influenced by several factors like habitat, location, season, and stages in fish life (Mian *et al.*, 2015). According to Djumanto *et al.* (2019), sex ratio indicates the health status of fish population and that a balanced population may guarantee maximum recruitment of broodstocks. Fig. 2 shows the length frequency distribution of *C. striata* from Lake Mainit. In this study, most of the female samples have a total length of 32cm while 36cm for males. In terms of body weight distribution (Fig. 3), more females weighed at 500 - 600 g while males weighed 300 - 400g. According to Djumanto *et al.* (2019), variation in size, as indicated on the length and weight of the samples may be caused by type of fishing gear used for sampling as well as the period or duration the sampling was conducted.

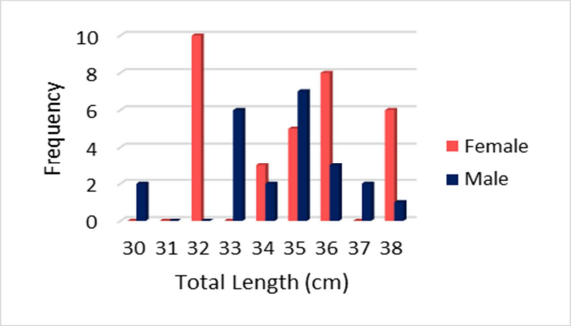


Fig. 2. Total length frequency distribution of *C. striata* from Lake Mainit, Philippines.

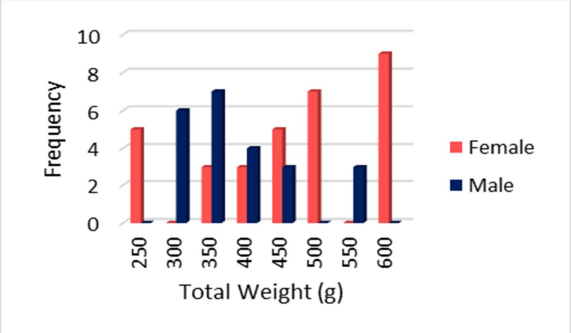


Fig. 3. Body weight frequency distribution of *C. striata* from Lake Mainit, Philippines.

Stages of Gonadal Development of C. striata from Lake Mainit, Philippines

There were four stages of gonadal development observed in this study as shown in Fig. 4. Mature stage for female *C. striata* dominated the catch with 53.13% while a maturing stage for males with a percentage of 47.83%. On the other hand, immaturity stage has the least percentage of 6.25% for females while mature stage of 13.04% for males. This variation of stages in gonad development between female and male may be due to the sampling periods and type of fishing gear used which may possibly affect the size and number of fish caught. Moreover, Boonkusol *et al.* (2020) noted that biological factors such as food availability and the presence of aquatic plants and animals determine the fertility and development of young fish. Micale *et al.* (1987) highlighted those physical factors like water temperature, water content, amount of light and water pH are important aspects controlling reproductive cycles of fish species.

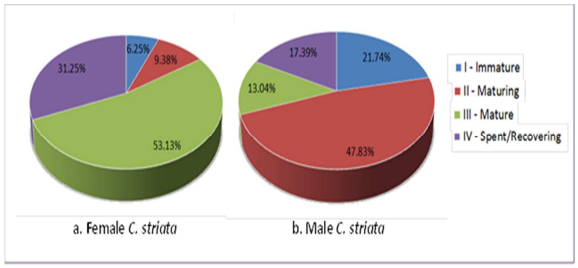


Fig. 4. Gonadosomatic and Hepatosomatic Indices of Female and Male *C. striata* from Lake Mainit, Philippines

Length-weight relationship and condition factor of C. striata from Lake Mainit

Table 2 presents the LWR, growth pattern and K of *C. striata* from Lake Mainit. Based on the result, female snakeheads obtained a *b*- value of 3.3143 indicating positive allometric growth pattern which implies that the fish becomes relatively stout as length increases. On the other hand, male snakeheads showed negative allometric growth pattern with a *b*-value of 1.7267 which indicates that they tend to become lean or slim as they gain weight. The correlation coefficients of the length-weight for both sexes of *C. striata* were positive but insignificant.

The allometric growth pattern of snakeheads from Lake Mainit is similar to the growth pattern of the same fish species from Lake Kilobidan, Agusan

Marsh, Philippines as studied by Dumalagan *et al.* (2017). These lakes belong to the same region in the Philippines - the Caraga region. This result implies that the lakes may exhibit the same environmental condition which possibly affects the *C. striata*'s growth pattern. However, an isometric growth pattern on both sexes of *C. striata* from Lake Rawa, Pening Indonesia was found out in the study of Djumanto *et al.* (2019).

This variability of growth patterns in *C. striata* may be brought by multiple external and internal factors.

Habitat, seasonal differences, food availability and density are some of the external factors affecting growth of fish species (Djumanto *et al.*, 2019) while fish development stages, sex and level of gonad maturity are some of the internal factors (Safran, 1992) influencing patterns of growth.

Table 2. Length - weight relationship, correlation coefficient (b), growth pattern (Al) and condition factor (K) of *C. striata* from Lake Mainit, Philippines.

Sex	n	Logarithmic growth equation (logBW=log *a* + *b* log TL)	a	b	r^2	Al	K
Female	32	logBW = -2.4615 + 3.3141 logTL	0.0853	3.3143	0.6132	+	1.07
Male	23	logBW = -0.0443 + 1.7267 logTL	0.9567	1.7267	0.2679	-	1.02
Pooled	55	logBW = -1.6933 + 2.8105 logTL	0.1839	2.8105	0.5154	-	1.04

Note: $p \leq 0.05$ significance level; -, negative allometric growth pattern; +, positive allometric growth pattern

As revealed in Table 2, the values for the condition factor of female and male *C. striata* were 1.07 and 1.02, respectively. At 0.05 level of significance, these results showed no significant difference. Moreover, the values of K for both sexes were less than 3 which indicate that the snakeheads from Lake Mainit were in poor condition. This health condition may be attributed to the environmental and human factors that threatened the biodiversity and productivity of the lake recently (Biña-de Guzman *et al.*, 2013).

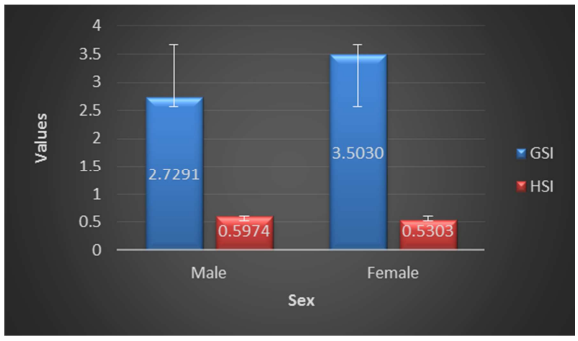
Gonadosomatic and Hepatosomatic Indices of C. striata from Lake Mainit

Fig. 2 showed the gonadosomatic and hepatosomatic indices of *C. striata*. The GSI value of female snakehead (3.5030) was higher than the male (2.7291). The GSI values in both sexes were greater than 1 which indicates that *C. striata* from Lake Mainit is fecund or capable of producing during the time of sampling. This result can be linked to the gonadal development observed in the samples. Majority of female samples were in mature gonadal development while males were in maturing stage. According to Al Mahmud *et al.* (2016), the evidence of mature stages of gonads and high GSI values signifies breeding season of fish species.

Hence, the *C. striata* utilized in this study were possibly in their spawning season as indicated by the high percent values for mature (female) and maturing (male) stages of gonad development was well as the high GSI values. The high values of GSI are indicative of mature stage of ovary and testis in fish species (Lovedeep & Ram, 2020). Yeldan and Avsar (2000) expounded that GSI is commonly used in the assessment of spawning period for bony fishes because its value is directly related to their gonadal development.

The HSI values of female *C. striata* was 0.5303 while for male was 0.5974. The result of Student's t- test revealed an insignificant difference in the HSI values in both sexes. As disclosed in Fig. 4 that the HSI values of female and male snakeheads were lower compared to the GSI values which may indicate an inverse relationship between these two body parameters. This result conforms with the study of Lovedeep and Ram (2020) on carp fish and on snow trout by Muddasir and Ahmed (2016). According to Zin *et al.* (2011), when HSI values are minimal while GSI are highest, the condition demonstrates that liver has lost its weight during reproduction due to the mobilization of hepatic reserve for gonads' maturation.

Al Mahmud *et al.* (2016) further explained that the elaboration of yolk in the oocyte marks the beginning of vitellogenesis where at the end cells reached their maximum size and undergo maturation/ovulation followed by the extrusion of the egg to the exterior. As indicated in the high percentage of maturing and mature stage of gonadal development, this study showed a low hepatic activity of *C. striata* from Lake Mainit, Philippines.



Based on the Student's t - test of significant difference, the *C. striata* from Lake Mainit, Philippines displayed a significant difference in the body weight and gonad weight and an insignificant difference on the total length, liver weight, sex ratio and condition factor. The GSI and HSI values a and data on morphological measurements, length - weight relationship and condition factor obtained in this study are essential biomarkers in understanding the reproductive life cycle of *C. striata* which may serve as basis for capture production and possible aquaculture cultivation.

Conclusion & recommendation

The *C. striata* from Lake Mainit, Philippines displayed a significant difference in terms of body weight and gonad weight. Females weighed heavier than males. Female gonads were heavier than males as it had high percentage of mature stage in terms of gonadal development compared to male which were in maturing stage. Female snakeheads preponderated the males in terms of sex ratio. The length-weight relationship revealed an allometric growth pattern of *C. striata*. Female snakehead demonstrated positive allometric pattern while male snakehead showed negative allometric growth pattern.

The values for the condition factor in both sexes of snakehead were less than 3, indicative of a poor condition which may be attributed to the threatened environmental condition of the lake. The GSI values of *C. striata* in both sexes are high and greater than 1, implying their fecundity as revealed and consistent to the stages of gonadal development observed in this study.

The HSI values for female and male snakehead were minimal, suggestive of low hepatic activity. An inverse relationship between GSI and HSI has been shown in this study. The values on the body parameters and reproductive biology of *C. striata* from Lake Mainit, Philippines are vital baseline information for rational fishery management in the lake.

A study on temporal and spatial distribution of *C. striata* caught from this lake and its tributaries may be conducted to elaborate further its reproductive biology particularly on its spawning season to provide significant knowledge in the promotion of *C. striata* utilization and capture production as well as in the restoration of Lake Mainit fishery resources to sustainability.

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Abbreviations

KBA- Key Biodiversity Area, LWR – Length-weight relationship, GSI- Gonadosomatic index, HIS- Hepatosomatic index

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