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The weight-length relationship, conditional factor and reproduction of the female cork fish in Sumatra, Indonesia

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ABSTRACT

The characters of growth pattern and conditional factor of cork fish describe its ideal morphological condition between weight and length in various ecosystems of inland waters. Different ecosystems enable the occurrence of variation in these two characters and may affect the reproduction factor of female cork fish analyzed in this study. A total of 118 cork fish specimens were collected from nine inland waters of Sumatra, including rivers (Kampar, Merang and Batang Hari Sembilan), lakes (Ranau, Singkarak and Cala) and flood swamps (Kumpeh, Siak and Lubuk Lampam). Gonad weight, index of gonad maturity (IGM), level of gonad maturity (LGM), oocyte diameter, and the number of eggs were addressed. Data were analyzed for the relationship of weight-length using regression exponential assay, while the conditional factor and reproduction character were tested with the analysis of variance (ANOVA). The growth pattern of all populations was negative allometric (b<3), while the highest significant value of conditional factor was recorded in the population of Ranau Lake (1.63±0.1). The highest reproduction character for gonad weight was found in the population of Batang Hari Sembilan River (6.9±2.9 g), and the highest significant IGM occurred in the population of Singkarak Lake (5.6±2.7%). Whereas, the population of Lampam Swamp recorded the highest egg number (29.198±7.938 eggs). Under mature condition (LGM IV), the population of Merang River showed the largest significant diameter of the oocyte (1.26±0.5 mm) amongst all other populations; thus, they might be utilized as candidates of brood-stock for future cultivation.

INTRODUCTION

Cork fish is one of germplasms of water resources in Indonesia, with economic price of IDR 50,000 - IDR 60,000 / kg. Its high market demand is facing a threat due to the shortage of resource caused by over catch exploitation **(Djumanto *et al*., 2020)**. Its habitat is distributed in inclusive inland waters or isolated geographical areas such as lakes and open inland waters or connected inland waters between areas, viz. rivers and flood swamps. Cork fish that live in inland waters of different water environments,

followed by geographical isolations have potential various morphological characters, reproduction and gene polymorphism **(Ali, 1999; Ahmadi, 2018; Muslimin *et al.*, 2020)**. In 2011, the statistical data of fish catch from inland waters revealed that the cork fish formed the main commodity of the caught fish, with the second highest catch number in the inland waters of Sumatra (9,405 ton) **(Ministry of Marine and Fisheries, 2011)**.

The inland waters of Sumatra Island has three types of waters, viz. rivers, lakes and peat flood swamps, each of which has different water characteristics. Inland waters in Sumatra include the rivers of Batang Hari Sembilan, Merang and Kampar, flood swamps of Lubuk Lampam, Siak and Kumpeh, and lakes of Ranau, Cala and Singkarak. Those waters have different borders of water areas or watersheds.

The weight-length relation and conditional factors of fish can provide researchers with information on growth pattern and fish health **(Muthmainah, 2013; Alahyene *et al.*, 2021; El-Aiatt *et al.*, 2021)**. Growth pattern gives the interpretation on fish shape with the status of fat (positive allometric), slim (negative allometric) or ideal (isometric). Indonesian cork fish from different populations exhibit various trends of growth pattern such as the condition in the cities of Bekasi and Bogor (isometric and allometric, respectively) **(Saputra *et al.*, 2017)**. Whereas, the populations in Kalimantan, South Sumatra had negative allometric of growth pattern **(Muthmainah, 2013; Ahmadi, 2018)**. The environmental capacity of the population impacts cumulatively on the weight-length relationship of fish, which is examined using the analysis of conditional factor and the Fulton analysis.

Water environment is significant for fish to cover their daily need for reproduction purposes and their offsprings. It is a source of habitat and feed, and a target for migration to reproduce, search for feed and mature. In addition, the variety in ecosystems may affect the reproduction. Furthermore, fish potential to generate offsrings is influenced with the environmental conditions; for example, the number of cork fish eggs (*Channa striata*) is higher in China (24,479) than in India (11,811) and Malaysia (9,017) **(Li *et al.*, 2016)**. While, the cork fish in the inland waters of South Sumatra recorded, approximately, 16,486 eggs **(Makmur *et al.*, 2003)**. The quality of fish offsprings depends mainly on egg diameter; large size of fish egg allows the production of egg yolk **(Ali, 1999)**.

Fish reproduction is a radical process to attain sustainable fish production. Natural cork fish and inland cultivation require parent stock of mature male and female cork fish to generate offsprings. The reproduction status of the cork fish stock was addressed in the inland waters of Sumatra, reporting more female stock compared to male, parent of sex mature cork fish of 18 cm- 40cm in range, number of cork fish eggs around 1,141-16,486, and egg diameter between 0.65 mm-1.34 mm **(Makmur, 2006)**.

Information on the reproduction capability of cork fish in nature and hatchery of controlled environment is required to get an the insight on the biological parameter of cork fish reproduction in nature. On the other hand, reproduction character is needed to

get the information on the reproduction of female cork fish, such as the capability in producing eggs, egg diameter and gonad weight. Under dissimilar geography and a variety of fish size associated with the development of the female gonad, all combined would result in different weight-length relationship of cork fish.

Thus, this study aimed to describe the information on the relationship between weight-length and the reproduction of female cork fish (*Channa striata*) from different inland waters in Sumatra. Also, it aimed to figure the reproductive characters of female cork fish such as gonad weight (GW), index of gonad maturity (IGM), gonad maturity level (LGM), egg diameter (ED) and egg number (F).

MATERIALS AND METHODS

2.1. Sampling locations and times

Cork fish were sampled from nine inland waters in Sumatra as catch yield of local fishermen. The location of fish collection is illustrated in Fig. (1). The catching area of cork fish was divided into four provinces: the Kampar River (SK) and Siak Flood Swamp (RS) in Riau Province; Singkarak Lake (DS) in West Sumatra Province; Batanghari Sembilan River (SB) and Kumpeh Flood Swamp (RK) in Jambi Province, and Merang River (SM), Lubuk Lampam Flood Swamp (RL), Ranau Lake (DR) and Cala Lake (DC) in South Sumatra Province. This study was conducted during May 2018 - February 2019. Fish was collected from May 2018- August 2018, and histological observations of cork fish gonad were conducted during August 2018- February 2019 in the laboratory. The preparation for observations of reproduction histological (diameter of oocytes, egg number and gonad histology) of cork fish were carried out in the Laboratory of Development Structure of Animal (SPH), Faculty of Biology, UGM.

Fig. 1. Location of cork fish specimen collection on the island of Sumatra, Indonesia. The location points show: Kampar River (SK), Merang River (SM), and Batang Hari Sembilan River (SB), Lampam Floodplain (RL), Kumpeh Floodplain (RK), Siak Floodplain (RS), Ranau Lake (DR), Cala Lake (DC), and Singkarak Lake (DS). "Image source: Google Earth".

2.2. Materials and equipments

The cork specimens were collected with standard length ranging from 18- 27cm. The samples were collected once from each location, with a total of around 196 female cork individual. Clove oil was used with concentration of 1mg/L, in addition to xylene, toluidine, blue and red staining of haematoxylin and eosin, neutral buffer formalin (NBF), paraffin, and 50-96% alcohol.

Digital balance (OHAUS NVT 1601/3, OHAUS instruments Co., Ltd., Shanghai, China) was used to measure fish weight; while, the standard length was measured using caliper. The histological sections were examined using microscope of Leica DM750 (Germany) and then photographs were captured with its camera of Leica ICC50 E (Germany) under 4× magnification. For reproductive characters, observations were recorded using a microtome, a hot plate, a slide glass, a cover glass and a dissecting set.

2.3. Data Collection

The data of two datasets were randomly collected. The first dataset was related to the weight-standard length of cork fish, while the second was that of the female cork fish gonad (gonad weight, IGM, LGM, egg number and egg diameter). The analysis of weight-standard length relationship (W-SL) was only examined on female cork fish, since the level of gonad maturity could increase the weight of fish influencing the growth pattern of female cork fish **(Ahmadi, 2018)**.

2.4. Measurements of weight-length

The number of collected female cork fish from nine locations ranged from 6- 18 specimens at each collecting site (Fig. 1). They were then anesthetized with clove oil, followed by morphological measurements including standard length (SL) and weight (W). The length and weight of fish were measured using caliper and digital balance (OHAUS), respectively. This observation was conducted to obtain data of relationship of weight-length and conditional factor. Those weight and length were illustrated with the relationship generating allometric and isometric situations. Allometric is the growth condition in which fish length is not equal to its weight, while isometric is the growth condition in which fish length is equal to its weight **(Rodriguez *et al.*, 2017)** using:

$$W=aL^b$$

Where, W = fish weight (gram); L = fish length (mm); a = constant or intercept, and b = exponent or tangential angle. If b value is 3, meaning fish isometrically grow, and inversely if b value is not 3, then fish allometrically grow **(Mitu *et al.*, 2019)**. Data were then analyzed using one way analysis of ANOVA with SPSS program. Conditional factor (CF) was calculated using Fulton analysis **(Jonnson *et al.*, 2012)**:

$$CF=\frac{W\times 100}{L^3}$$

Where, W = fish weight (gram), and L = fish standard length (mm). Fish sex was identified based on genital pore next to the annals fin with the principal identification of **Requieron *et al.* (2012)**.

2.5. Reproductive parameters

One hundred ninety gonads of female cork fish were collected, dissected and fixated using neutral buffer formalin solution for 24h and then washed using 70% alcohol and brought to SPH laboratory, Faculty of Biology UGM for the observation of gonad maturity level (LGM). Meanwhile, the reproductive characters were observed in situ, such as gonad weight (GW), index of gonad maturity (IGM), egg number (F) and egg diameter (ED). LGM was histologically observed starting with the preparation of specimen, fixation, dehydration, clearing, embedding, deparaffination, staining using blue-red (Hematoxylin Eosin) and dehydration. The gonad specimen for histological observation was prepared following the standard method of **Ratucoreh and Retnoaji (2018)**.

The gonad of female cork fish was collected under the steps of dissection on anterior urogenital, gonad collection, the measurement of gonad weight, gonad fixation, histological preparation, calculation of egg number, and the observation on level of gonad maturity using microscope under magnification of 4×. Egg number was gravimetrically calculated using the equation of **Holden and Raitt (1974)**:

$$F = \frac{n \times G}{g}$$

Where, n = egg number of sub sample; G = gonad weight (gram), and g = gonad weight of sub sample (gram).

The egg diameter of fixated gonad was also observed. All parameters were monitored, using binocular microscope and digitalized for the presentation, using image J program. LGM and oocyte diameter were histologically observed using binocular microscope under magnification of 4×.

2.6. Data Analysis

Dataset of weight-length of male and female cork fish was analyzed using statistical assay of exponential correlation and analysis of variance (ANOVA), with confidence level of 95%. The difference in water quality and reproductive parameters (gonad weight, IGM, egg number and egg diameter) amongst locations was statistically tested using ANOVA. Data were processed using program of MS. Excel (2010) and IBM SPSS version 23.

RESULTS

3.1. Weight-Length Relationship (W-SL)

The exponential relationship between W and SL of female cork fish from populations of river, lake and flood swamp is presented in Table (1). The regression assay of W-SL on slope (b) column for all populations was <3, indicating that the growth pattern of female cork fish in this study was negative allometric as presented in Fig. (2). A strong relationship was detected between W and SL, with determination coefficient (R^2) ranging from 0.88- 0.98.

Table 1. Variation in weight-length relationship data and reproductive parameters of female cork fish from different inland water sites in Sumatra

Area	N	SL (cm)	W (g)	*Slope* (b)	r	R^2	GW (g)	IGM (%)	ED (mm)	F
SM	13	25±2.3^{de}	247±57^{cd}	2.23	0.88	0.83	6.1±3.1^{bc}	2.6±1^{b}	1.26±0.5^{c}	16,575±9,700^{bc}
SK	16	26±4.3^{e}	275±116^{e}	2.84	0.98	0.98	6±3.5^{c}	3.1±1.7^{b}	1.07±0.1^{bc}	13,986±17,349^{bc}
SB	10	23±3^{cd}	197±75^{bc}	2.80	0.99	0.98	6.9±2.9^{c}	2.6±1.1^{b}	1.17±0.1^{c}	24,665±12,993^{cd}
RS	6	25±5.1^{de}	257±165^{cd}	2.98	0.97	0.98	3.4±1.3^{b}	1.5±0.5^{ab}	1.11±0.07^{bc}	19,017±11,764^{cd}
RK	11	18±0.8^{a}	93±12^{a}	2.62	0.83	0.71	0.2±0.3^{a}	0.3±0.3^{a}	0.3±0.09^{a}	5,709±5,924^{ab}
RL	13	26±4.5^{e}	271±138^{d}	2.82	0.98	0.95	4.6±2.8^{bc}	1.7±1.8^{ab}	0.95±0.37^{b}	29,198±7,938^{d}
DS	15	19±1.1^{ab}	108±18^{a}	2.65	0.87	0.80	6.1±3.3^{bc}	5.6±2.7^{c}	1.2±0.02^{c}	19,254±12,105^{cd}
DC	16	22±1.7^{bc}	155±34^{ab}	2.72	0.90	0.90	0.3±0.1^{a}	0.3±0.2^{a}	0.15±0.1^{a}	1,583±814^{a}
DR	18	21±1.7^{abc}	148±36^{ab}	2.85	0.95	0.93	0.2±0.1^{a}	0.2±0.04^{a}	0.1±0.01^{a}	469±244^{a}

Note: **N**: Number of specimens; **SL**: Standard length; **W**: Total weight; **b**: Slope of W-SL; **r**: Correlation coefficient; **R^2**: Determinant correlation; **GW**: Gonad weight; **IGM**: Index of gonad maturity; **ED**: Egg diameter and **F**: Egg number. (Area: SM = Merang River, SK = Kampar River, SB = Batanghari Sembilan River, RL = Lampam Swamp, RS = Siak Swamp, RK = Kumpeh Swamp, DS = Singkarak Lake, DR = Ranau Laku, and DC = Cala Lake)

Correlation coefficient (r) between SL-W for all populations ranged from 0.71-0.98. They had strong correlation with the correlation coefficient close to 1.

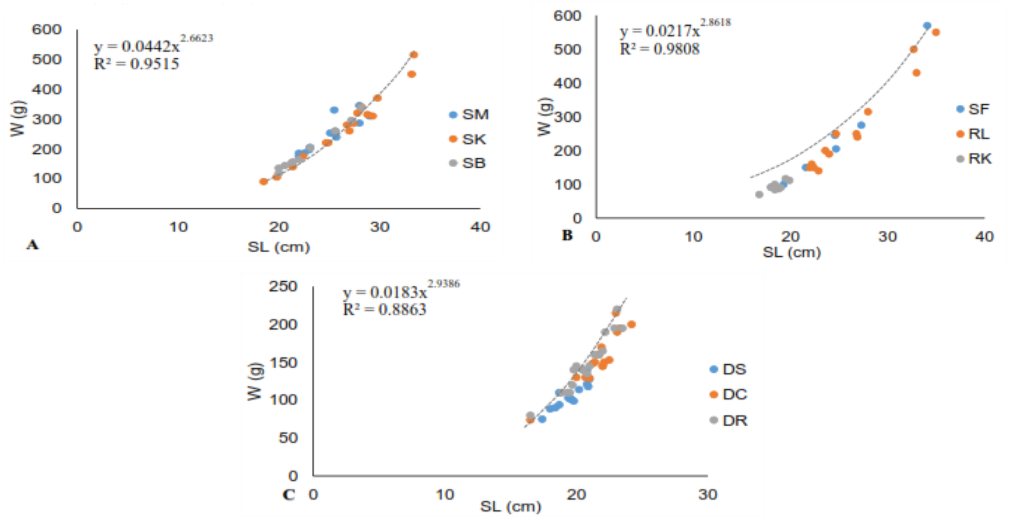


Fig. 2. Regression of weight-length with exponential analysis based on types of population. **A:** River group; **B:** Swamp group, and **C:** Lake group

3.2. Conditional Factor (CF)

The majority of the populations had similar value of conditional factor for female cork fish (Fig. 3A). However, the highest and the lowest values for the conditional factor

of female cork fish were found in DR population (1.63±0.1) and RL population, respectively, and they were significantly differed.

Female fish with standard length ranging from 14-19cm (Fig. 3B) showed higher CF value (1.49), which was not significantly different. On the other hand, the lowest significant difference of CF value (1.27) was recorded from female fish under the standard length ranging from 30- 35cm. The significance of CF value is shown in Fig (3). Nevertheless, overall values of CF were in good condition, suggesting environmental capacity of cork fish in all populations and all sizes, having good impact on its growth and health.

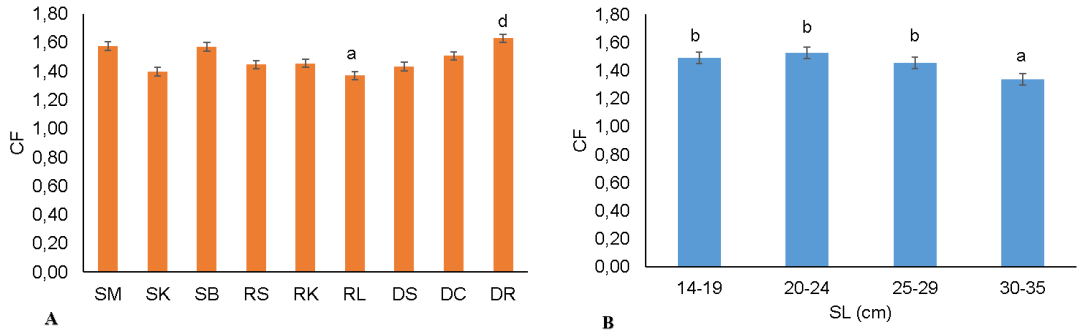


Fig. 3. A: Conditional factor value of female cork fish in nine inland waters in Sumatra. B: CF value of female cork fish according to size groups of SL. (SM = Merang River, SK = Kampar River, SB = Batanghari Sembilan River, RS = Siak Swamp, RK = Kumpeh Swamp, RL = Lampam Swamp, DS = Singkarak Lake, DC = Cala Lake, and DR = Ranau Lake).

3.3. Reproductive parameters

Cork fish from SK population had significant highest SL (26±4.3 cm) and W (275±116 g) ($p<0.05$). Data for reproduction of female cork fish from inland waters in Sumatra was presented in Table (1). The lowest and highest gonad weights were respectively found on DR population (0.2±0.3 g) and SB population (6.9±2.9 g). Index of gonad maturity (IGM) was noted to be lowest (0.2±0.04%) on DR population and highest (5.6±2.7%) on DS population. Furthermore, RL population had smallest egg diameter (0.1±0.01mm) and SM population had the largest one (1.26±0.5 mm). The least egg number (469±244) occurred on DR population and the most one (29,198±7,938) was on RK population.

Histological observation on gonad of cork fish from each location was illustrated on figure 4. Level of gonad maturity on cork fish for all specimens was on level I until level IV. Histological of cork fish on SM population was on level IV (figure 4A). Other populations were found to have maturity level between I and IV (figure 4B-4I). The percentage on level of gonad maturity was presented on figure 5. Maturity level IV with the largest percentage (38%) was found in SM population and other populations had maturity level II with the percentage of (22-67%) in range.

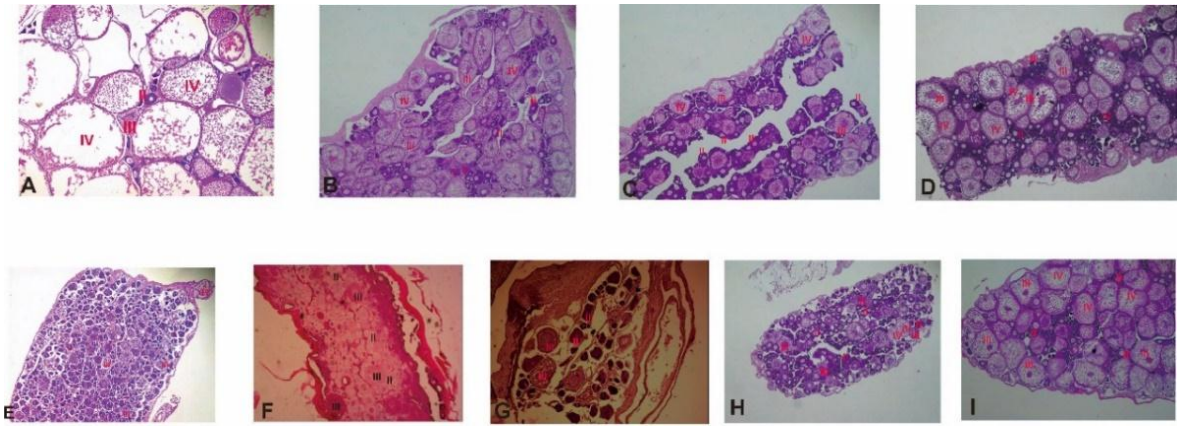


Fig. 4. Histological illustrations of female cork fish from nine populations (A: Merang River; B: Kampar River; C: Batanghari Sembilan River; D: Siak Swamp; E: Kumpeh Swamp; F: Lampam Swamp; G: Singkarak Lake; H: Cala Lake; I: Ranau Lake). LGM is noticed with roman letters on figures such as I, II, III, and IV.

The gonad development on cork fish (Fig. 5) comprised of four stages, i.e., immature, maturing, mature, and spent, based on previous investigation **(Boonkusol *et al.*, 2020; Mahmud *et al.*, 2016)**. The development on reproduction maturity of female cork fish was also observed according to oocyte development (Table 2). It consisted of seven stages, such as: a) Nuclear chromatin, b) Early perinuclear, c) Late perinuclear, d) Yolk vesicle, e) Early yolk granule, f) Late yolk granule and g) Spent ovary, with the characteristics in Table 2.

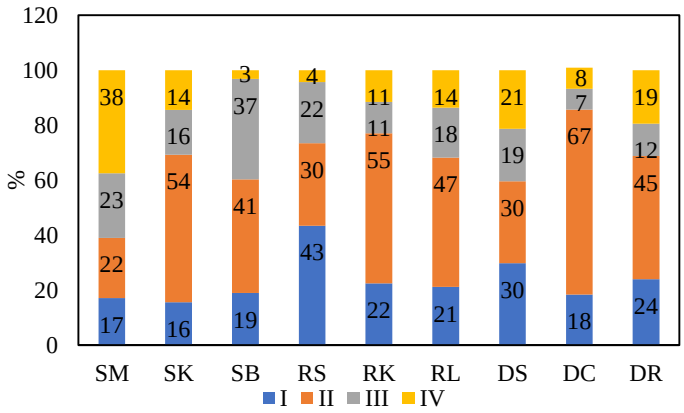
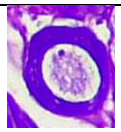
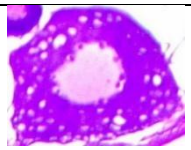
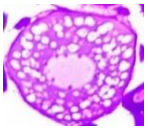
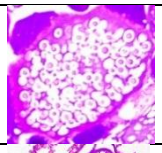
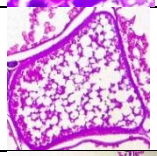


Fig. 5. The percentage of LGM from each population. X axis represents population for SM (Merang River), SK (Kampar River), SB (Batanghari Sembilan River), RS (Siak Swamp), RK (Kumpeh Swamp), RL (Lampam Swamp), DS (Singkarak Lake), DC (Cala Lake), and DR (Ranau Lake). Different color and roman letter describe LGM. Y axis represents the percentage of LGM.

Table 2. The stages of oocyte development in cork fish

Figure of oocyte development	Developmental stages of oocyte	Level of Gonad Maturity
	**Nuclear chromatin stage**: Small cell with nuclear occupying most of cell room. Nuclear on part of cell peripheral.	**I**
	**Early perinuclear stage**: Oocyte enlarges and forms polygon. Nuclear volume also enlarges and rounded. Nuclei are seen occupying cytoplasm room. Oocyte in this stage is still immature	**I**
	**Late perinuclear stage**: oocyte is polygon and sometimes oval. Nuclear volume shrinks, in peripheral, and nuclei spread around cytoplasm.	**II**
	**Yolk vesicle stage**: cytoplasm is filled with yolk bubble or empty vacuole. Nuclear is vaguely seen.	**III**
	**Early yolk granule stage**: nuclear does not appear. Cell room is filled by bubble of yolk protein. Size of oocyte is getting bigger.	**IV**
	**Late yolk granule stage**: oocyte size is bigger than prior stage. Granule yolk does not appear and there is remaining lipid.	**IV**
	**Spent stage**: follicle appears on most cytoplasm and other most in nuclear chromatin. The establishment of new oocyte is seen as initial sign for gonad development.	**IV**

The stage of yolk vesicle was not categorized into mature since small size of nuclei and white nuclear; while yolk granule phase had been considered as mature **(Boonkusol *et al.*, 2020)**. These characteristics indicated the maturity on LGM III in this experiment.

DISCUSSION

4.1. Relationship of weight-standard length

The relationship of weight-standard length on this experiment showed that female cork fish in every location was negative allometric. It was similar with prior study for growth pattern of female *Channidae* fish. Some of them were *C.* with b value of 2.739 and R^2 value of 0.988 **(Koundal *et al.*, 2014)**, *C. striata* in Taiwan with b value for

female of 2.93 **(Li *et al.*, 2016)**, *C. striata* from catch of fishermen in Batang River, Kalimantan with slope (b) value below cube law or negative allometric (2.912) **(Ahmadi, 2018)**. The b value of *C. striata* in Malaysia is negative allometric (2.76) with correlation coefficient of 0.93 **(Ali, 1999)**.

There is also found the relationship of weight-length, which is different with current work, i.e., *C. punctatus* fish in rivers of Gomti, Kolkata and Malihabad, India has b values of 3.026, 2.837, and 2.861, respectively, with regression correlation of 0.9661-0.9928 in range **(Kashyap *et al.*, 2015)**. The relationship of weight-length on *C. punctatus* fish is significantly different for all population **(Singh and Serajuddin, 2017)**. The b value of *C. punctatus* fish on different population reveals different growth pattern, some of them is positive allometric and isometric **(Singh *et al.*, 2012)**.

The b value of *C. striata* fish from nine populations is not recognized yet. Former investigation showed that its population in rivers of Kampar and Musi Banyuasin had variative b value (positive and negative allometric) **(Wahyuni *et al.*, 2017)**, while the swamp population had negative allometric value **(Mutmainah, 2013)**. Similar finding was reported on *C. striata* fish from Bogor exhibiting negative allometric growth pattern (b=1.915) and population of Bekasi with positive allometric growth pattern (b=3.216) **(Saputra *et al.*, 2017)**.

The difference in growth pattern for such *Chanidae* fish is affected by the difference in growth pattern of each size and age of different fish. The alteration of size on life phase of cork fish in nature or various ontogeny has impact on its growth pattern in which lighter weight was found in germ phase (negative allometric) and balance between weight and total length (isometric**) (Ahmadi, 2018)**. During its life cycle, fish could have negative or positive allometric growth pattern. It is due to the occurrence of dynamics of addition and reduction of tissue weight which might be influenced by aspects of variation in sample size, phase of fish growth, and environment **(Datta *et al.*, 2013)**. Fish on larvae phase until mature can change its growth pattern to be isometric and or allometric depending on feed adequacy, sex maturity and feeding habit **(Khan *et al.*, 2012)**.

This study exhibited that both mature and immature cork fish had negative allometric growth pattern. Otherwise, the mature gonad could add and affect the growth pattern **(Froese, 2006)**. In addition to gonad, other factors influencing b value on fish are habitat, area, season, feed adequacy in fish body, sex, health, sampling technique and difference in length of fish sample **(Mitu *et al.*, 2019)**. Difference in growth pattern (relationship of weight-length) is also due to the occurrence of overfishing and competitor on predator of same feed **(Kashyap *et al.*, 2015)** intra-species and inter-species. For example, feed competition of *Channidae* fish in Brahmaputra drainage, India with varying b value of 3.26, 3.04, 2.78 and 2.74 for *C. andrao*, *C. aurantimaculata*, *C. stewartii*, and *C. bleheri*, respectively. Water quality may also affect fish growth pattern, such as temperature, salinity, pH, hypoxia, and eutrophication on *C. punctatus* with b

value <3 **(Khumari and Kumar, 2014)**. Another influencing factor is change of season **(Jisr *et al.*, 2018)**. For instance, *Liza ramada* has b value < 3 on warm, spring, summer, and cold, but its b value is > 3 on winter; *Oblada melanura* has b value < 3 on warm, cold, and winter b<3, but its b value is > 3 on summer **(Jisr *et al.*, 2018)**. Significant different between wet and dry season may has impact on the growth. It is assumed that on dry season fish metabolism is able to process its intestine well thus affect the increment of weight and length of fish.

4.2. Conditional factor

The value of CF for all population in this experiment was ranging of 1.30-1.63, suggesting that fish on all those population was in well-being condition and good fitness. It was presumed that cork fish in this research had good environmental condition compared to that of former investigations with CF value < 1 **(Mutmainah, 2013)**. The value of CF<1 can indicate low water quality on water body such as temperature instability, pH, DO, and sediment charge **(Singh and Serajuddin, 2017)**. Fish with CF value >1 is also assumed in healthy condition and has enough nutrition followed by ideal weight body, but it as presumed that fish is in malnutrition condition if CF value <0.8 **(Ahmadi, 2018)**.

Feed preference also affects CF value as reported on *Brycon falcatus* fish which is collected from nature and maintained in river with and without natural feed showing b value of >3 (positive allometric) and revealing faster weight addition compared to length. However, CF value with natural feed is relatively lower (close to 1) and CF value >1 is found on without natural feed population **(Matos *et al.*, 2018)**.

The value of CF is useful for recognition the health and productivity of fish in inland waters. Low CF value is assumed due to low feed for hunting or many competitors feeding similar type of feed **(Mitu *et al.*, 2019)**. Fulton's (CF) is affected by gonad maturity level of fish on certain season. The CF is used to analyse fish response in environment and fish health correlating with feed, parasite, disease, and fish physiology either in natural habitat or cultivation environment **(Datta *et al.*, 2013)**. Fulton's CF is used to assess well-being, fitness, and comparison of fish weight-length with the healthy assumption if weight quantity is larger than length. CF value is believed as dynamic number on every growth phage of fish species which may have impact on feed abundance and availability, feed competitor, age-sex, and sex maturity **(Singh and Serajuddin, 2017)**.

The findings of this study revealed the lowest CF value of female cork fish on RL population (1.37) due to it was on gonad development stage affecting its less feeding behaviour because of feed competition intra-species and inter-species. Fish consumption behaviour on each LGM would experience the difference in total of feed consumption **(Koundal *et al.*, 2014)**. Gonad formation until reaching the maturity may influence feeding frequency and performance **(Singh *et al.*, 2012)**, thus female cork fish on difference population showed variative CF value.

Cork fish in this study based on its size had different CF value. Similar finding was reported on another research grouping conditional factor value of Fulton's (CF) on Channa punctata into six weights. The value of CF on male and female *C. punctata* was ranging of 1.5-2.23 and 1.76-2.37, respectively. However, fish with size of 40-60 cm in range had the highest CF value, whereas that of 30-35 cm in size had the lowest CF value. It could be due to LGM level on each group was different and feed requirement on such level had different consumption level on *Chanidae* fish **(Khumari and Kumar, 2014)**. Another investigation found that cork fish (*Channa striata*) when it reaches standard level of 40-60 cm in range had more feeding behaviour and it was predicted that it had good gonad maturity condition **(Koundal *et al.*, 2014)**. The gap of this current project and previous one is due to aspects influencing fish growth pattern and Fulton's value, i.e., quantity and quality of feed, sex development, feed competition **(Khumari and Kumar, 2014)**. High CF value on cork fish with standard length of 14-29 cm indicated that it had more feeding behaviour than that with size above 30 cm experiencing gonad development period thus its feed consumption level was predicted to be lower.

4.3. Reproductive parameters

The heaviest significant different gonad of cork fish was found on SB population (6.9±2.9 g), the highest significant different IGM was documented on DS population (5.6±2.7%), the largest significant different egg diameter was recorded on SM population (1.26±0.5 mm), the most significant different egg number was noted on RL population (29.198±7.938), and 38% of LGM on cork fish of SM population had reached 4 level. Gonad weight in this study was found to be vary with the significant different of lowest and heaviest about 0.2 g and 6.9 g, respectively, whereas the significant different of lowest and highest IGM were 0.2% and 5.6%, respectively. Cork fish in Thailand has the lowest and highest IGM of 0.14% and 6.15%, respectively **(Boonkusol *et al.*, 2020)**.

The lowest egg number in this experiment (469) was almost similar to that of Bekasi population (576) **(Saputra *et al.*, 2017)**. Cork fish in Taiwan has egg number of 2,284-96,498 in range **(Li *et al.*, 2016)**. Cork fish in flood swamp of Muara Enim Regency, South Sumatra is able to produce ranging of 1,567-16,486 eggs **(Makmur, 2006)**.

The ovary diameter of cork fish on SM population (1.26 mm) was belonged to large compared to other investigation. Ovary diameter for mature and immature cork fish was ranging of 736-810 µm and <300 µm, respectively **(Ali, 1999)**. Oocyte diameter of cork fish is reported to be 280-1.257 µm in range **(Mahmud *et al.*, 2016)** and ovary of mature cork fish is ranging from 1,000 µm **(Ali, 1999)**. Ovary diameter of *Channa gachua* is 0.54-1.12 mm in range **(Milton *et al.*, 2017)**. The lowest and highest ovary diameter on *C. punctata* in Ganga River, India is 0.34 mm and 1.10 mm **(Prasad *et al.*, 2011)**. Oocyte diameter of *C. striata* is 0.022-0.528 mm in range under immature and it reaches up to 1.48 mm under peak of mature **(Irmawati *et al.*, 2019)**. Difference in egg diameter of

Channidae in Sumatra is significant in each location. The average of egg diameter on *C. lucius* under LGM III and IV in Singkarak, Jambi and Riau are 1.12 mm and 1.35 mm, 1.28 mm and 1.53 mm, as well as 1.32 mm and 1.7 mm **(Azrita and Syandri, 2013)**. Egg diameter of *Channa striata* in Regency of Muara Enim, South Sumatra under LGM III-LGM V level is 0.72-1.13 mm **(Makmur, 2006)**.

The highest significant different IGM on DS population (5.6±2.7%) of this work was larger than that of previous study. Different IGM on *Chanidae* fish is also reported by prior researchers. IGM of cork fish IGM in flood swamp of South Sumatra is reported to be 0.03-4.83% in range **(Makmur *et al.*, 2003)**. IGM of Bogor population (0.67-9.94%) is lower than that of Bekasi population (2.03-8.17%) **(Saputra *et al.*, 2017)** and ranging of 0.01-4.83% **(Ferdausi *et al.*, 2015)**. This difference in gonad maturity was assumed due to weather factor in which rain fall and height of water surface faster the gonad maturity on fish **(Ali, 1999; Li *et al.*, 2016; Boonkusol *et al.*, 2020; Milton *et al.*, 2017; Ferdausi *et al*., 2015)**.

Mature cork fish in this study had standard length and body weight of 19-26 cm and 108-275 g in range, respectively, particularly on populations of SM, SK, SB, and DS. That maturity is initiated on fish with size of 15.4 cm and 18 cm for male and female, respectively **(Makmur *et al*., 2003)**. Cork fish had initial gonad maturity on various sizes. Mature cork fish in Malaysia had length and weight of 25-47 cm and 150-785 g in range, respectively **(Ali, 1999)**. Female cork fish in Taiwan has gonad mature under total length of 28 cm **(Li *et al.*, 2016)**. *C. punctatus* with gonad mature in Gangga River, India is found from the size of 12.5 cm **(Prasad *et al.*, 2011)**. Female *C. striata* in regencies of Barru and Bantaeng (South Sulawesi) is found to be mature on the total length of 11.5 cm - 23 cm in range **(Irmawati *et al.*, 2019)**.

Cork fish in this experiment with gonad maturity level (LGM) III above 15% was found in populations of Merang River (SM), Kampar River (SK), Batanghari Sembilan River (SB), Siak Swamp (RS), Lampam Swamp (RL), and Singkarak Lake (DS). Those six populations had weight above 200 g, excluding DS population with 108±18 g in weight. However, this population had relatively smaller size (standard length and total weight) as well as relatively large gonad weight and egg size. Meanwhile, SK population had the highest size (fish standard length-weight) and relatively smaller egg size than that of DS population. It was assumed that cork fish on DS population experienced birth period (LGM IV), while other populations were towards that period. Cork fish in mature reproduction period reduces its feed frequency thereby its weight could decrease, fish weight would increase, and it was found allometric cork fish **(Khan *et al.*, 2012** and **Prasad *et al.*, 2011)**. Factors affecting fish growth are biotic, abiotic, feed availability, season, habitat condition, sex formation, reproduction maturity and water temperature **(Singh *et al.*, 2012)**. Gonad development process is also influenced by weather and tide, as well as in general fish mating period during monsoon **(Mahmud *et al.*, 2016)**. Other factors influencing reproduction of mature fish and larvae development are water physical (temperature, pH, and photography) and biological (abundance of aquatic plant and animals) characteristics) **(Boonkusol *et al.*, 2020)**.

CONCLUSION

The population of female cork fish from Merang River had the lowest negative allometric relationship of weight- standard length amongst other populations. The conditional factor of all populations was good. It was also found that the maturity level of gonad III-IV and egg diameter of cork fish population in Merang River were higher than those of other populations. Variation on population of cork fish population may be further used for development and investigation of pure parent strain in the future.

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