

Growth performance of hatchery-reared mahseer (*Tor soro*) based on different cultural periods

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Abstract. This study was carried out to evaluate growth performance, length-weight relationship, and condition factors of mahseer based on different culture stages. Fish larvae were produced by artificial spawning and reared in indoor tanks. Fingerlings were stocked in three replicate concrete ponds, fed with commercial pellets, and sampled within 4, 6, 12, and 24 months. In the first six months, the growth of fish increased much slower than in the 12 and 24 months of cultures. There were no significant differences in total weight at six months of culture ($p>0.05$) compared with two and four months. Fish started to grow significantly different from 12 and 24 months of culture periods ($P<0.05$). The specific growth rate in the four-month culture was 2.01 ± 0.40 (%) and slightly increased in six-month culture periods ($2.10\pm 0.22\%$), but it started to decrease with increasing the day of culture (12 months : $1.58\pm 0.09\%$ and 24 months: $1.13\pm 0.04\%$). Negative allometric trends ($b<3$) were implied for all stages, but a high correlation occurred in the 12 and 24-month rearing periods with the equation $W=0.331\times L^{1.527}$ and $W=0.375\times L^{1.332}$, respectively. The condition factor ranged from 0.99 to 1.04, indicating fish tend to be poor, long, and thin.

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1 Introduction

Mahseer has been well known as an economic and cultural significance of cyprinid fish in Asia, especially South and Southeast Asia [1]. One of Indonesia's highly valued Mahseer species is *Tor soro*, primarily in Sumatra, Java, and Borneo islands [2]. For a long time, this species has represented an iconic tradition for cultural ceremonies, especially in North Sumatra. Recently, the price of the fish reached IDR 500.000 (USD34)/kg. It is significantly higher than the price of African catfish (*Clarias* sp.), Striped catfish (*Pangasius hypophthalmus*), Tilapia (*Tilapia niloticus*), and Snakehead (*Channa striata*), ranging from IDR 20.000 to 100.000 (USD 1.5 to 6). Mahseer production mainly relies on the capture fisheries in the natural habitat [3]. In the last decades, over-exploitation and habitat degradation have threatened the fish stock population, which impacts the endangered status of the fish in some areas [4]. Thus, it is essential to increase the production of this species by aquaculture.

Since 2011, the Research Institute for Freshwater Aquaculture and Fisheries Extension (RIFAFE) in Bogor, Indonesia, has successfully domesticated the fish. The hatchery technology has been established for seed production and distributed to its original habitat for conservation [5]. Cultured mahseer can be obtained from sure fish farmers as breeding technology has been transferred to the farmers in several Indonesian provinces and the regions where this species still exists. However, the development of mahseer aquaculture has not been optimal yet as the fish is reported to have a low growth rate [6]. Studies to evaluate the growth performance of the fish commonly were conducted in wild mahseer *Tor soro* [7-8]. Still, there is a lack of scientific information on the growth performance of cultured mahseer species.

The growth performance of fish in the aquaculture production system differs from that of fish in the wild habitat [9]. The growth of cultured fish primarily depends on feed intake and quality, stocking density, sex, age, genetic variance, and water quality parameters [10]. Here, we investigated the growth performance of cultured mahseer based on different ages, especially its culture period representing the nursery, growth, and brood-stock stages. Growth, defined as increased body dimensions over time, can be reported using absolute weight, relative weight, and specific growth rates [11]. Additionally, length-weight relationship and factor conditions can be used to assess the growth performance of the cultured fish. Length-weight relationship (LWR) is an essential factor in fisheries and aquaculture fields to estimate fish weight from the length, to measure body condition in selected fish species, and to compare morphological parameters in different populations and regions [12-13]. Meanwhile, the condition factor (K) value is frequently used to quantify the physical well-being of the fish [14]. The K value is associated with age, gender, growth and maturation phases, diet, and environmental conditions [15-16]. The present study evaluated growth performance, length-weight relationship, and condition factors of Indonesian Mahseer (*Tor soro*) based on different culture periods. Data and information related to fish growth patterns are essential for initial aquaculture development studies.

2 Materials and methods

2.1 Material

Broodstocks (375 individuals) were collected from semi-permanent ponds at the hatchery facility of the RIFAFE, Bogor, Indonesia. Sexually mature fish were selected by checking external urogenital organs and ovarian maturation stages. Mature females were determined based on the performance of eggs using the cannulation method, while the stripping method

was conducted to check the sperm of mature male fish. Commercial hormone Ovaprim™ was administrated intramuscularly at a 0.6 ml/kg body weight dose to accelerate broodstock maturation. After 12 hours, the eggs and sperm were stripped and mixed in a container with NaCl solution. The fertilized eggs were incubated in rectangular incubation tanks, and commonly, fish larvae hatched within 24 hours. After four days, the first feeding was started using artemia for 14 days. Subsequently, the larvae were fed commercial diets (crumble) for two months to reach the fingerling stage.

The two-month fingerlings measured 1.58 ± 0.06 cm in length, weighed ± 0.01 g, and were stocked in three replicate concrete ponds (2×1 m²) with a density of 125 fish per m². Concrete ponds have circulation systems with a water level of 80 cm. During the experiment, fish were fed with commercial pellets (28% protein) about 3% body weight twice daily. Fish sampling was carried out using a completely randomized design of about 20% from stocking density based on different culture periods, including the fingerling stage (4 months), growing stage (6 and 12 months), and broodstock stage (24 months). Before measurement, fish were anesthetized (Ocean Free, five mL/L) in an anesthetic solution tank. The standard length, total length, and weight of fish in each pond were measured using a flexible ruler (accurate to 0.1 cm) and a digital balance (precise to 0.1 gram), respectively. The standard length was measured from the snout to the last vertebrae, while the total distance was calculated from the nose to the caudal fin. Water parameters, including temperature, dissolved oxygen, and pH, were measured during the experiment, ranging from 21-26°C, 4.49-7.23 ppm, and 5.0-6.0, respectively.

2.2 Data analysis

2.2.1 Analysis of Specific Growth Rate (SGR)

The growth parameters were analyzed in this research, including absolute growth, specific growth rate (SGR), the length-weight relationship, and condition factor (K). Absolute growth includes absolute weight ($\Delta W = W_t - W_i$) and absolute length ($\Delta L = L_t - L_i$), where w_t/l_t is the final weight/length, and w_i/l_i is the initial weight/length. The specific growth rate (SGR) was used to identify the growth rate of the fish within the Mahseer population in different culture stages. SGR refers to the percentage increase of fish in size per day [11] (Hopkins, 1992), calculated by :

$$SGR = \frac{\ln W_t - \ln W_i}{t} \times 100 \quad (1)$$

\ln =logarithm natural, w_t =the final weight, w_i =the initial weight, and t =day's cultured period.

2.2.2 Analysis of length-weight relationship

The relationship between the fish's length (L) and weight (W). samples were calculated using the logarithmic transformation of the equation [17]:

$$W = aL^b \quad (2)$$

The value of 'a' refers to the intercept of the regression curve, and the b value is the regression coefficient. The degree of association between L and W was calculated using coefficient determination (R²). The 'b' value indicates fish growth models whether the fish

is isometric ($b=3$), allometric positive ($b>3$), or negative allometric ($b<3$). Using a t-test with a 0.05 significance level, we determined if the mean value of b was significantly different from 3.

2.2.3 Fulton's condition factor (K)

Fulton's condition factor (K) was calculated to assess the fish condition [18] estimated from the formula :

$$K=WL^{-3} \times 100 \quad (3)$$

'W' is the weight of the fish in grams, 'L' is the length of the fish in centimeters, and we employ the value 100 to ensure that the 'K' value approaches unity. The condition factor serves as an indicator of the overall well-being of the fish within their habitat. The 'K' value, representing the fish's condition factor, ranges from 0.84 to 1.12. This 'K' value is a predictive measure of the fish's physical condition, helping categorize them as lean or plump. A 'K' value of 1.00 suggests that the fish's condition tends toward being poor, indicating a long and slender body shape. Conversely, a 'K' value around 1.20 indicates that the fish is in moderate and acceptably proportioned condition [20].

3 Results and discussions

The growth of Indonesian mahseer commonly increased in line with increasing culture periods (figure. 1). In the first six months, fish growth increased much slower than in the 12 and 24 months of cultures. There were no significant differences in total weight at the month of culture ($p>0.05$) compared with two and four months. The total weight of the fish started to show a significant difference from the 12-month and 24-month culture periods ($P<0.05$). The experiment's most significant growth occurred from 12 months (9.86 ± 2.72 gr) to 24 months (153.60 ± 21.39 gr). There were significant differences in total length among periods of culture, while the standard length of fish was not significant differences between two-month and four-month periods. Specific growth rate-based weight in the four-month culture was 2.01 ± 0.40 (%) and slightly increased in six-month culture periods ($2.10\pm 0.22\%$), but it started to decrease with increasing the day of culture (12 months: $1.58\pm 0.09\%$ and 24 months: $1.13\pm 0.04\%$). This trend was similar to SGGR-based length (Table 1).

Significant differences were started from 6 months to 24 months of culture periods. The growth performance of fish species is an essential factor impacting economic benefits in commercial aquaculture production [9]. The information about the growth patterns helps evaluate the rearing process of fish species to improve the production and profit of the business. In pond aquaculture, growth primarily depends on feed consumption and quality, stocking density, culture age, and water quality [10]. As the increased and decreased growth can be properly understood, it can be used to determine the harvest time and minimize input and waste to the pond.

In the study, cultured Mahseer *Tor soro* (SGR $1.13\pm 0.04\%$, 24 months) grew faster than wild mahseer. Over a 32-month rearing period, the SGR of three mahseer *Tor soro* wild populations was only around 0.61 percent [21]. However, observation on the growth of mahseer was categorized as slow growth performance compared with other cultured cyprinid fish. *Tor soro* had a lower growth rate than Indian major carp *Catla catla* (341.55 ± 38.07 gr, SGR: $3.01\pm 0.27\%$) and *Labeo rohita* (246.21 ± 32.81 gr, SGR: $2.31\pm 0.35\%$), grass carp *Ctenopharyngodon Idella* (288.03 ± 60.90 gr, SGR: $2.85\pm 0.095\%$) and silver carp *Hypophthalmichthys molitrix* (276.52 ± 50.21 gr, SGR: $2.85\pm 0.095\%$) [22]. Investigation on other mahseer species conducted by [23] revealed that

T. tambroides could reach an average weight of about 179 gr (100 to 270g) over 15 month rearing period, with SGRs value at 5 to 15 months of age were 2.1-6.4% and 0.09-1.87%, respectively. Specific growth rates (SGRs) of *Tor soro* declined with increasing age. This condition also occurred in other mahseer species, such as *Tor tambroides* and *Tor douronensis* [23]. The growth of Indonesian mahseer was significantly lower below the 12 months compared to other culture periods, indicating that nutrient value in these stages likely did not meet the requirements for optimal growth. *Tor soro* is categorized as omnivorous fish with the leading food in the natural habitat, including phytoplankton, crustaceans, insects, rotifers, and oligochaete [24]. Thus, it is essential to understand the nutritional requirements for the optimal growth of this species. The growth of *Tor soro* fingerlings at four months and six months culture periods only reached 0.28 ± 0.06 g and 1.06 ± 0.32 gr, respectively. It was much lower than a six-month fingerling of *Tor douronensis* (5.1 gr, 3.7 to 7.2 g) [23]. Using a fish diet with 45% protein content can improve the growth performance of Mahseer *Tor pitutora* around three-fold from 0.24 ± 0.05 gr (fed with 30%) to 0.61 ± 0.01 gram over four-month rearing periods [25].

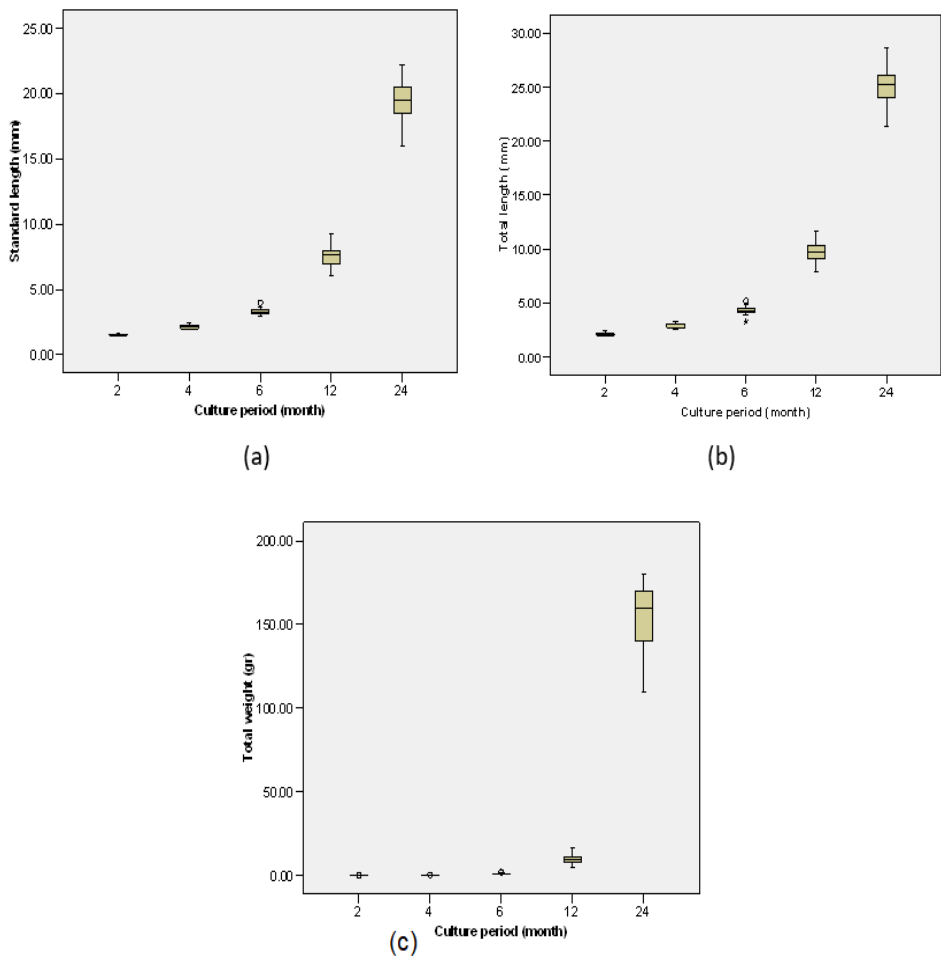


Fig. 1. The growth of Mahseer *Tor soro* includes (a) standard length, (b) total length, and (c) total weight based on different culture periods.

Table 1. Length and weight, specific growth rate, estimated weight, and condition factor of the Indonesian Mahseer (*Tor soro*).

Parameter	Day of culture (month)				
	2	4	6	12	24
Length (mm)					
Minimum	2.0	2.6	3.3	7.9	21.4
Maximum	2.4	3.3	5.2	11.7	28.7
Average±SD	2.14 ± 0.12	2.93 ± 0,22	4.35 ± 0.38	9.74 ± 0.92	24.93 ± 1.54
Weight (g)					
Minimum	0.06	0.21	0.7	5.1	110
Maximum	0.1	0.4	1.5	16.7	180
Average±SD	0.08 ± 0.01	0.28 ± 0.06	1.06 ± 0.32	9.86 ± 2.72	153.60 ± 21.39
Specific Growth Rate (SGR)					
Parameter	Day of culture (month)				
	2	4	6	12	24
SGR-Total Weight (%)	-	2.01±0.40	2.10±0.22	1.58±0.09	1.13±0.04
SGR-Standard Length (%)	-	0.56±0.16	0.62±0.07	0.52±0.04	0.38±0.01
SGR-Total Length (%)	-	0.52±0.18	0.59±0.10	0.50±0.04	0.37±0.01
Ws (Estimated Weight)					
Minimum	0.08	0.27	0.57	5.16	120.12
Maximum	0.09	0.29	1.46	16.30	167.18
Average±SD	0.083±0.00	0.28 ± 0.01	1.02 ± 0.18	9.74 ± 2.66	151.21 ± 19.59
Condition Factor					
Minimum	0.83	0.71	0.68	0.94	0.84
Maximum	1.23	1.39	1.74	1.14	1.14
Average±SD	1.00 ± 0,13	0.99 ± 0,20	1.04 ± 0,23	1.01 ± 0.05	1.02 ± 0.07

Based on condition factor (K), fish under the six-month culture period were lower (0.99-1.00) than over six-month periods (1.01 to 1.04), but there were no significant differences among culture periods (Table 1). The relationship between the mahseer's length and weight suggested that the growth of the fish was allometrically negative ($b < 3$) (Fig. 2). However, the correlation value (b) of fish under six months condition were low, ranging from 0.02 to 0.20. The allometric negative was established in the 12 and 24-month culture period using the equation $W = 0.331 \times L^{1.527}$ ($R^2 = 0.970$) and $W = 0.375 \times L^{1.332}$ ($R^2 = 0.791$), respectively.

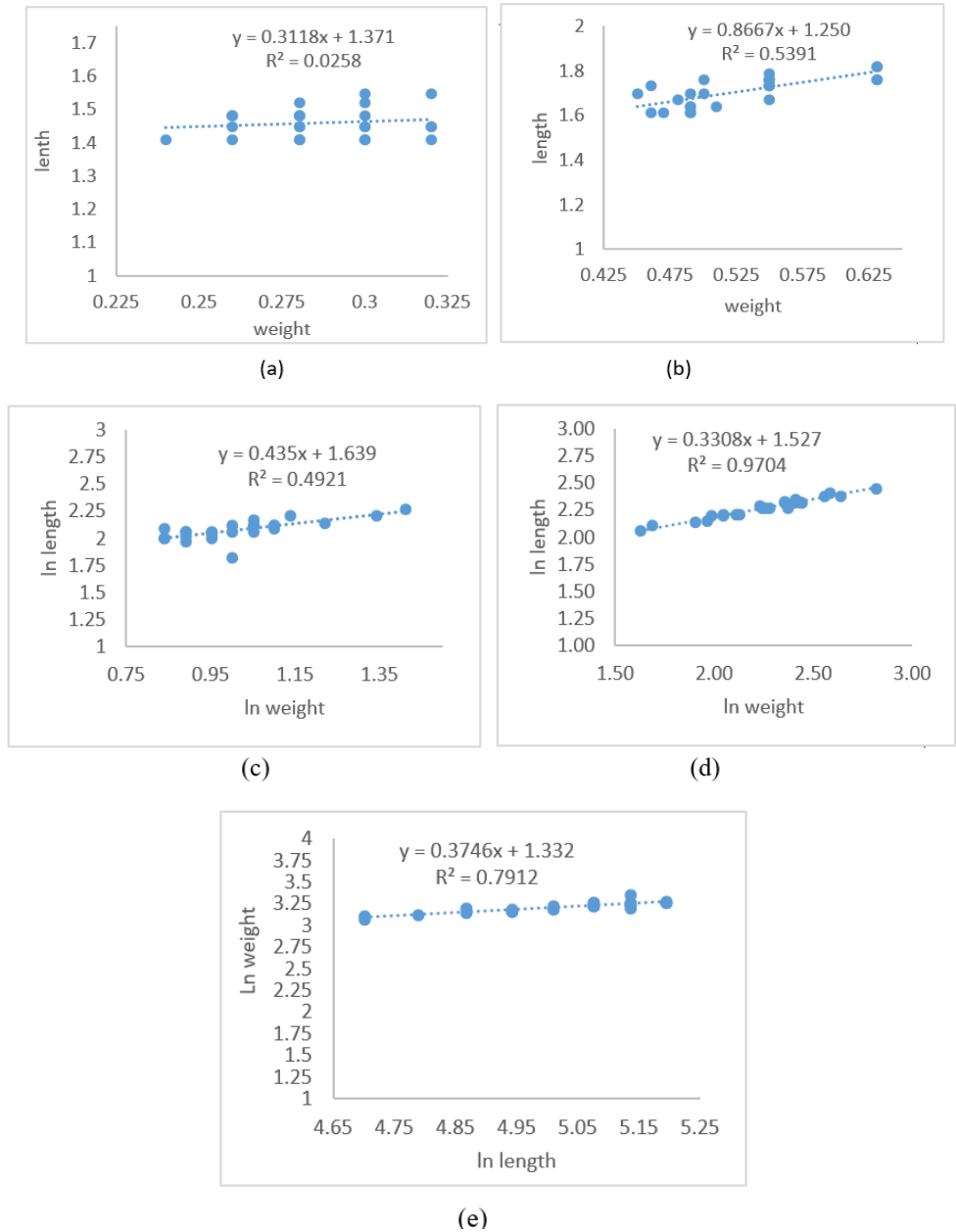


Fig. 2. Length-weight relationships (LWRs) of Mahseer *Tor soro* calculated from 5 different culture periods including (a) 2 months culture, (b) 4 months culture, (c) 6 months culture, (d) 12 months culture and (e) 24 months culture period.

The growth pattern of fish was allometric negative ($b < 3$), indicating that the increase in length was greater than weight [26]. Negative allometric suggests that the fish is becoming tinnier as it increases in length [27-28]. The fish trend was commonly allometric negative in line with the observation of wild *Tor soro* in the natural habitat [8]. However, the magnitude of the regression coefficient (b) of fish below six six-month periods had a lower

correlation value than 12 months and 24 months of culture periods. The different values of b in the length-weight relationship can be affected by environmental factors, gender, maturity level of gonads, and feeding rate [29-30]. The condition factor (K) is vital in aquaculture production systems. It is a crucial parameter for predicting the specific conditions of cultured fish and their physical capacity to thrive and reproduce [31]. The condition factor (K) of the Mahseer ranged from 0.99 to 1.04. This indicated that the condition of fish tends to be poor, long, and thin [20], or the fish performed a plump shape [19]. The condition factor of fish can be influenced by various factors, including age, sex, growth, maturation stage, diet, and environmental conditions [15-16]. Concerning feed quality, factor condition commonly increases as the diets are optimum for fish growth [32]. As the environmental condition was optimal for fish growth, it can be suggested that improving diet quality and breeding programs is essential to accelerate the growth of Indonesian mahseer.

4 Conclusion

The growth of mahseer *Tor soro* varied across different culture periods, with this species generally displaying slower growth rates when compared to other cultured cyprinid fish. The growth of fish was not significantly different below the six months, indicating that nutrient value in these stages likely did not meet the requirements for optimal growth. Negative allometric trends implied to all stages of cultured fish. Condition factors indicated that fish are poor, long, and thin. This information suggested that rearing management needed improvement for optimal fish growth to accelerate the species' economic benefits.

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