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# Comparison of the Morphology of Local Indonesian Fish (Tor soro) from Cultivation and Rivers Habitats on the Island of Java

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### *Abstract*

*Mahseer fish is a local Indonesian fish whose population is decreasing in nature. Cultivation and restocking are conservation efforts aimed at maintaining the sustainability of natural populations. However, low genetic variation is often found in cultivated fish populations, making this an obstacle when released into the wild. Morphometric measurements are an efficient way to determine the population status of cultivated and wild Mahseer fish, which also provides initial information that has never been revealed before for the Mahseer fish species Tor soro on the island of Java. T. soro fish samples collected from the KF Balong fish pond in Subang, West Java, and the Progo tributary in Central Java. Nineteen morphological traits were used as morphometric data and analyzed using Principal Component Analysis (PCA). The results showed significant differences between cultivated ponds and wild populations, with PCA separating populations based on morphological traits, such as standard length (SL), body depth (BD), pre-anal length (PAL), body width (BW), pre-anal length (BW). -Dorsal (PDL), pre-ventral length (PVL). These findings indicate that the Mahseer fish species T. soro is able to maintain most of its non-functional characteristics in cultivation habitats, while functional characteristics such as BD adapt to environmental conditions. In addition, body deformities of Mahseer fish are also found in cultivated populations but not in wild populations.*


***Keywords:*** *Aquaculture, Farmed Fish, Mahseer Fish, Morphometry, Wild Fish.*

## Introduction

Mahseer fish is a freshwater species belonging to the subfamily Torinae, order Cyprinidae. The genera Neolissochilus and Tor are members of the Torinae family found in the Indo-Malaya region. The families Torinae and Barbinae are subfamilies of the order Cyprinidae that exhibit similarities in the morphology of each genus. The revision and redescription of species within the second group of subfamilies is a subject of ongoing discussion among taxonomic researchers (Nelson et al., 2016; Tan & Armbruster, 2018).

Mahseer fish exhibit distinctive morphological features that facilitate their identification. These characteristics encompass expansive, smooth scales, a dorsal fin composed of nine segmented

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rays with the terminal ray lacking branching, a mentum lobe situated on the inferior mandible, and a lower jaw characterized by a blunt configuration. (Roberts & Khaironizam, 2008; Yang et al., 2012, 2015).

Mahseer fish predominantly inhabit upstream rivers in mountainous regions. These species require clear, fast-flowing water habitats, characterized by a rocky sand bottom substrate with a depth ranging from 13 to 100 cm, dissolved oxygen levels between 5 to 7 mg/l, and a pH of 6-7 (Safitri et al., 2021).

The mahseer fish possesses significant value as a cultural and religious symbol, a recreational target for anglers, a nutritional resource, an indicator of ecosystem functionality, and a provider of associated ecosystem services (Das & Binoy, 2023; Lau et al., 2021; Muchlisin, Nur, et al., 2022; Pinder, 2020; Pinder et al., 2015, 2019). Despite its ecological significance, the mahseer population faces severe threats from various anthropogenic factors, including dam construction, water pollution, overexploitation, and habitat destruction (Muchlisin, Fadli, et al., 2022; Pinder, 2020).

Mahseer fish populations in the Asian region, such as the species T. putitora, T. rimadevii, and T. larerivitatus, are classified as endangered. Furthermore, two species in Indonesia, T. tambra and T. tambroides, are currently estimated to be experiencing population decline in riverine habitats (Jha et al., 2018; Kottelat, 2018; Kottelat et al., 2018; Pinder et al., 2018).

Cultivation and restocking represent conservation efforts to preserve mahseer fish populations in their natural habitats; however, these initiatives encounter challenges due to the paucity of genetic and morphological data on mahseer fish, which may result in potential incompatibility with environmental conditions in natural habitats upon release. The necessity for morphological measurements between cultivated and wild fish populations arises from the need to determine phenotypic changes that influence adaptability. (Onyekwelu et al., 2021).

This phenomenon occurs because aquatic organisms maintained in cultivation containers tend to exhibit increased genetic uniformity in their progeny due to inbreeding, bottleneck effects, and genetic drift (Tizkar et al., 2020). Morphometric measurements provide quantitative data on morphological characteristics influenced by environmental conditions, thereby reflecting the growth and genetic composition of each population.

This study compares the morphology of Mahseer T. soro fish from cultivation ponds in Balong KF, Subang, West Java, with specimens from wild habitats in the Grabag River, Kanci River, and the main channel of the Progo River. The novel contribution of this research is the elucidation of variations in morphometric characters of indigenous Indonesian fish from cultivated and wild populations, which have not been previously investigated. These findings can serve as a reference for developing local fish cultivation strategies to produce broodstock capable of adapting to environmental conditions upon release into natural habitats.

## Materials and Methods

### Sampling Location

The sampling locations in this study were situated in the Subang, West Java and Magelang, Central Java regions, as presented in Table 1. Mahseer fish from cultivation ponds were obtained from Balong KF, Subang, West Java. Conversely, the wild population of Mahseer fish was sourced from the Kanci River, the Grabag River (a tributary that flows into the Progo River), and the main course of the Progo River in Magelang, Central Java (lihat Gambar 1).

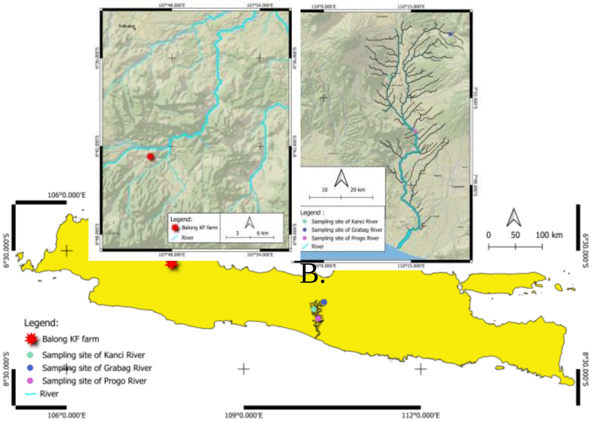



Figure 1. The research locations are (A) the KF Balong location in Subang, West Java, (B) the sampling location for mahseer fish in the Progo River Basin (Kanci River, Grabag River, and Progo River) in Central Java, Indonesia.

| Sample origin | Species | Location | GPS Coordinates |
|---|---|---|---|
| Balong KF | *T.soro* | Subang, West Java | 6°42'42.84"S 107°46'28.21"E |
| Kanci river | *T.soro* | Progo Watershed, Central Java | 7°25'37.78"S 110°11'30.78"E |
| Grabag river | *T.soro* | Progo Watershed, Central Java | 7°22'37.62"S 110°21'46.79"E |
| Progo river | *T. soro* | Progo Watershed, Central Java | 7°38'43.10"S 110°15'41.52"E |

Table 1. The Coordinates of Samples Locations.

**The Mahseer Fish Samples**

A total of 29 samples were taken from the Progo Watershed, Magelang, Central Java, and Balong KF, Subang, West Java (see Figure 1). Each sample is labeled according to location and individual number, with the following description:

B = Balong KF

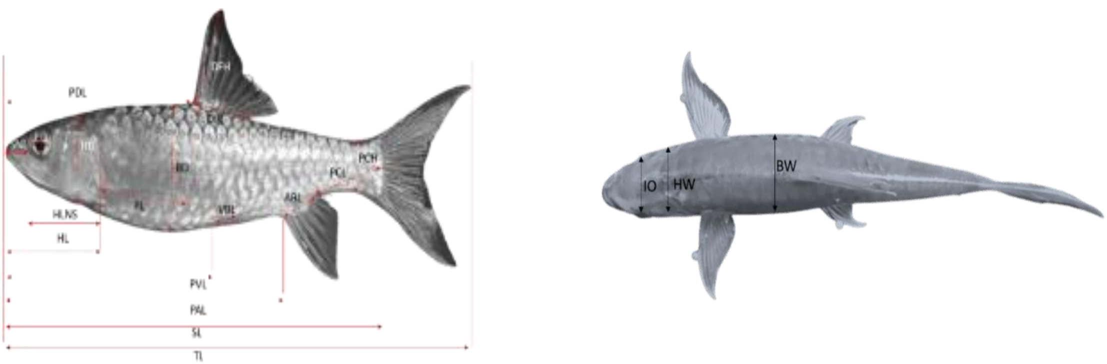
K = Kanci River

G = Grabag River

P = Main chanel of Progo River

1-16 = Sample number

Fish samples were photographed and morphometric measurements were carried out using Digimizer version 6 image analysis software. Morphometric characters (see Figure 2) were used to identify fish from the sampling location (Haryono & Tjakrawidjaja, 2006; Rahayu, et al., 2013).




A

B

Figure 2.

Morphometric characters of mahseer fish. Ventral view (A), Total length (TL), Standard length (SL), Pre-anal length (PAL), Pre-ventral length (PVL), Head length other than snout (HLNS), Snout length (SNL), Base length dorsal fin (DFL), anal fin base length (ABL), peduncle length (PCL), pre-dorsal length (PDL), pectoral fin length (PL), eye diameter (ED), peduncle height (PCH), dorsal fin height (DFH), Body depth (BD), Head depth (HD). Dorsal view (B), Intra orbital distance (IO), Head width (HW), Body width (BW).

**Statistical Analysis**

The morphometric data were subsequently subjected to multivariate analysis to generate Principal Component Analysis (PCA) quadrants. PCA is employed to reduce data dimensionality, enhance interpretability, and maximize variance by creating new uncorrelated variables while simultaneously minimizing information loss (Jollife dan Cadima, 2016).

PCA ordination was processed using PAST 4.10 software. Eigen values are used as a reference to determine the morphometric characters that contribute to grouping between populations, visualized using the variance-covariance matrix for each group. The sample size was standardized using the formula:

$$Standardization\ size = \frac{Measured\ characters}{Total\ Length\ (TL)}\ x\ 100$$

The result of this calculation is the ratio of morphological character size to Total Length (TL) which is then transformed into Log 10. SIMPER is used to determine the similarity of morphometric characters for each population. The p value obtained from the measured characters is used to determine the significance grouping of each population sample.

## Results and Discussion

### Multivariat Analysis for Morphometry Characteristics

Twenty-nine samples of mahseer fish from cultivated and wild populations from Java Island, Indonesia, were collected from the upper reaches of the Progo River, Central Java, and the Balong KF fishpond, Subang, West Java, Indonesia, during the rainy season from November 2022 to June 2023. Mahseer fish from cultivated and wild populations belong to the species T. soro (Table 1).

The average total length of mahseer fish from the cultured population was 15.5 cm, while the average length for the Grabag River population was 24.6 cm and 20 cm from the Kanci River and Progo River main stream populations. The samples from the Grabag River population were more dispersed within the wild population in the PCA quadrant. Meanwhile, samples from the Kanci River and the Progo mainstream dominated the middle axis of the PCA quadrant. Samples from the cultured population appeared more clustered and slightly separated from the wild population (see Figure 3).

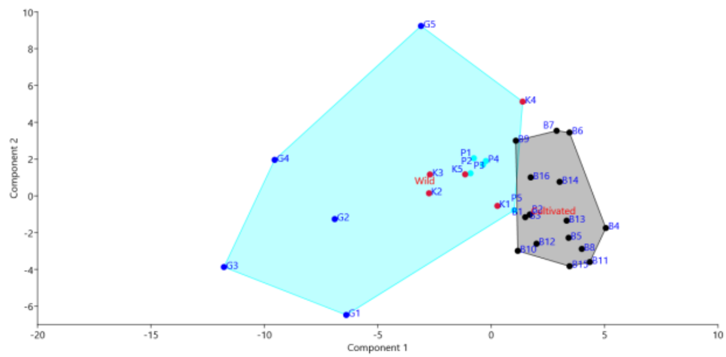



Figure 3. The PCA Axis of Each Mahseer Fish Population.

The PCA produced the highest eigenvalue of the six components. Where the value of each component is 28.47, 14.53, 8.01, 4.20, 3.27, and 2.43 with a total variance of 41.65%, 21.25%, 11.71%, 6.15%, 4.79%, and 3.55%, respectively, as shown in Table 2. Principal component 1 consists of six characters: standard length (SL), pre-ventral length (PVL), pre-anal length (PAL), pre-dorsal length (PDL), body depth (BD), and body width (BW). Principal component 2 consists of five characters, namely pre-anal length (PAL), pectoral fin length (PL), head depth (HD), body width (BW), and head width (HW). Principal component 3 comprised five characteristics: standard length (SL), pre-ventral length (PVL), pre-anal length (PAL), ventral fin base length (VBL), and body depth (BD).

Principal component 4 consists of six characters: pre-ventral length (PVL), head length (HL), snout length (SNL), dorsal fin base length (DFBL), dorsal fin height (DFH), and pectoral fin length (PL). Principal component 5 has four characters: pre-anal length (PAL), pre-dorsal length (PDL), dorsal fin base length (DFBL), and head depth (HD). Principal component 6 has four characteristics: head length (HL), non-snout head length (HLNS), snout length (SNL), and eye diameter (ED). Pre-anal length (PAL) is often found in four principal component analyses after pre-ventral length (PVL).

| PC | Morphometric characters | Eigenvalue | % variance |
|---|---|---|---|
| 1 | SL, PVL, PAL, PDL, BD, BW | 28.47 | 41.65 |
| 2 | PAL, PL, HD, BW, HW | 14.53 | 21.25 |
| 3 | SL, PVL, PAL, VBL, BD | 8.01 | 11.71 |
| 4 | PVL, HL, SNL, DFBL, DFH, PL | 4.20 | 6.15 |
| 5 | PAL, PDL, DFBL, HD | 3.27 | 4.79 |
| 6 | HL, HLNS, SNL, ED | 2.43 | 3.55 |

Table 2. Eigenvalue of Each Principal Component of Masheer Fish Morphometry.

## Percentage of Similarity of Morphological Characters

The SIMPER test was used to diagnose the characters that contributed to the similarity between populations (Table 3). The morphometric characteristic that had high similarity between the cultivated and wild populations was peduncule height (PCH), with an average dissimilarity value of 0.07%. Standard length (SL), body height (BD), and pre-anal length (PAL) contributed to variation between populations. The maximum contribution of the standard length (SL) was 88.82%, indicating that the sample size was relatively homogeneous. Multivariate analysis between populations showed a p-value <0.05, indicating that the six morphological characteristics of standard length (SL), body height (BD), pre-anal length (PAL), body width (BW), pre-dorsal length (PDL), and pre-ventral length (PVL) contributed strongly to the separation of Mahseer fish from the cultivated and wild populations in this study.

| Taxon | Av. Dissim | Contrib. % | Cumulative % |
|---|---|---|---|
| SL | 0.4541 | 11.18 | 11.18 |
| BD | 0.3638 | 8.956 | 20.14 |
| PAL | 0.3498 | 8.613 | 28.75 |
| BW | 0.3219 | 7.926 | 36.68 |
| PDL | 0.2955 | 7.276 | 43.95 |
| PVL | 0.2853 | 7.025 | 50.98 |
| HD | 0.1957 | 4.818 | 55.79 |
| DFH | 0.1956 | 4.817 | 60.61 |
| HW | 0.1907 | 4.694 | 65.31 |
| PL | 0.1894 | 4.663 | 69.97 |
| DFBL | 0.1691 | 4.164 | 74.13 |
| ABL | 0.1544 | 3.803 | 77.93 |
| ED | 0.1473 | 3.627 | 81.56 |
| HL | 0.1316 | 3.241 | 84.8 |
| IO | 0.1116 | 2.748 | 87.55 |
| VBL | 0.1111 | 2.736 | 90.29 |

| | | | |
|---|---|---|---|
| PCL | 0.1087 | 2.676 | 92.96 |
| SNL | 0.1082 | 2.664 | 95.63 |
| HLNS | 0.1019 | 2.51 | 98.14 |
| PCH | 0.07563 | 1.862 | 100 |

Table 3. The Percentage of Similarity of Each Morphometric Character Between the Cultivated Population and the Wild Population

## Morphology of Cultivated and Wild Mahseer Fish

There were differences in the morphology of the mahseer fish T. soro between the cultivated and wild populations in the PCA quadrant (see Figure 3). These differences were observed in the standard length (SL), body height (BD), pre-anal length (PAL), body width (BW), pre-ventral length (PVL), and pre-dorsal length (PDL) of each mahseer fish sample. Mahseer fish of the T. soro species from the cultivated population had shorter and taller bodies than the wild population. Pre-anal length, pre-ventral length, and pre-dorsal length are characteristics that are proportional to the length and height of the fish body.


Figure 4. Morphology of Mahseer Fish from A Cultivated Population With Snout Abnormalities (A) And Mahseer Fish With A Normal Body Shape (B).

Morphological characteristics were reflected in the grouping pattern in the PCA quadrant of the mahseer fish. The T. soro species and the cultivated population were grouped in the same quadrant, as was the Kanci 1 sample from the wild population. Mahseer fish from the Grabag River have an elongated body and a lower body height. Based on previous research by (Patiyal et al., 2014), there are significant differences in morphological characteristics such as body height, head height, head length, dorsal fin length, and dorsal fin height between cultivated and wild T. putitora species. In addition to differences in morphometric characteristics, Mahseer fish from the cultivated population of Balong KF also experienced a smaller head shape deformation than the normal shape.

The small head size is caused by the deformation of the snout and smaller mouth parts without rostral barbels, called parrot-shaped heads (see Figure 4. a), whereas in normal fish, the snout shape is more pointed (see Figure 4. b). This morphological deformation is caused by the small cranial shape of the head, which affects the shape of the head and mouth. This morphological deformation was not found in the wild Mahseer fish population and only one individual from the Mahseer fish sample from the Balong KF population.

This change in body shape can also be observed in other cultivated populations with different forms of deformation. Skeletal deformation is a form of head abnormality that often occurs in Cyprinid fish from cultured populations and is caused by genetic mutations and embryonic development in unfavorable environments (Näslund & Jawad, 2022). These morphological abnormalities can be used as indicators of a decline in the quality of the aquatic environment, such as water pollution, temperature fluctuations, and nursery management that does not comply with the habitat needs of mahseer fish (Eissa et al., 2021; Kužir et al., 2015; Näslund & Jawad, 2022). Morphological variations between Mahseer fish populations from the Grabag, Kanci, and main Progo River populations are generally influenced by geomorphological factors such as river elevation, which influences the speed of water currents (Wang et al., 2022; Liu et al., 2024; Tan et al., 2021).

The elevation of the three river habitats ranged from 300 to 1000 m asl, which is included in the category of fast-flowing upstream rivers. River habitats in these highlands are generally inhabited by fish that can swim in strong currents because they have slimmer bodies, longer pectoral fins, and dorsal fins that are higher than the height of the body (Leavy & Bonner, 2009; Shuai et al., 2018). Schakmann & Korsmeyer,(2023) also stated that the morphology of fish with a more steamlined body shape can swim more stably under strong currents.

Influence of aquaculture habitats on changes in fish morphology.

Aquaculture environments are generally designed to be economical and practical for farmers, with little attention paid to animal welfare. Thus, freshwater fishponds tend to have high levels of environmental stress due to decreased water quality, such as accumulation of nitrogen and phosphorus, increased biological oxygen demand (BOD) from fish food, and metabolic waste that is potentially harmful to fish (Mavraganis et al., 2017; Wisnu et al., 2019). Mahseer fish in wild habitats require environmental conditions such as high oxygen levels, low temperatures, strong currents, and rocky and clear sandy substrates with insects, moss, and microalgae as their food.

It is difficult to determine these conditions in aquaculture ponds. Therefore, morphological changes in other ponds also occurred in the cultivated mahseer fish in the present study. In addition, morphological variations in mahseer fish groups were also found in wild populations, especially in body depth, which can be caused by environmental variations and may be due to phenotypic plasticity.

Java Island is the southernmost location in the Sundaland region, which is the habitat of the masher fish. The habitat of mahseer fish on Java Island is limited, occupying the upstream part of the watershed, and has the characteristics of fast and clear water currents, high dissolved oxygen levels, low temperatures, sandy and rocky substrates, and overgrowth with vegetation along the river channel. These conditions can change due to anthropogenic factors that threaten the population of Mahseer fish (Aziz et al., 2021; Cheng et al., 2016; Tanaka et al., 2016). Aquaculture is one way to maintain the sustainability of endangered fish populations, in addition to preserving their habitat in nature (Oboh, 2022). Efforts to restock Mahseer fish from cultivation ponds to their natural habitat are one solution to the decline in Mahseer fish populations in nature; however, the restocking of cultivated fish must come from fish that have normal bodies so that they can withstand unfavorable conditions in the wild.

## Conclusion

There are morphological variations between the cultivated and wild mahseer fish populations. These morphological variations are located in the characteristics of SL, PAL, PDL, PVL, BD, and BW in the Mahseer fish population from the Balong KF. Mahseer fish samples from this location appear more grouped and somewhat separated from the wild mahseer fish population in the PCA quadrant. In addition, abnormalities in head shape found in Mahseer fish in the Balong KF were not observed in the wild Mahseer fish population.

The highest intrapopulation morphological variation in the wild type was found in the Grabag River population, followed by the Kanci River population, and finally in the Progo River mainstream population, indicating that Mahseer fish from these populations have good plasticity and can be recommended as a source of broodstock. On the other hand, Mahseer fish from Balong KF are at risk of body deformities; therefore, more attention needs to be paid to broodstock resources for fish restocking initiatives in natural habitats.

Further research is needed to investigate the physiology, reproduction, behavior, and types of physical abnormalities of native farmed fish to detect negative effects caused in the cultivation area for restocking fish in their natural habitat.

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