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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 native Indonesian species whose population is declining in the wild. Cultivation and restocking efforts are important conservation strategies aimed at maintaining the sustainability of natural populations. However, low genetic variation is often observed in cultivated populations, posing a challenge when these fish are reintroduced into natural habitats. Morphometric measurements offer an efficient method for assessing the population status of both cultivated and wild Mahseer fish. This approach also provides novel baseline information for the Mahseer species *Tor soro* found on the island of Java. Samples of *T. soro* were obtained from the KF Belong fish pond in Subang, West Java, and from the Prego tributary in Central Java. Nineteen morphological traits were recorded and analyzed using Principal Component Analysis (PCA). The results revealed significant differences between the cultivated and wild populations. PCA effectively separated these populations based on traits such as standard length (SL), body depth (BD), pre-anal length (PAL), body width (BW), and pre-dorsal length (PDL), as well as pre-ventral length (PVL). These findings suggest that *T. soro* is capable of maintaining most of its non-functional morphological traits in cultivation environments, while functional traits such as BD tend to adapt in response to environmental conditions. Additionally, body deformities were observed in the cultivated population but not in the wild population.

INTRODUCTION

Mahseer fish is a freshwater species belonging to the subfamily Torian, order Cyprinid. The genera Neoclassicists and Tor are members of the Torian family found in the Indo-Malaya region. Torian and Babina are subfamilies of the order Cyprinid 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 **(Britz *et al*., 2017; 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 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; Yang *et al*., 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 100cm, dissolved oxygen levels between 5 to 7mg/ 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 **(Pinder *et al*., 2014; Pinder *et al*., 2019; Pinder *et al*., 2020; Lau *et al*., 2021; Muchlisin *et al*., 2022; Das & Binoy, 2023)**. Morphometric measurements allow for the assessment of the success of conservation efforts by providing external quantitative indicators of fish population enhancement activities over time. These data allow researchers to track changes in the size, shape, and health of fish populations, both farmed and wild, following restocking efforts. By comparing these measurements to baseline data, conservationists can determine whether their management actions are successful in improving conditions for stock sustainability and minimizing genetic erosion. Despite its ecological significance, the mahseer population faces severe threats from various anthropogenic factors, including dam construction, water pollution, overexploitation, and habitat destruction **(Muchlisin *et al*., 2022)**.

Mahseer fish populations in the Asian region, such as the species *T. petitory, T. Ramadani,* and *T. laevigates*, are classified as endangered. Furthermore, two species in Indonesia, *T. Tambra* and *T. tabloids*, are currently estimated to be experiencing population decline in riverine habitats **(Betts *et al.*, 2019; Pinder *et al*., 2020; Akhtar *et al*., 2021; Jaafar *et al*., 2021)**.

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. There are several potential impacts of released cultivated mahseer fish into semi-natural environments. These effects could include the spread of maladaptive characteristics like bodily injuries which could lessen the viability of the natural population. Furthermore, released cultivated fish may compete with the native populations for resources or spread pathogens. Stringent screening of cultivated fish for morphological and genetic fitness is necessary prior to their release so that the welfare of both the fish and the population they integrate into is monitored to evaluate the success of stockings attempts. 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*., 2020; Tizkar *et al*., 2020)**.

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.

1. Implications for conservation efforts

The results of the study can be used to design more effective conservation schemes for mahseer fish populations. First, the marked morphological distinctions between farmed and wild populations suggest that restocking strategies may need to be adjusted to ensure that farmed fish can survive and thrive in natural ecosystems. Furthermore, genetic diversity and adaptability can inform breeders and conservationists about which populations are the best candidates for rehabilitation action and opening their fish to the wild. The observable body deformities in farmed fish indicate that broodstock selection must be done with the utmost care to prevent future generations from suffering from maladaptive traits and misguided control of population welfare by wild populations.

This study compares the morphology of Mahseer *T. sore* fish from cultivation ponds in Belong KF, Subang, West Java, with specimens from wild habitats in the Graba River, Kanci River, and the main channel of the Prego 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 **(Boussou *et al*., 2024)**. 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.

2. Insights into local fish farming strategies

The results of the study can inform local fish farming methods, as they highlight the need for genetic variability and for simulating environmentally friendly conditions in natural environments. This may include developing culture systems that mimic the morpho dynamic and oxygenated waters associated with mahseer habitats. In addition, selection of broodstock could be done from wild populations that are morphologically and genetically well adapted to such environments. Such actions would increase the likelihood that farmed fish will continue to adapt to the wild and thus improve the chances of survival, which is advantageous for maintaining population levels.

3. Applications for other fish species

The results of this study may be useful for the conservation of other fish species, especially in the face of habitat degradation and overfishing. Methods for analyzing morphometric traits, measuring genetic variability, and monitoring the effectiveness of culture and restocking efforts can be modified for other species and regions. This could improve conservation efforts by integrating the specific habitat needs and ecological functions of different fish species, resulting in improved biodiversity and ecosystem health.

MATERIALS AND METHODS

1. Lokasi Pengambilan Samples

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

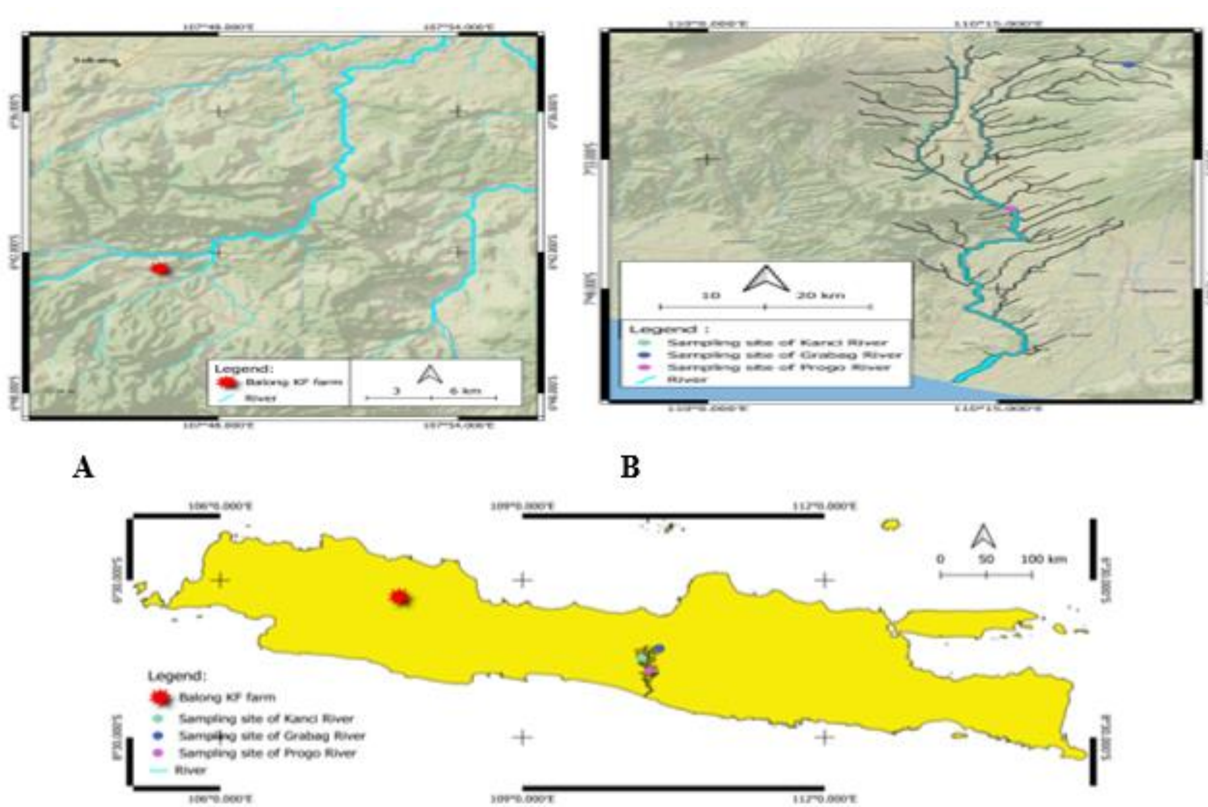

Fig. 1. The research locations are **(A)** the KF Belong location in Subang, West Java, **(B)** the sampling location for mahseer fish in the Prego River Basin (Kanci River, Graba River, and Prego River) in Central Java, Indonesia

Table 1. The coordinates of samples locations

Sample origin	Species	Location	GPS Coordinates
BALONG KF	*T. sore*	Subang, West Java	6°42'42.84"S 107°46'28.21"E
Kanci river	*T. sore*	Prego Watershed, Central Java	7°25'37.78"S 110°11'30.78"E
GRABAG river	*T. sore*	Prego Watershed, Central Java	7°22'37.62"S 110°21'46.79"E
PROGO river	*T. sore*	Prego Watershed, Central Java	7°38'43.10"S 110°15'41.52"E

Source: Prepared by the author (2025)

2. The Mahseer fish samples

A total of 29 samples were taken from the Prego Watershed, Magellan, Central Java, and Belong KF, Subang, West Java (Fig. 1). Each sample was 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 Digitizer version 6 image analysis software. Morphometric characters (Fig. 2) were used to identify fish from the sampling location **(Haryono & Tjakrawidjaja, 1970; Rahayu *et al*., 2013)**.

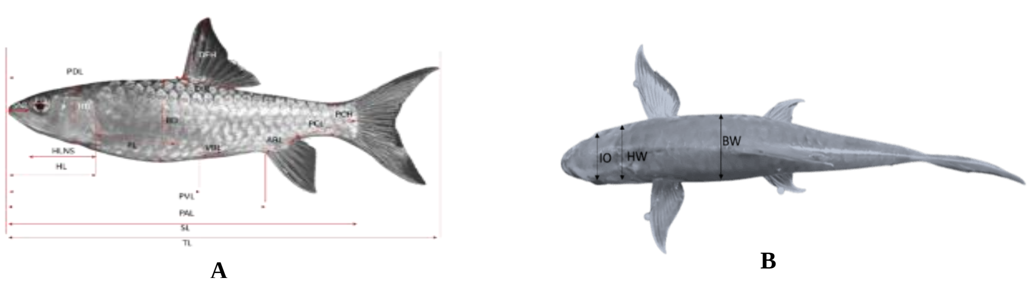

Fig. 2. Morphometric characters of mahseer fish. Ventral view (A), Total length (TL), Standard length (SL), Pre-anal length (PAL), Pre-ventral length (PVL), Head length other than snout (HLNS), Snout length (SNL), Base length dorsal fin (DFL), Anal fin base length (ABL), Peduncle length (PCL), Pre-dorsal 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)

3. Statistical analysis

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

PCA ordination was performed using PAST 4.10 software. Eigen values were used to identify the morphometric characters that contribute to population grouping, as visualized through the variance-covariance matrix for each group. The sample size was standardized using the following formula:

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

The result of this calculation is the ratio of each morphological character to the total length (TL), which is then log-transformed using base 10 (Log_{10}). SIMPER analysis is used to assess the similarity of morphometric characters among populations. The *P*-values obtained from the measured characters are used to determine the significance of population groupings.

RESULTS AND DISCUSSION

1. Multivariate 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 Prego River, Central Java, and the Belong 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. sore* (Table 1).

The average total length of mahseer fish from the cultured population was 15.5cm, while the average length for the Graba River population was 24.6 and 20cm from the Kanci River and Prego River main stream populations **(Abass *et al.*, 2024)**. The samples from the Graba River population were more dispersed within the wild population in the PCA quadrant. Meanwhile, samples from the Kanci River and the Prego mainstream dominated the middle axis of the PCA quadrant. Samples from the cultured population appeared more clustered and slightly separated from the wild population (Fig. 3).

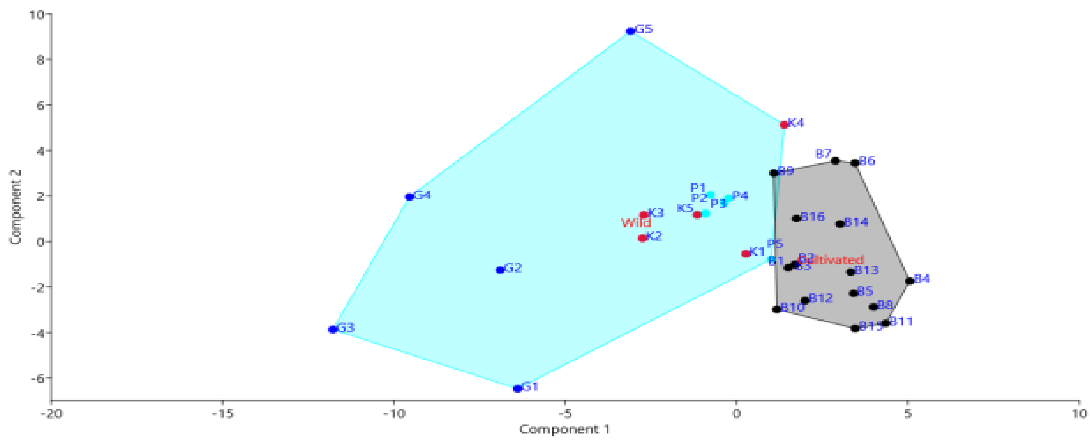

Fig. 3. The PCA axis of each mahseer fish population

The PCA produced the highest eigen value of the six components. Where the value of each component was 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).

Table 2. Eigen value of each principal component of masheer fish morphometry

PC	Morphometric characters	Eigen value	% 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

Source: Prepared by the author (2025).

2. Percentage of similarity of morphological characters

The SIMPER test was employed to identify the morphometric traits that contributed to the similarity observed between the cultivated and wild populations (Table 3). Among these traits, pedunculi height (PCH) exhibited the highest similarity, with an average dissimilarity value of just 0.07%. In contrast, traits such as standard length (SL), body height (BD), and pre-anal length (PAL) were responsible for variations between these populations. Notably, the standard length (SL) accounted for 88.82% of this variation, suggesting a relatively homogeneous sample size. Additionally, the effectiveness of PCA in our research played a crucial role; by simplifying the complex morphometric data into principal components, we uncovered significant trends and relationships that might otherwise have been overlooked in a more complex dataset. This method allowed for a more detailed interpretation of the morphological variations occurring between the populations. Multivariate analyses indicated a *P*-value of less than 0.05, asserting that six morphological characteristics—including standard length (SL), body height (BD), pre-anal length (PAL), body width (BW), pre-dorsal length (PDL), and pre-ventral length (PVL)—strongly facilitated the differentiation between the mahseer fish from the cultivated and wild populations observed in this study.

Table 3. The percentage of similarity of each morphometric character between the cultivated population and the wild population

Taxon	Av. disarm	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

Source: Prepared by the author (2025).

3. Morphology of cultivated and wild mahseer fish

There were differences in the morphology of the mahseer fish *T. sore* between the cultivated and wild populations in the PCA quadrant (Fig. 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. sore* 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.

Fig. 4. Morphology of **(a)** mahseer fish from a cultivated population with snout abnormalities and **(b)** mahseer fish with a normal body shape

The morphological characteristics of the mahseer fish were evident in the grouping patterns observed in the PCA quadrant. Utilizing PCA is essential, as it not only allows for the exploration of intricate datasets but also improves our capacity to draw meaningful comparisons between different groups, specifically the cultivated and wild Mahseer fish populations. Notably, the *T. sore* species and the cultivated population were positioned in the same quadrant, alongside the Kanci 1 sample from the wild population. In contrast, the mahseer fish from the Graba River displayed an elongated body and reduced body height. The framework established through PCA is instrumental in elucidating the specific morphological traits that differentiate the cultivated and wild populations. This understanding not only contributes to our biological knowledge but also informs future conservation and aquaculture practices for mahseer fish. We are glad you recognize this integration as a strength of our study. By combining PCA with detailed morphometric measurements, we have developed a holistic view of the mahseer fish biology. This comprehensive approach enables us to draw robust conclusions regarding the impact of environmental factors and cultivation practices on fish morphology, which may guide future research and intervention strategies.

Based on previous research by **Patiyal *et al*. (2013)**, 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. petitory* species. In addition to differences in morphometric characteristics, the mahseer fish from the cultivated population of Belong 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 (Fig. 4a), whereas in normal fish, the snout shape is more pointed (Fig. 4b). This morphological deformation is caused by the small cranial shape of the head, which affects the shape of the head and mouth **(Esa & Rahim, 2013)**. This morphological deformation was not found in the wild mahseer fish population and only one individual from the mahseer fish sample from the Belong 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, 2021)**. 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 the mahseer fish **(Kužir *et al*., 2015; Eissa *et al*., 2021)**. Morphological variations between mahseer fish populations from the Graba, Kanci, and main Prego River populations are generally influenced by geomorphological factors such as river elevation, which influences the speed of water currents **(Wang *et al.*, 2022)**.

The elevation of the three river habitats ranged from 300 to 1000m above the sea, 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 and Korsmeyer (2023)** also stated that the morphology of fish with a more streamlined body shape can swim more stably under strong currents.

4. 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 Sunda land region, which is the habitat of the masheer 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 **(Tanaka *et al*., 2015; Cheng *et al*., 2016; Aziz *et al*., 2021)**. 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 Belong 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 the mahseer fish in the Belong KF were not observed in the wild mahseer fish population.

The highest intrapopulation morphological variation in the wild type was found in the Graba River population, followed by the Kanci River population, and finally in the Prego 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 Belong 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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