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Growth Pattern, Gonadal Maturity, Condition Factor and Gill Net Selectivity of the Hard-Lipped Barb (*Osteochilus hasselti* CV) from Sungai Batang River, Indonesia

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ABSTRACT

This study examined the growth pattern, condition factor (K), length at first capture (Lc50), length at first maturity (Lm50), gonadosomatic index (GSI), and selection factor (SF) of the hard-lipped barb (*Osteochilus hasselti* CV) in Sungai Batang River, Indonesia. Fish were weekly purchased from local fishermen over a two-month period (April-May 2024). A total of 355 specimens were studied, consisting of 204 males and 151 females, with total lengths ranging from 60 to 190mm and weights from 2 to 91g. The fish exhibited an isometric growth (b = 2.98–3.04) and were in good condition, with a sex ratio of 1.4:1. The length-weight relationship was strongly positive (r = 0.9575–0.9863). No significant differences were observed in total length (TL), body weight (W), or the mean W/TL ratio between the sexes. However, females had higher mean values for body depth (BD), BD/TL ratio, and K value compared to males. The Lc50 was greater than the Lm50, indicating a high likelihood of spawning. The Lc50 and SF values were 116.5mm and 3.65, respectively, suggesting that the use of a 1.25-inch mesh size gillnet is suitable for fishing practices. A follow-up collection of fish samples was conducted three months later (June-August 2024) to investigate the maturity stages of both sexes and determine their GSI. Macroscopic morphological characteristics revealed that testes could be classified into four stages: immature, mature, ripe/spawning, and spent. Female ovaries were classified into five stages: immature, mature, ripe, spawning, and spent. The GSI values for males ranged from 1% to 10.52%, while those for females ranged from 1% to 13.46%. The findings of this study provide a valuable baseline for evidence-based fisheries management.

INTRODUCTION

Fish species of the Cyprinidae family are broadly allocated in freshwater bodies of Southeast Asia, Africa, and other countries. It is one of the economically prominent freshwater fish species that are useful for supporting the culinary business, as well as ornamental fish markets **(Manorama & Ramanujam, 2011; Lim *et al.*, 2013, Sarkar *et al.*, 2013)**. It can also help the fishery manager or conservationists assess habitat degradation or environmental health **(Isa *et al.*, 2010; Zakeyudin *et al.*, 2012)**. It can be found in rivers lakes, reservoirs, ponds, rice fields, and wetlands **(Mondol *et al*., 2005; Hamid *et al*., 2015; Muhammad *et al.*, 2016)**. Several active and passive fishing gears are being used to assemble them from the wild, like hand net for *Puntius chola* **(Salam *et al.*, 2005)**, cage nets for *P. shalynius* **(Manorama & Ramanujam, 2011)**, gill net and cast net for *P. conchonius* and *P. sophore* **(Shafi & Yousuf, 2012; Latif *et al*., 2017)**, electrofishing for *P. binotatus* **(Situmorang *et al.*, 2013)** lift net, and hook and line for *Barbodes binotatus* **(Escote & Jumawan, 2017)**. It is categorized as an omnivorous species that consumes green algae, detritus, protozoa, diatom, and fragments of aquatic insect **(Hanjavanit & Sangpradub, 2012)**. *Osteochilus vittatus* and *P. conchonius* are considered partial spawners **(Shafi *et al.*, 2013; Syandri *et al.*, 2015)**, which are similar to *Rasbora argyrotaenia* **(Lisna, 2013)** and *Channa striata* **(Ahmadi & Ansyari, 2021)**.

Previous studies have specifically described fish species of Cyprinidae family in terms of their geographical distribution **(Isa *et al*., 2010)**, reproductive biology **(Solomon *et al*., 2011)**, habitat characteristics **(Alam *et al*., 2012)**, population structure **(Rahman *et al*., 2012)**, morphometric characteristics **(Vitri *et al.*, 2012)**, biometric relationships **(Hossain *et al*., 2013)**, breeding biology **(Shafi *et al.*, 2013)**, growth and reproduction **(Rochmatin *et al*., 2014)**, the length-weight relationship and condition factor **(Das *et al*., 2015)**, feeding habit **(Muchlisin *et al*., 2015)**, domestication technique **(Sukendi *et al.*, 2015)**, level of gonadal maturation and fecundity **(Rostika *et al*., 2017)**, genetic characteristic **(Astuti *et al*., 2020)**, and ectoparasite examination **(Fira *et al*., 2021)**. The length-weight relationship (LWR) is the most commonly utilized logical method to analyze structure, maturation and reproduction in numerous fish species from various geographical areas **(Rahman *et al*., 2012; Escote & Jumawan, 2017; Ahmadi & Ghanem, 2024)**, and to examine the growth patterns of fish species **(Rochmatin *et al.*, 2014)**. It is confirmed that the fish length is the most appropriate guide of production efficiency **(Ghorbani *et al*., 2012)**. On the other hand, fish weight is reflected as a function of length **(Weatherley & Gill, 1987)**. Hence, growth is a function of both length and weight **(Das *et al.*, 2015)**. In other words, stronger fish of a certain length are evaluated to be healthy and well- conditioned **(Dodds, 2002)**. Studies on the LWR can also be utilized as basic information on the conservation and management of the commercially important and the endangered fish species in natural waters **(Hossain *et al*., 2015)**.

The hard-lipped barb (*Osteochilus hasselti* CV) is one of fishing targets in Sungai Batang waters, which is conducted through the year nevertheless of the season. Although the selling price of fish is much cheaper than that of the snakehead and climbing perch, the fishermen still benefit from this species. Overfishing pressure, water pollution, environmental quality degradation and the presence of predators have been linked to decrease fish population **(Hossain *et al*., 2012; Muhammad *et al*., 2016; El-Ghazaly *et al*., 2017; Ghanem, 2021; Abdelmeguid *et al*., 2024)**, and ultimaltely affecting the overall socio-economic condition **(Kalita *et al*., 2015; Hanif *et al*., 2019)**. To ensure the fish population can be maintained, domestication and gonad maturation techniques were applied **(Sukendi *et al*., 2015; Eissa *et al*., 2024a)**. **Hsieh *et al*. (2010)** and **Liang *et al*. (2014)** agreed that changes in fish population structure associated with age structure and stock size are largely due to size-selective fishing gear. As there are no published report on the biology of *O. hasselti* from this river, we investigated the length-weight relationship, length at first capture, condition factor, length at first maturity, maturity stages and gonadosomatic indices of both sexes, as well as selection factor of gillnet to provide better fisheries management strategies for this species.

MATERIALS AND METHODS

1. Sampling site

The study was carried out in Sungai Batang River, Martapura of South Kalimantan Province (Fig. 1), located on 03°25' 32" S and 114°43'21" E, as revealed by GPS-60 Garmin, Taiwan. The river is interconnected to Riam Kanan Lake and Barito River, which strongly supports irrigation, capture fisheries, aquaculture and agriculture. The village area involves wetland zone with fluctuations in water level between 0.6 and 2.1m. The dry season starts from June to November, whereas the rain period extends from December to May, and the fish samples with the size range of 268-326mm were collected between April and August. Some aquatic plants found along the river include *Eichornia crasipes*, *Salvinia molesta*, *Salvinia natans*, *Pistia* sp., *Azolla pinnata*, and *Lemna purpusilla*.

As illustrated in Fig. (2), the observed fish *O. hasselti* is mostly caught by the gillnet with a 1.25 inch (31.75mm) stretched mesh size. Other traditional fishing gears comprising *hancau* (portable liftnet) and *tempirai* (bamboo stage-trap) can also be used to catch them in this river, but in small numbers. Therefore, we did not include data from these fishing gears.

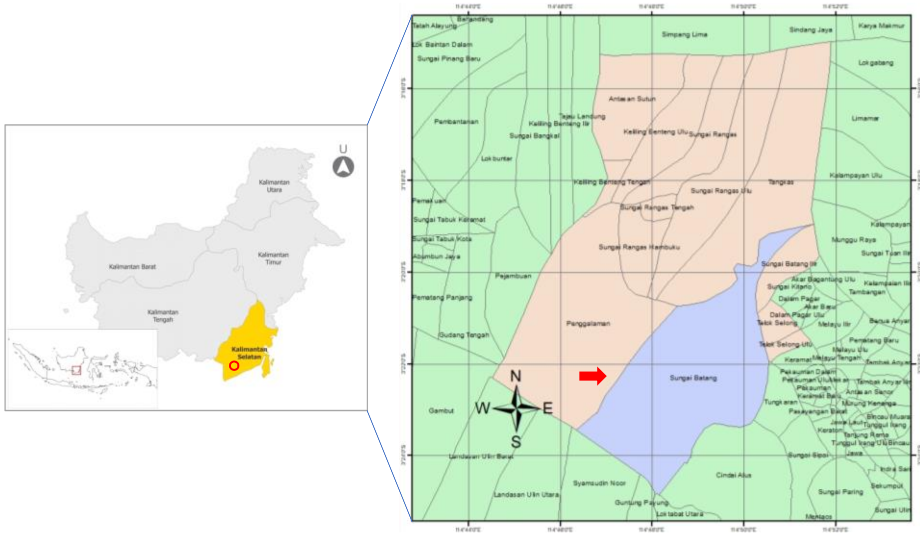

Fig. 1. Geographic location of Sungai Batang Village, in South Kalimantan, Indonesia

2. Data collection

A total of 355 *O. hasselti* individuals (204 males, 151 females) of various sizes were studied. Fish were weekly purchased from local fishermen over a two-month period (April-May 2024). A subsequent collection of fish samples was conducted three months later (June-August 2024) to investigate the maturity stages of both sexes and determine their gonadosomatic index (GSI). All applicable institutional and national policies concerning the care and usage of dead animals have been respected following the guidelines of Directive 2010/63/EU for animal experiments. Fish specimens were sex-identified, and morphometric measurements were taken for total length (TL), body depth (BD), and weight (W). TL was measured from the angle of the snout to the elongated caudal fin tip. Body depth was scaled perpendicularly from the dorsal fin basis to the ventral midline of fish body. TL and BD of each specimen were measured to the closest millimeter using a ruler, while the whole-body weight was determined to 0.01g using a digital scale (CE, SF-400, China). The W/TL and BD/TL ratio were calculated as a non-dimensional number based on established empirical methods. To analyze the size distribution, the sampled fish were grouped into 10mm intervals for both length and weight.

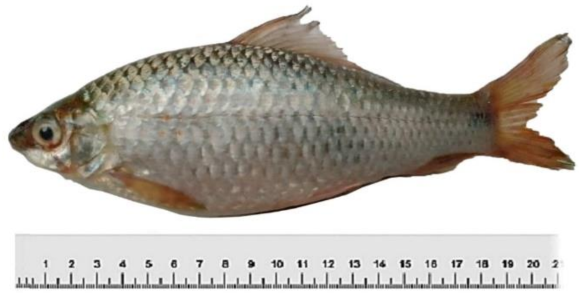

Fig. 2. Whole mount of *Osteochilus hasselti* CV from Sungai Batang River, in South Kalimantan, Indonesia

3. Measured parameters

3.1. Length-weight relationship

According to **Froese (2006)**, the length-weight relationship (LWR) of fish was calculated as follows:

$$W = aL^b$$

Where, W is the total weight (g); L is the total length (mm); *a* is the constant showing the initial growth index; and *b* is the slope showing growth coefficient. The expected *b* exponents to outline a fish growth pattern ranged from 2.5 to 3.5 **(Bagenal, 1978)**. The statistical significance of the isometric exponent (b) was expressed by the following function **(Pauly, 1984)**:

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

Where, *t* is the student's *t*-test value, SD (x) and SD (y) represent the standard deviation of log L and the standard deviation of log W, respectively. The slope of the curve (b), the coefficient determination (R^2) and the samples number (*n*) are also included . The *t*-value is then compared to the *t*-table value (0.05) for degrees of freedom at 95% significance level. If the calculated *t*-value was smaller than the *t*-table value, then the fish grows isometrically ($b = 3$). If the *t*-value was greater than the *t*-table value, the fish grows allometrically ($b \neq 3$). The *b* value has an valuable biological significance; Isometric growth (b = 3) indicates a constant length-weight relationship. Positive allometry (b > 3) means weight increases quicker than length, while negative allometry (b < 3) means length rises earlier than weight. Determination coefficient (R^2) and regression coefficient (r) between morphological variables were also calculated for both sexes.

3.2. Condition dactor

The condition factor (K) of fish was assessed by the following equation **(Weatherley & Gill, 1987)**:

$$K = 100(W/L^3)$$

Where, K is the Fulton's condition factor; L is total length (cm); and W is weight (g). To make K value nearly a value of one, a factor of 100 is applied. K value is calculated to estimate the health condition of fish of dissimilar sexes and in various localities and seasons. If the K value is less than one, this indicates that fish individual is not in a good condition. Conversely, a fish is said to be in a good condition if the K is greater than one.

3.3. Evaluation of length at first capture

The length at first capture (L_{c50}) is defined as the total *length* at which 50*%* of specimens were caught by gill nets. Moreover, it also represents 50% of the recruits that are under full manipulation. The capture probability is estimated by plotting the cumulative frequency of the catch (%) with total length (mm). It is evaluated using a standard selectivity logistic curve set at 50% of the resultant cumulative curve as described by **Saputra (2009)**.

3.4. Determination of length at first maturity

The size of fish at first maturity (L_{m50}) is the length at which 50% of the population have matured. This data is important for fisheries managers to designate firm decisions especially for fish stock management and conservation of fish population **(Soares *et al*., 2020)**. The Spearman-Karber formula was used to estimate L_{m50} value **(Udupa, 1986)**:

$$m = X_k + \frac{X}{2} - (X \Sigma P1)$$

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

Where, X_k is the last log size at which 100% of fish are fully mature; X is log size increment; P1 is the proportion of fully mature fish in the first size group; and q1 is 1 – P1. Antilog (m) = L_{m50} is used to indicate the average size at first maturity.

3.5. Gonadal maturity stages

The gonadal maturity stages of 10 fish specimens (5 males and 5 females) were determined macroscopically using the criteria of **Nunez and Duponchelle (2009)** and **de Souza *et al*. (2011)**, considering factors such as color, shape, transparency, degree of coelomic cavity occupation, and gonadal visibility.

3.6. Gonadosomatic index (GSI)

The gonads of individual fish were carefully removed and weighed. The gonadosomatic index (GSI) was determined using the formula outlined by **Eissa *et al.* (2024b)**:

$$\text{GSI (\%)} = 100 \times \frac{\text{(gonads weight (g)}}{\text{gutted body weight(g)}}$$

3.7. Selection factor

The selection factor (SF) is an indicator related to an escapement factor that expresses the relationship among L_{c50} and the mesh size utilized. In this study, 1.25 inch (31.75mm) was set as the basis for calculation. This factor is also known as the selectivity coefficient. According to **Pauly (1984)**, the SF value for *O. hasselti* can be predicted easily using the following formula:

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

4. Statistical analysis

Analysis of covariance (ANCOVA) was used to examine variations between male and female in terms of growth patterns. The *t*-test was used to evaluate the condition factors, body sizes and size ratios between both sexes. SPSS-18 software program was used to analyze all tests at the 0.05 significance level.

RESULTS AND DISCUSSION

1. Length-weight relationship

The body shape of both males and females showed an isometric growth pattern, indicating that the weight and length of the fish increased in the same proportion. The calculated *t*-value for the *b* exponent was smaller than *t*-table value. The LWR between males and females were calculated as $W = 5\times10^{-5}TL^{2.9848}$ and $W = 5\times10^{-5}TL^{3.0453}$, respectively (Fig. 3a). The R^2 values ranged from 0.9169 - 0.9727 implying that more than 97% of weight variability was explicated by the length. Moreover, the length-weight relationship was positively correlated (r = 0.9575 - 0.9863) (Table 1).

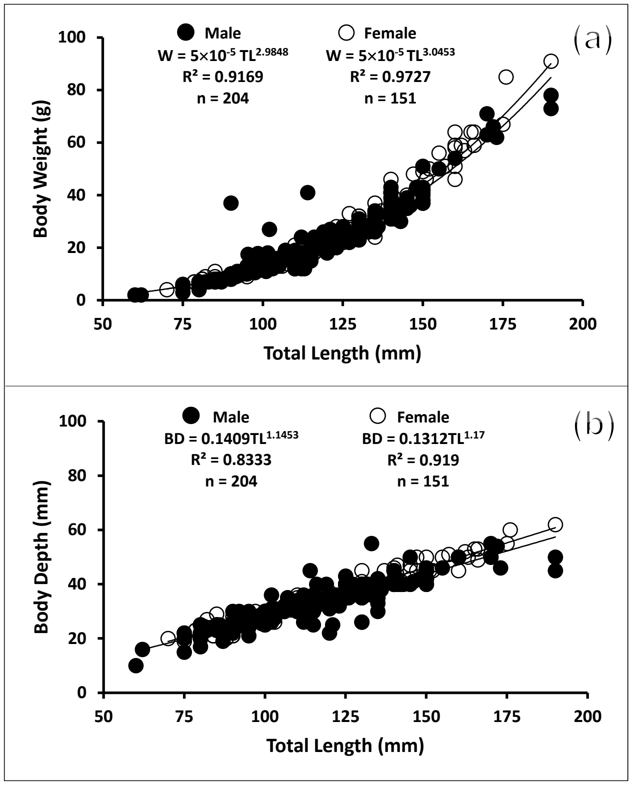

Fig. 3. [a] Correlation between total length and body weight; **[b]** Correlation between total length and body depth for *O. hasselti* sampled from Sungai Batang River. Females were found to have a significantly greater average body depth than males

Table 1. Comparison of body size, growth pattern and condition factor between male and female *O. hasselti* from Sungai Batang River

Sex	n	Total length (mm)			Weight (g)			a	b	R^2	r	Growth pattern	K
		Min	Max	Mean ± SD	Min	Max	Mean ± SD						
Male	204	60	190	116.83 ± 23.48	2	78	22.40 ± 13.39	5×10^{-5}	2.9848	0.9169	0.9575	I	1.23 ± 0.09
Female	151	70	190	118.72 ± 24.78	4	91	24.75 ± 16.75	5×10^{-5}	3.0453	0.9727	0.9863	I	1.29 ± 0.07

Note: a = constant, b = exponent, R^2 = determination coefficient, r = regression coefficient, A- = negative allometric, I = isometric, K = Fulton's condition factor

Table 2. The mean body size ratio of *O. hasselti* sampled from Sungai Batang River

Sex	n	W/TL	a	b	R^2	r	BD/TL	a	b	R^2	r
Male	204	0.18 ± 0.07	5×10^{-5}	1.9848	0.8299	0.9110	0.28 ± 0.03	0.1409	0.1453	0.0744	0.2728
Female	151	0.19 ± 0.09	5×10^{-5}	2.0453	0.9415	0.9703	0.30 ± 0.02	0.1312	0.1700	0.1933	0.4397

Note: a = constant, b = exponent, R^2 = determination coefficient, r = regression coefficient, W = body weight, BD = body depth, and TL = total length

The results of this study are comparable to the previous studies (Annex I). Similar isometric growth pattern was also found in *Puntius chola* from Mathabhanga River, Bangladesh **(Hossain *et al*., 2006)**, as well as or in the Pakistanian Indus River **(Muhammad *et al*., 2016)**, in addition to female *Barbodes binotatus* from Tamblingan Lake, Indonesia **(Putri *et al*., 2022)**. However, this is in contrast to *Puntius gonionotus* from Pedu Lake, Malaysia **(Isa *et al*., 2010)**, *P. sophore* from Chalan Beel, Bangladesh **(Rahman *et al*., 2012)**, *P. binotatus* from Kerian River in Malaysia **(Zakeyudin *et al*., 2012)**, *B. binotatus* collected from pond-cultured, Sabah-Malaysia and Barambai River, Indonesia **(Lim *et al*., 2013; Jusmaldi & Hariani, 2018)**, and *P. ticto* from Indus River, Pakistan **(Muhammad *et al*., 2016)**, which grew allometrically positive.

On other words, *Puntius chola* in Hatchery Rawalpindi, Pakistan **(Salam *et al.*, 2005)**, *P. shalynius* in Umiam River, India **(Manorama & Ramanujam, 2011)**, *P. sophore* in Padma River, Bangladesh **(Alam *et al*., 2012)**, *P. ticto* in Ganges River in Bangladesh **(Hossain *et al*., 2012)**, *P. conchonius* in Dal Lake, Kashmir **(Shafi & Yousuf, 2012)**, and *B. binotatus* in Sta. Ana Dam, Philippines **(Escote & Jumawan, 2017)** exhibited a negative allometric growth. Food availability, seasonal changes, sexual reproduction, gonad development, life cycle, environmental conditions, change in physiological condition during spawning periods, sample size variation, fishing pressure, and water quality changes can greatly influence slope variation **(Latif *et al*., 2017; Jusmaldi & Hariani, 2018)**.

No significant differences in total length (TL), body weight (W), and the mean ratio of W/TL between males and females (P>0.05) were reported. Male body size ranged from 60- 190mm TL (116.83 ± 23.48mm) and 2 - 78g weight (22.40 ± 13.39g); whereas, female body size fluctuated between 70- 190mm TL (118.72 ± 24.78mm) and 4- 91g weight (24.75 ± 16.75g), with a sex ratio of 1.4 male to 1 female (1.4 : 1), as shown in Table (1). Females had a slightly greater mean W/TL ratio (0.19 ± 0.09) than males (0.18 ± 0.07), and the relationship was expressed by $W/TL = 5\times10^{-5}TL^{1.9848}$ ($R^2 = 0.8299$) for males and by $W/TL = 5\times10^{-5}TL^{2.0453}$ ($R^2 = 0.9415$) for females (Table 2).

In the current study, the observed W/TL ratio of *O. hasselti* was in agreement with other family Cyprinidae (Annex I), but it was lower than *P. gonionotus* collected from Pedu Lake, Malaysia **(Isa *et al*., 2010)** or *B. Binotatus* from Tamblingan Lake, Indonesia **(Putri *et al*., 2022)**. During fishing season, a fish with less than 60mm TL might be caught by the gill net accidentally, but releasing the fish back to the river was a better way than making a meager profit. Empirically, fishermen may try all means to get fish larger than 190mm TL, but this is unexpected since fish sales transactions between fish traders and fishermen take place in the morning before the fish are transmitted elsewhere. There are no records of catches and price, possibly leading to unrecorded fishing procedures. We cannot estimate the exact ratio of growth rate to exploitation rate of fish in the studied river because fishing activities take place throughout the year regardless of seasons. Our findings can be used to reformulate better fisheries management strategy. Comparatively, the mean body depth of females (35.32 ± 9.01mm) was higher than males (33.12 ± 7.96mm). Moreover, the body depth of fish was increasingly proportional to the total length (Fig. 3b). The mean BD/TL ratio of females (0.30 ± 0.02) was also much higher than that of males (0.28 ± 0.03) (Table 3). This relationship was expressed as $BD/TL = 0.1312\ TL^{0.1700}$ for females and $BD/TL = 0.1409TL^{0.1453}$ for males.

O. hasselti fish observed in the present investigation were mostly allocated in the middle size class. Most individuals caught were between 110 and 129mm TL, with 16.18% males and 17.88 - 18.54% females, followed by the lengths of 130 - 139 and 90 - 99mm TL (Fig. 4a). Less than 10% of the catch was examined for smaller (<99mm) or larger (>139mm) individuals. In terms of weight size, approximately 30.39 - 30.88% of the total catch of males weighed between 14 and 24g, while for females, the number remained at 28.48 - 33.11% in the same class (Fig. 4b). More males than females were caught, i.e. individuals with body size >129mm TL and weight >24g.

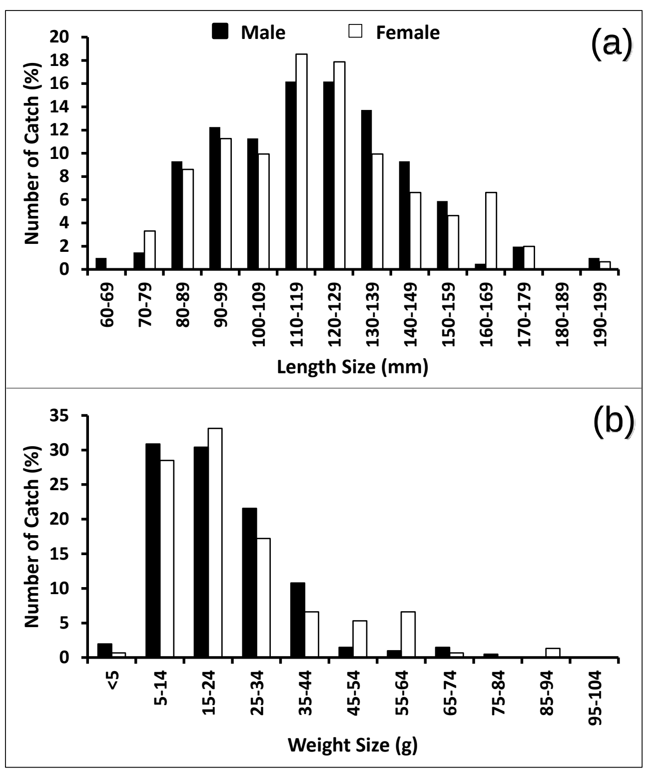

Fig. 4. The percentages of **[a]** length and **[b]** weight size distributions between male and female *O. hasselti* collected from Sungai Batang River

2. Condition factor

The mean K value of females (1.29 ± 0.07) was comparatively higher than that of males (1.23 ± 0.09) (Table 3). From the curve equation, it can also be seen that the initial growth index of females (0.0790) was greater than that of males (0.0536). The relationship between condition factor and the ratio of body weight to total length was represented as $W/TL = 0.079K^{3.1426}$ for females and $W/TL = 0.0536K^{5.3600}$ for males. The increase in K value corresponds to a value of W/TL.

The K values estimated in the present study are also in agreement with other family Cyprinidae from different geographical areas that range from 1.00 to 1.85 (Annex I), and reaffirm that the fish population at the study site was in a good condition. Variation in the K values linked very closely to the availability of food, feeding habits, gonad maturity levels and biological interaction concerning intraspecific competition for space and food among species **(Muhammad *et al*., 2016; Escote & Jumawan, 2017; Jusmaldi & Hariani, 2018)**. Practically, the technology of breeding and spawning can help increase the value of K **(Sukendi *et al*., 2015)**. According to **Rostika *et al.* (2017)**, *Osteochilus vittatus* with the length size of 274mm and weight of 356g produced 88,954 eggs at gonad maturity level (GML) VI of the spawning period. Meanwhile *P. binotatus* reared in culture ponds at 36.4ºC and pH 7.35 grew allometrically positive, and the fish were in good fitness and health condition **(Lim *et al*., 2013)**.

Table 3. Descriptive statistics of parameters observed for *O. hasselti* CV in Sungai Batang River

Observed parameter	**Mean ± SD of body sizes**		***t*-test for equality of means**		
	Male	**Female**	***T***	**df**	**Sig.**
Total length (mm)	116.83 ± 23.48	118.72 ± 24.78	-0.739	353	0.461
Body weight (g)	22.40 ± 13.39	24.75 ± 16.75	-1.476	353	0.141
Body depth (mm)	33.12 ± 7.96	35.32 ± 9.01	-2.448	353	0.015
W/TL	0.18 ± 0.07	0.19 ± 0.09	-1.438	353	0.151
BD/TL	0.28 ± 0.03	0.30 ± 0.02	-4.516	353	0.000
Condition factor (K)	1.23 ± 0.09	1.29 ± 0.07	-6.019	353	0.000

Note: W = body weight, BD = body depth, and TL = total length.

3. Assessment of the length at first capture

The length at first capture (L_{c50}) for both males and females of *O. hasselti* was estimated at 116.5mm, indicating the sizes at which 50% of the catches were kept by the gill nets. Based on the L_{c50}, we approximately predicted the proportion of smaller individuals (<116.5mm) and larger individuals (>116.5mm) for males to be 48.75 and 50.25%, while for females it was 49.34 and 50.66%, respectively. It can be said that the fish length size corresponds to the mesh size of gill nets utilized (Fig. 5).

Gill nets are a widely used fishing gear for catching fish species of family Cyprinidae in their natural habitats (Annex II). They are not only used in Sungai Batang River but are frequently used with different mesh sizes, for example in Pedu Lake, Malaysia **(Isa *et al*., 2010)**, Indus River, Pakistan **(Muhammad *et al*., 2016)**, Barambai River **(Jusmaldi & Hariani, 2018)** or Tamblingan Lake, Indonesia **(Putri *et al*., 2022)**. According to **Winston *et al*. (2019)**, a mesh size of gill net can be selected according to the size, type and behavior of the targeted fish species.

The studies on gill nets reviewed here did not report the length at first capture (L_{c50}). Our study determined the L_{C50} for *O. hasselti* to be 116.5mm for both sexes. The present gill nets capture smaller individuals (< 116.5mm) or larger individuals (> 116. mm) in equal proportions. Our findings suggest that gill nets with a 1.25-inch mesh size can be used to harvest *O. hasselti* from this river without negatively impacting the population, provided that appropriate fishing regulations are in place to prevent overfishing.

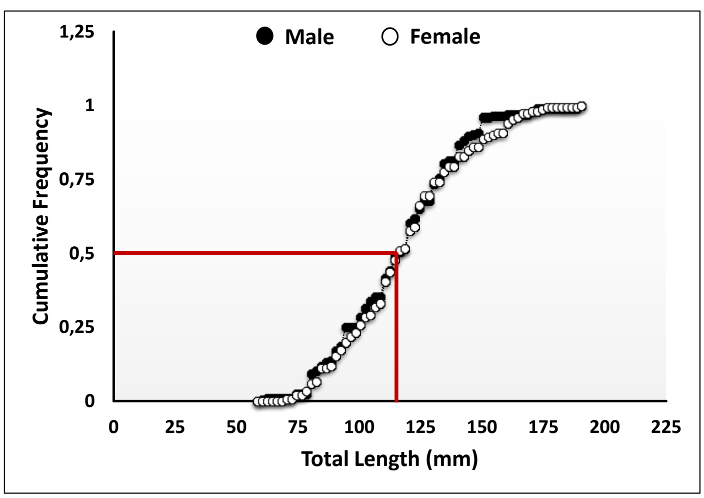

Fig. 5. The length at first capture (L_{c50}) for both male and female *O. hasselti* was estimated at 116.5mm, corresponding to a stretched mesh size of 31.75mm

4. Evaluation of length at first maturity

The length at first maturity for males and females of *O. hasselti* was estimated by applying the Spearman-Karber formula and was found to be 98.7 and 97.2mm TL, which was smaller than the length at first capture (116.5mm). The proportion of sexually mature fish individuals based on size class distribution was 50.25 and 50.66% for males and females, respectively, with a sex ratio of 1:1. The highest number of mature individuals was observed at 119-121mm TL (35.82%) for males and 123-125mm TL (21.71%) for females. Concurrently, the sexually immature individuals' proportion was predicted to be 49.75% for males and 49.34% for females with a sex ratio of 1:1. Furthermore, the highest number of immature individuals was 26.13% for males and 22.30% for females, which were between 109-111mm TL.

Empirical evidence shows that the length at first capture was greater than the length at first maturity; this indicates that *O. hasselti* has a great opportunity to spawn so as to maintain the population of fish in this river. This condition was greatly expected in sustainable fisheries management.

5. Macroscopic observations of male and female gonadal maturity stages

Accurate classification of fish gonadal maturation stages is crucial for effective fisheries assessment **(Soetignya *et al*., 2020)**. Table (4) presents the morphological characteristics of different gonadal maturity stages for male and female *O. hasselti* CV in Sungai Batang River. Male testis was classified into four stages: immature (I), mature (II), ripe/spawning (III) and spent (IV). However, female ovaries were categorized into five stages: immature (I), mature (II), ripe (III), spawning (IV) and spent (V). These findings are consistent with previous studies on *O. hasselti* CV **(Hayati *et al.*, 2018)**, *O. waandersii* **(Soetignya *et al*., 2020)** and *Ailia coila* **(Das *et al*., 2023)**. However, **Boufekane *et al.* (2021)** classified *Diplodus sargus* gonadal maturity into five stages: immature, developing, spawning, regressing and regenerating.

Table 4. Macroscopic characteristics of gonadal maturity stages of male and female *O. hasselti* CV from Sungai Batang River

Maturity stages	Testis	Ovaries
I	Gonads were translucent, whitish and thread-like structure.	The ovaries were thin, small, partly transparent, reddish or white in color.
II	Testis appeared pinkish-white, strip in shape, occupying half of the body cavity.	They were opaque, with color ranging from yellow to red. Small and average-sized oocytes can be observed.
III	Testis were white, swollen. Semen can be observed by pressing the testicle.	They were more voluminous and larger, with coloring varying from orange to greyish.Oocytes were clearly seen through the ovarian wall.
IV	They were white to reddish in color, flaccid and hemorrhagic.	Ovaries were greyish, sack-shaped, appeared fully distended with granular surface.
V		Ovaries were greyish brown in color, flaccid and wrinkled with thick walls.

6. Gonadosomatic index

GSI is a common indicator of gonad maturity, used to estimate reproductive seasons and spawning times **(Eissa *et al*., 2024b)**. In the present study, the mean GSI values displayed temporal variation across months. GSI values ranged from 1 to 10.52% for males and 1 to 13.46% for females. Generally, female GSI was higher than male GSI. The highest GSI values were observed in fish at the ripe stage or near spawning stage, specifically stage III for males and stage III and IV for females. Minimum GSI values for both sexes were observed in July and August, suggesting a potential reproductive quiescent period. The peak reproductive period is inferred to occur between April and June, as evidenced by the elevated GSI values observed during these months. Comparable GSI trends in *O. hasselti* were also reported by **Khakim *et al*. (2015)** and **Fitriatin *et al.* (2018)**. Higher GSI indicates imminent spawning, while lower GSI suggests recent spawning **(Iliyasu *et al.*, 2024)**.

7. Selection factor

The selection factor (SF) value obtained for male and female fish was 3.65, which was derived from the corresponding L_{c50} value of 116.5 and 31.75mm stretched mesh size used. The value of selection factors varies by species target and mesh sizes used. Considering a 1.25-inch mesh size of the gill net, the SF for *O. hasselti* (3.65) in the current work was relatively higher than the SF for *Kryptopterus palembangensis* (2.08) in Batu Lake, Pulangpisau District **(Aryantoni *et al*., 2014)** or *K. lais* (2.36) in Sungai Batang River, Martapura **(Ahmadi, 2021)** on the basis of 1.5 and 2.5-inch mesh sizes. While the SF of *Puntius dorsalis* (4.24) in Uruwal Oya riverine, Sri Langka corresponds to a mesh size of 1.5-inch **(Amarasinghe &Pushpalatha, 1997)** was observed relatively higher than the current result. Variations in the L_{c50} in these studies are due to the sampling period, mesh size, gear type, number, and size of fish observed. As the mesh size of the gillnet was associated with fish size, the length at fish capture can be adjusted by modifying the mesh size correctly.

The present gill net and cast nets were considered male-biased fishing gears **(Bhuiyan *et al*., 2020; Putri *et al*., 2022)**. However, other fishing gears (e.g., scoop net, cage net, seine nets traps, hook and lines) catch more females than males **(Beevi & Ramachandran, 2005; Ahamed *et al*., 2012; Manorama & Ramanujam, 2017; Jusmaldi & Hariani, 2018)**. Difference in the sex ratio was tightly correlated to water temperature, DO, migration cycle and food availability **(Lisna *et al*. 2013; Ahmadi & Ansyari, 2021; Putri *et al*., 2022)**. Fishing gear selectivity for specific species needs to be adjusted by providing acurate LWR database information, and all investors must be precisely implied in fisheries management decision-making process as many features associated with *O. hasselti* have not been verified.

CONCLUSION

O. hasselti CV was in good condition showing an isometric growth pattern. Females exhibited higher GSI values compared to males. The length at first capture was greater than the length at first maturity, indicating a high chance of spawning. Using a 1.25-inch mesh size is acceptable for fishing practice that is in line with its selection factor. However, the precautionary measure should be prioritized to prevent overfishing by involving all stakeholders to implement better fisheries management.

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Annex I. Comparative length-weight relationship, condition factor and growth pattern of Cyprinidae family from other localities.

Species	Sex	n	TL (mm)	W (g)	W/ TL	b	Growth pattern	K	Locations	References
Osteochilus hasselti	M	204	60-190	2-78	0.18	2.98	I	1.23	Sungai Batang River, Indonesia	Present study
O. hasselti	F	151	70-190	4-91	0.19	3.04	I	1.29	Sungai Batang River, Indonesia	Present study
Barbodes binotatus	M	166	50-120	2-21	0.14	3.06	I	1.31	Barambai River, Indonesia	Jusmaldi and Hariani (2018)
B. binotatus	F	181	46-146	1.3-43	0.23	3.11	A+	1.01	Barambai River, Indonesia	Jusmaldi and Hariani (2018)
B. binotatus	P	85	40-95.5	0.7-11	0.09	3.36	A+	1.01	Pond-cultured, Sabah, Malaysia	Lim *et al*. (2013)
B. binotatus	P	6	82-153	11-61	0.31	2.48	A-	N/A	Sta. Ana Dam, Philippines	Escote and Jumawan (2017)
B. binotatus	M	184	39-85	0.9-61	0.50	2.83	A-	1.00	Tamblingan Lake, Indonesia	Putri *et al*. (2022)
B. binotatus	F	168	52-156	14-49	0.30	3.02	I	1.01	Tamblingan Lake, Indonesia	Putri *et al.* (2022)
Puntius chola	P	52	50-95	1.9-13	0.10	2.80	A-	1.82	Hatchery Rawalpindi, Pakistan	Salam *et al*. (2005)
P. chola	P	38	30-83	0.5-10	0.09	3.02	I	1.83	Indus River, Pakistan	Muhammad *et al*. (2016)
P. sophore	P	231	30-160	0.4-31	0.17	2.64	A-	N/A	Chenab River, Pakistan	Latif *et al*. (2017)
P. sophore	P	132	30-85	0.3-9	0.08	3.18	A+	1.60	Indus River, Pakistan	Muhammad *et al*. (2016)
P. sophore	P	51	35-108	N/A	N/A	1.94	A-	1.50	Gomti River, India	Sarkar *et al*. (2013)
P. sophore	P	61	51-92	6-14	0.14	1.59	A-	1.01	Deepar Beel, India	Das *et al*. (2015)
P. sophore	P	70	72-106	5-17	0.12	0.48	A-	N/A	Padma River, Bangladesh	Alam *et al*. (2012)
P. sophore	P	185	36-90	0.7-13	0.11	3.39	A+	1.64	Chalan Beel, Bangladesh	Rahman *et al*. (2012)
P. sophore	P	441	32-102	0.5-16	0.12	3.05	I	N/A	Mathabhanga river, Bangladesh	Hossain *et al*. (2006)
P. shalynius	M	102	41-67	N/A	N/A	0.88	A-	N/A	Umiam River, India	Manorama and Ramanujam (2011)
P. shalynius	F	113	40-70	N/A	N/A	1.62	A-	N/A	Umiam River, India	Manorama and Ramanujam (2011)
P. conchonius	P	150	38-84	1.4-11	0.10	2.94	A-	1.85	Dal Lake, Kashmir	Shafi and Yousuf (2012)
P. ticto	P	24	91-108	14-24	0.19	2.96	A-	1.78	Ganges River, Bangladesh	Hossain *et al*. (2012)
P. ticto	P	16	44-94	0.5-10	0.08	4.10	A+	1.58	Indus River, Pakistan	Muhammad *et al*. (2016)

P. binotatus	P	92	50-126	1-32	0.19	3.91	A+	N/A	Kerian River, Malaysia	Zakeyudin *et al*. (2012)
P. binotatus	P	76	50-126	1-32	0.19	4.11	A+	1.21	Kerian River, Malaysia	Isa *et al*. (2010)
P. gonionotus	P	32	101-308	12-429	1.08	3.23	A+	N/A	Pedu Lake, Malaysia	Isa *et al*. (2010)

Note: M = male, F = female, P = pooled, n = number of fish samples, A+ = positive allometric, A- = negative allometric, I = isometric, W = weight, TL = total length, K = condition factor, N/A = not available

Annex II. Comparative mesh size of gill nets, catch proportion and sex ratio of Cyprinidae family collected from different habitats

Fishing gears used	Targeted fish species	n	Fish size (mm)		Catch proportion (%)		Sex ratio M:F	Locations	References
			Male	Female	Male	Female			
Gill net	*Osteochilus hasselti*	355	60-190	67-190	57.46	42.54	1.4:1	Sungai Batang River, Indonesia	Present study
Gill net	*Barbodes binotatus*	352	39-85	52-156	52.27	47.73	1.1:1	Tamblingan Lake, Bali, Indonesia	Putri *et al*. (2022)
Gill net, trap, hook and line	*B. binotatus*	347	50-120	46-146	47.84	52.16	1:1.1	Barambai River, Indonesia	Jusmaldi and Hariani (2018)
Cast nets	*B. gonionotus*	274	N/A	180-240	52.55	47.45	1:0.9	Rajshahi city, Bangladesh	Bhuiyan *et al.* (2020)
Scoop net	*Puntius vittatus*	342	N/A	N/A	33.88	66.12	1:2.0	Muvattupuzha river, India	Beevi and Ramachandran (2005)
Cage nets, trap	*P. shalynius*	215	41-67	40-70	47.44	52.56	1:1.1	Umiam River, India	Manorama and Ramanujam (2011)
Cage nets, trap	*P. shalynius*	609	41-67	40-66	46.47	53.53	1:1.2	Umiam River, India	Manorama and Ramanujam (2017)
Cast nets, seine nets	*P. sophore*	1755	19-76	23-91	46.30	53.70	1:1.2	Brahmaputra River, Bangladesh	Ahamed *et al*. (2012)
Cast net, square lift net, conical trap	*P. sophore*	185	36.2-90.2		N/A		N/A	Chalan Beel, Bangladesh	Rahman *et al*. (2012)
Hand net	*P. chola*	52	50-95		N/A		N/A	Hatchery Rawalpindi, Pakistan	Salam *et al*. (2005)
Gill net, cast net, drag net	*P. ticto*	16	43-94o		N/A		N/A	Indus River, Pakistan	Muhammad *et al*. (2016)
Cast net, gill net	*P. sophore*	46	56-119		N/A		N/A	Gomti River, India	Gupta *et al*. (2017)
Hand net	*P. binotatus*	85	40-95.5		N/A		N/A	Pond-cultured, Sabah, Malaysia	Lim *et al*. (2013)

Note: n= number of fish samples, M = males, F = females, N/A = not available