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Morphometric Differences of Mullets (Mugilidae) in the Estuary of Yogyakarta Special Territory, Indonesia

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ABSTRACT

The purpose of this study was to determine the diversity, morphometric characteristics, and species relationships of mullet species found in the estuaries of Yogyakarta Special Territory. Thus, 384 samples were collected from the Bogowonto, Serang, Progo, and Opak estuaries. The fish collected were identified based on their morphological characteristics and grouped by species. Then, the sample was measured for its total length, meristic, and morphometric characteristic. Data were analyzed using discriminant analysis, Duncan analysis, canonical analysis, and cluster analysis. The results showed six mullet species in the estuaries of Yogyakarta Special Territory, namely *Chelon macrolepis*, *Chelon melinopterus*, *Chelon subviridis*, *Moolgarda engeli*, *Mugil cephalus*, and *Valamugil buchanani*. The main difference between each species was shown by the number of lateral linear scales and the inner truss line on the side and the tail. The morphometric variation between the species of mullet ranged from 33.3 to 71.4%. *Moolgarda engeli* and *C. melinopterus* had the closest relationship, and both species were closely related to *C. macrolepis*. The phylogenetic relationship among species was slightly different compared to the morphometric character of their genetic characters. Morphometric variances may be seen in a variety of morphological features, including interorbital and interventral distances, as well as the distance between the cranial bones, dorsal and pelvic fins, and anal fin. The caudal peduncle height varies as well.

INTRODUCTION

The mullet (Mugilidae) inhabits intertidal estuaries, freshwater, and coastal waters. This fish family is widely distributed worldwide in tropical, subtropical, and temperate regions ranging from 58^{o} SL to 58^{o} NL. The species of the Mugilidae are catadromous fish that live in shallow waters, estuaries, and mangrove swamps with sandy mud substrates **(Putra *et al.*, 2021)**. According to **Heneish and Rizkalla (2022)**, mullets live mostly in marine and brackish environments, and rarely in fresh water. As a euryhaline

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species with a wide salinity tolerance, this fish individual can move from estuaries to salt water and vice versa. Mullets grow and find food around the estuary, then migrate to the sea for reproduction and spawning **(Herbst & Natalia, 2014)**. The larvae of floating mullet are carried away by the tides and into the estuary as a feeding ground and find shelter until sexually mature **(Chang & Lizuka, 2012)**. According to **Yulianto *et al.* (2020)**, there are 21 species of mullet in the Indonesian Sea out of 78 species in the world. **Crosetti *et al.* (2016)** reported that, approximately 21 genera and 69 species of these fish have been described worldwide. The classification and number of genera/ species in the Mugilidae family are likely to continue to grow due to a re-description process of the species found and new methods and approaches. The classification and number of genera/ species of the Mugilidae family is likely to continuously grow due to a re-description process on the species found and new methods and approaches.

Morphometric analysis provides more efficient, fast affordable, and powerful methods for discovering variations between groups and distinguishing between species of similar form. Morphometric advances offer sophisticated techniques for evaluating and showing shape differences, isolating form from size variation, and finding stocks of species with distinct morphological characteristics. However, these procedures need a significant commitment of time and money, and precise findings necessitate competent interpretation. It can be difficult to understand the interplay between phenotypic characteristics, the environment, and ontogeny **(Cadrin & Friedland, 1999; Mojekwu & Anumudu, 2015)**. The study of fish morphological variations can be done through traditional techniques and truss morphometrics **(Batubara *et al.*, 2018)**. Morphometrics is a low-cost tool for measuring and describing the form of biological structures. It includes measuring the length and spatial correlations of anatomical markers in fish, such as body components, fins, and body length ratios, in ichthyological taxonomy. This information allows for the understanding of morphological connections and behavioral features, which in turn serves to guide successful conservation measures for species with various phenotypes and genetic distances **(Muchlisin, 2013; Yulianto *et al.*, 2020; Nur *et al.*, 2022)**. The traditional morphometric approach does not measure the complete shape of the organism, and its measurements are often analyzed as independent of each other. However, since they are all part of the same structure, the information about the shape is limited and unclear **(Angulo-Bedoya *et al.*, 2019)**. While in the truss morphometric method, the constructed landmark configuration covers the entire body of the fish without losing any information, it is more sensitive to changes to distinguish phenotypic stocks **(Mojekwu & Anumudu, 2015)**. Compared to the traditional method, the truss morphometric uses various body parts for measurement to provide a more detailed and specific illustration of the body.

The similarity of morphological and morphometric characters has been used to determine the relationships among various organisms. Traditionally, phylogenetic trees described organism lineages that traced the relationships between species and their

evolutionary models **(Yang & Zhu, 2018)**. Relationships between organisms are an important aspect of taxonomy research and can be described using a phylogenetic and phenetic system. The relationship illustrates an organism's likeness with one another, both existing and having existed in the past during the evolution of phylogenetic history. The phenetic system explains the morphological character that can be directly observed. The phylogenetic system is a relationship based on the phylogenetic likeness between one taxon and another. In contrast, the phenetic relationship is a connection based on the similarities and differences in the characteristics seen in the taxon, such as morphological, anatomical, biochemical, or other observable traits **(Ningrum & Chasani, 2021)**. The phenetic relationship is determined by the number of similarities in the visible characters, such as morphological, anatomical, and biochemical characters. It can be detected through phenograms, while the phylogenetic relationship is determined based on the ancestors' origin according to development or evolutionary processes and can be done through a phylogram constructed using molecular data in silico **(Soltis *et al.*, 2012; Ningrum & Chasani, 2021)**.

Mullet is one of the targets of capture fisheries, mainly by traditional fishermen at the estuaries of Yogyakarta Special Territory. The production of mullet from the catch continues to increase and has a medium economic value, with the price ranging from 1.5 to 2USD per kg. Fishermen in the Yogyakarta region generally only recognize two types of mullets, namely mullet *Chelon subviridis* and mullet podo (*Mugil chepalus*). However, more than two species of mullets may live in estuary waters. Research on the morphometrics and relationships of mullets in Indonesia is still rare. This research aimed to know the difference between morphometric characters among mullet's species inhabiting the Yogyakarta Special Territory's estuaries.

MATERIALS AND METHODS

1. Sampling and fish samples

A total of 384 fish samples were collected from fishermen who caught the fish in Yogyakarta Special Territory estuaries, including the Opak-Oya estuary (5 of 6 species, number of samples = 201 individuals), Progo estuary (4 of 6 species = 48 individuals), Serang (4 of 6 species = 35 individuals), and Bogowonto estuary (3 of 6 species = 100 individuals). Fish samples were selected based on standard sizes for morphological studies of mullets; the size used as a sample was those with more than 10cm. Fish samples were identified using the **Harrison and Senou (1999)** identification method, which was then adjusted to the latest data following **Froese and Pauly (2023)** for fish name validation.

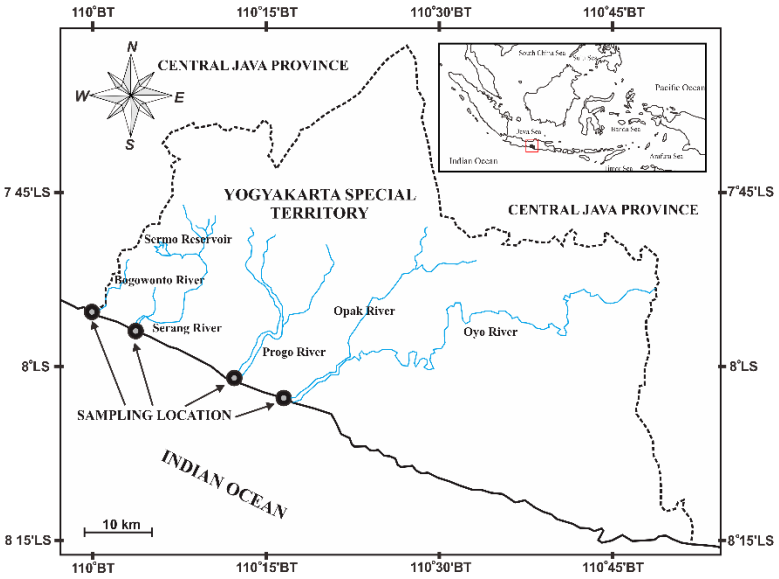


Fig. 1. The sampling location of mullet in the estuaries of Yogyakarta Special Territory

2. Data collection

2.1. Meristic character

Meristic measurements were made on 384 fish samples, including the number of scales and fin rays. The determination of fish fin formulas was carried out by counting both the spiny and soft fin rays on the D (dorsal), P (pectoral), V (ventral), A (anal), and C (caudal) fin rays. The meristic characters are illustrated in Fig. (2) and Table (1).

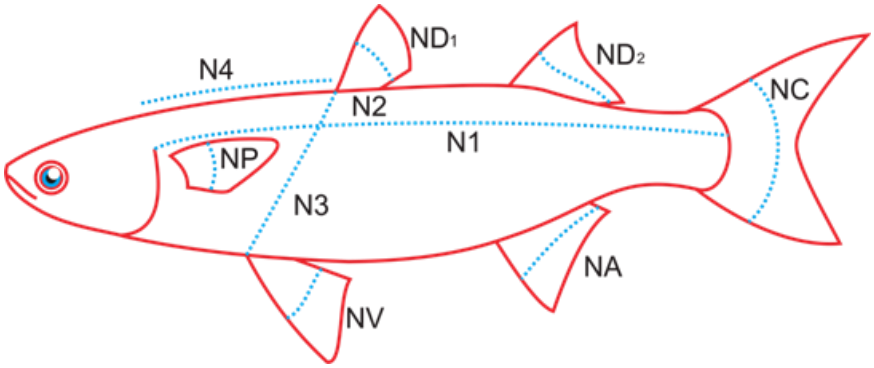


Fig. 2. Illustration of the meristic character of mullet caught from the estuaries of Yogyakarta Special Territory

Table 1. Meristic characters of mullet used in the study

Code	Explanation
ND_1	Number of fin rays on the first dorsal fin
ND_2	Number of fin rays on the second dorsal fin
NP	Number of fin rays on the pectoral fin
NC	Number of fin rays on the caudal fin
NV	Number of fin rays on the ventral fin
NA	Number of fin rays on the anal fin
N1	Number of scales on the lateral line
N2	Number of scales on the upper lateral line
N3	Number of scales under the lateral line
N4	Number of scales of the first dorsal side

2.2. Morphometric characters

A total of 384 fish samples were further examined using morphometric methods. The determination of 21 morphometric characters was carried out by modifying **(Turan *et al.*, 2011; Muchlisin *et al.*, 2013)**. The measurement of morphometric characters was done digitally, then the sample was documented using a digital camera and computer. Furthermore, the samples were measured in detail using the Corel Draw software. The visual data were made into a truss morphometric pattern and converted according to the standard length. Morphometric characters are shown in Fig. (3) and Table (2).

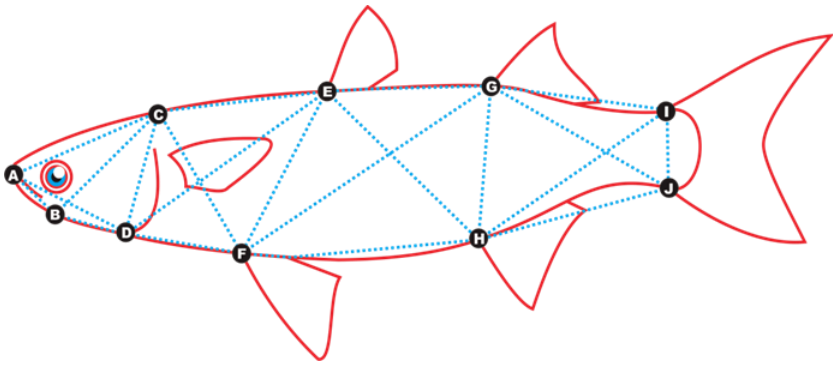


Fig. 3. Illustration of morphometric characters of mullet caught from the estuaries of Yogyakarta Special Territory

Table 2. Meristic characters of mullet used in the study

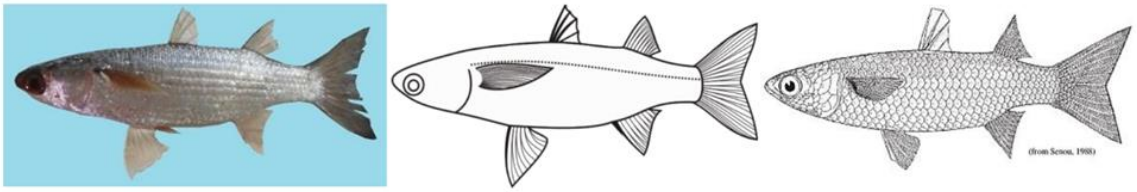
Code	Explanation
A-B	An interval from snout to anterior most margin of the eye orbit
A-C	An interval from snout to anterior dorsal
A-D	An interval from snout to the origin of the pectoral fin
B-C	An interval from posterior edge of mandible to anterior dorsal
B-D	An interval from posterior edge of mandible to edge of gill cover
C-D	An interval from anterior dorsal to edge of gill cover
C-E	An interval from anterior dorsal to first dorsal fin
C-F	An interval from anterior dorsal to ventral fin
D-E	An interval from edge of gill cover to first dorsal fin
D-F	An interval from edge of gill cover to ventral fin
E-F	An interval from first dorsal fin to ventral vin
E-G	An interval from first dorsal fin to second dorsal fin
E-H	An interval from first dorsal fin to anal fin
F-G	An interval from ventral fin to second dorsal fin
F-H	An interval from ventral fin to anal fin
G-H	An interval from second dorsal fin to anal fin
G-I	An interval from second dorsal fin to upper caudal fin
G-J	An interval of second dorsal fin to lower caudal fin
H-I	An interval of anal fin to upper caudal fin
H-J	An interval of anal fin to lower caudal fin
I-J	Vertical depth on caudal peduncle

2.3. Data analysis

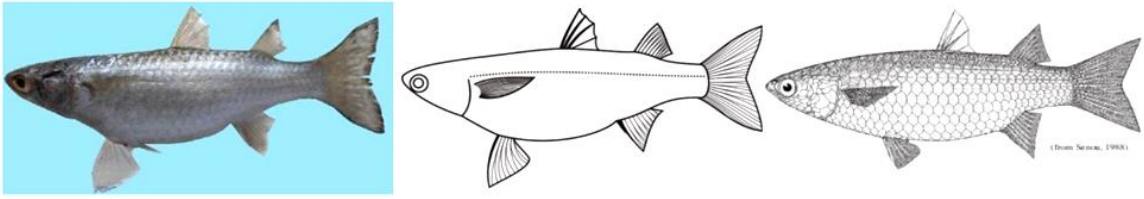
The truss morphometric characters of mullets were analyzed using SPSS version 17.0 software. A discriminant analysis was conducted to determine the main distinguishing morphological characteristics of mullets. The Duncan analysis was used to compare the species' significantly different morphometric characters. The other analysis used was the canonical analysis to correlate several morphometric characters in mullet and the cluster analysis to analyze the relationship between several mullet species. The determination of the relationship was based on truss morphometric measurements. The results of the analysis are presented in the form of a dendrogram with a Euclidean distance describing the relationship distance of each fish species.

RESULTS

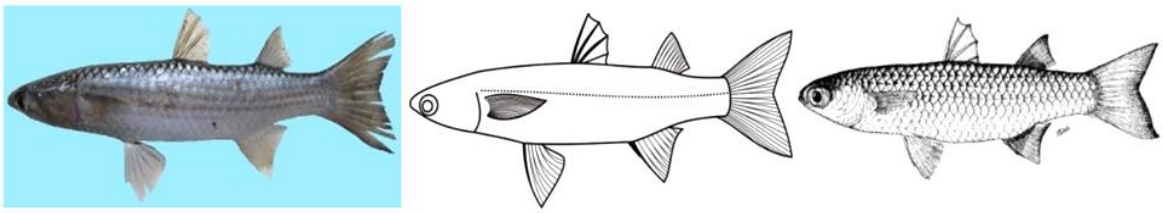
The results showed six different morphological variations (morphometric, meristic, and color pattern) of mullets (Fig. 4 & Table 3). The mullet generally has a fusiform and bilaterally symmetric body shape, such as a flathead at the top, a smallmouth that is protruding and located in a terminal position, a silvery body on the ventral side that tends to be dark on the anterior, more than one lateral line, and ctenoid-shaped scales. There are two dorsal fins; there is a modification of scales extending below the first dorsal fin, over the pectoral fin, and the ventral fin; the pectoral fin is in the thoracic position, and the caudal fin is forked. The number of scales on the lateral line, the position of the second dorsal fin to the lateral line scales, the shape of the head, body height, and color of the fish are the morphological variations that distinguish each species. Through the identification process following the study of**Harrison and Senou (1999)** and further validation following the guidelines of **Froese and Pauly (2023)** (www.fishbase.org), six mullet species from four genera were recognized and found in the estuaries of Yogyakarta Special Territory. These species are *Chelon macrolepis*, *Chelon melinopterus*, *Chelon subviridis*, *Moolgarda engeli*, *Mugil cephalus*, and *Valamugil buchanani*.



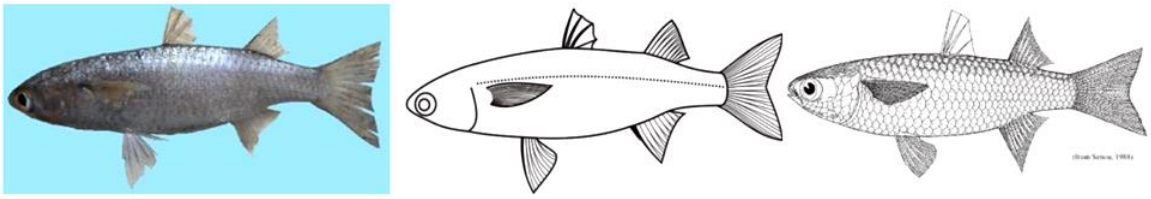
Mullet 1. *Chelon macrolepis* (SL: 10.7 cm): The body is whitish silver, the anterior and head are greenish silver, the lateral line has 31- 35 scales, the second dorsal fin is on the 21st scale, and the tail is flatter than other types of mullets



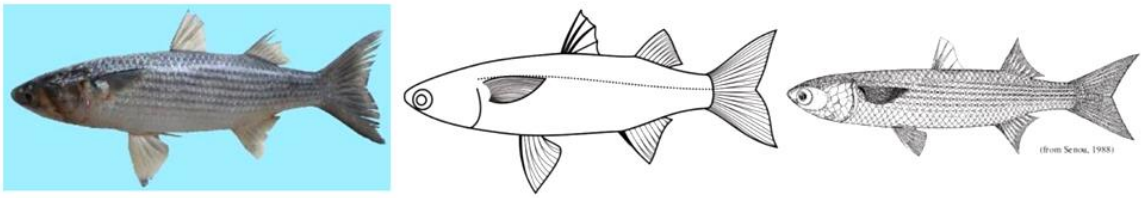
Mullet 2. *Chelon melinopterus* (SL: 11.0cm): Silver-gray color and has a 30% broader body when observed from the side of the standard length



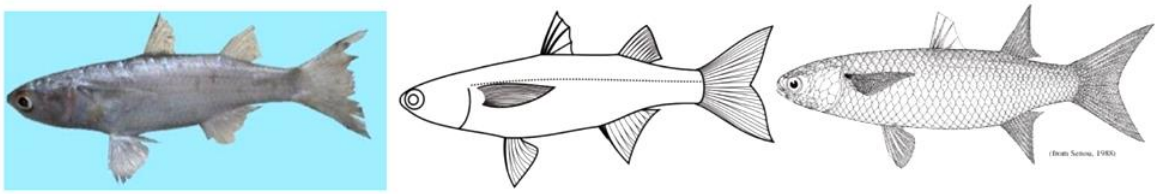
Mullet 3. *Chelon subviridis* (SL: 15.2cm): Pointed head shape, the head is horizontal with the upper anterior of the body, the body is silver-colored, and there is a dark line on each lateral line



Mullet 4. *Moolgarda engeli* (SL: 10.8cm): Silvery-colored body, the shape of the head tends to be more rounded; the first dorsal fin is located in the middle of the snout, and the caudal fin. Even in small fish, mature gonads are common



Mullet 5. *Mugil cephalus* (SL: 20.7cm): Torpedo-shaped and broad, the jelly membrane covers the entire iris, has 40 scales on the lateral line, and has countless black stipes and black spots on the sides of the body



Mullet 6. *Valamugil buchanani* (SL: 11.6cm): Flattened body after the second dorsal, silvery-white body color

Fig. 4. Variations in morphometric, meristic and color, each mullet 1-6, collected from the estuary of the southern coast of the Yogyakarta Special Territory

Table 3. Meristic characteristics of mullets found in the estuaries of Yogyakarta Special Territory

	N1	N2	N3	N4	ND_1	ND_2	NP	NA	NV	NC
Mullet 1 *C. macrolepis*	31-33	5	6	11-12	IV	I 8	14-17	III.9	I5	18
Mullet 2 *C. melinopterus*	29-34	5	6-7	10-12	IV	I 8	14-17	III.9-10	I5	18
Mullet 3 *C. subviridis*	28-32	5	6-7	10-11	IV	I 8	16	III.9-10	I5	18
Mullet 4 *M. engeli*	28-34	5	6	10-12	IV	I 8	14-16	III.9	I5	18
Mullet 5 *M. cephalus*	40	6	7	12	IV	I 8	16	III.9	I5	18
Mullet 6 *V. buchanani*	33-35	5	6	11-12	IV	I 8	15	III.9	I5	18

Table (3) shows the fin formula of the mullet found in the estuaries of Yogyakarta Special Territory, namely D1 IV D2 I8 P 14-17 V I5 A III9-10 C 18. There is a similarity in the number of fin rays on the first dorsal (ND1), the second dorsal (ND2), the caudal (NC), and the ventral (NV), and there are only slight differences in the number of the pectoral fin rays. The most significant difference among the mullet was the number of lateral line scales; the highest number was 40, and the least was 28. The identification of mullet species was improved by the addition of various traits for each species, especially the number of transverse scales on the sides of the body, the position of the 2nd dorsal fin to the linea lateralis, the ratio of body height to the standard length of the fish, and its size (Table 4).

Table 4. Morphometric and meristic characters of mullet **(Harrison & Senou, 1999)**

Valid name	N1	N_4	NP	NA	*Nll*- D_2	H : SL	Size
Chelon macrolepis	31-35	10-11	15-18	III.8-10	19-23		M-L
Chelon melinopterus	26-31	9-11	15-17	III.8-10	18-20	27-31%	S-M
Chelon subviridis	28-33	9-12	15-17	III.8-9	18-21	22-26%	M
Moolgarda engeli	32-36	10,5-12,5	15-18	III.8-9	19-23		S-M
Mugil cephalus	36-44	13-16	16-18	III.8-9	25-26		M-L
Valamugil buchanani	32-36	11-13	17-20	III.9	19-24		M

The difference between the specific characters and the most influential morphological variation in mullets was carried out using the discriminant analysis. The results of the discriminant analysis are illustrated in Fig. (5).

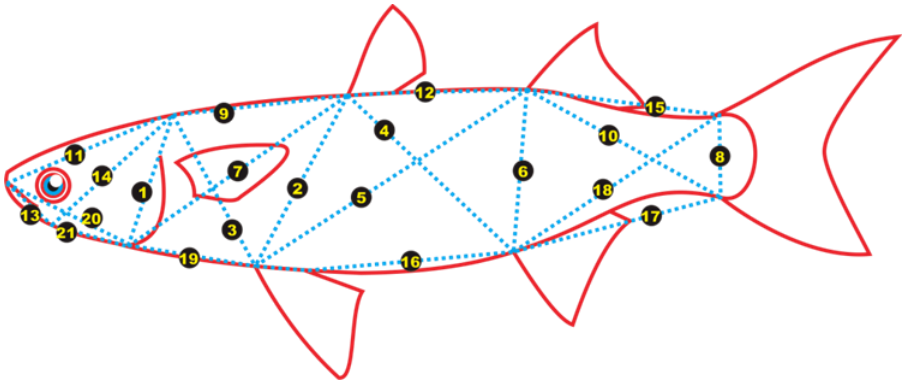


Fig. 5. The main distinguishing sequence of mullet morphometric characters

Fig. (5) displays the main distinguishing characteristics as the body's inner truss line and the caudal fin's height, presented in numbers from 1 to 8. Number 1 (C- D: Distance of anterior dorsal to edge to gill cover) is the most dominant distinctive character, with a variant value of 83.1%, and numbers 2 to 8 have 11.6%. The other characters have a total variant of only 5.3%.

The distribution of the morphometric character of mullets found in the estuaries of Yogyakarta Special Territory can be seen in Fig. (6). The distribution of mullet morphometric characters was analyzed using canonical analysis, which assists in determining the grouping of each species. The tangent groups indicate the similarity of the morphometric character of each group. The coordinate point represents a fish, with a different symbol representing each species.

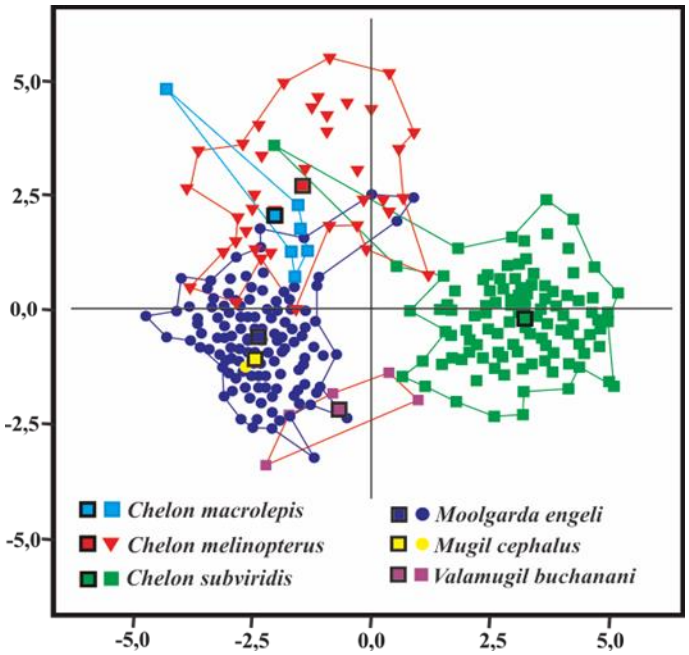


Fig. 6. The distribution of mullet morphometric characters

Fig. (6) exhibits the distribution of morphological characters of mullet concentrated in 3 groups, i.e., the first group: *C. melinopterus* and *C. macrolepis*; second group: *C. subviridis* ; and third group: *Moolgarda engeli*, *V. buchanani*, and *Mugil cephalus*. The separate distribution between *Moolgarda engeli* and *C. subviridis* shows different morphometric characters. In contrast, *Moolgarda engeli* and *Mugil cephalus* are close, indicating that these two species have many similarities.

Table 5. Similarities of morphometric characters among mullet species in the estuaries of Yogyakarta Special Territory

	C.sub M.eng	*M.eng C.me*	*C.ma C.me*	*M.eng M.ce*	*M.eng C.ma*	*C.sub C.me*	*V.bu M.ce*	*V.bu C.sub*	*M.ce C.me*	*M.ce C.sub*	*C.ma C.sub*	*V.bu M.eng*	*V.bu C.me*	*V.bu C.ma*	*M.ce C.ma*
%	66,7	66,7	61,9	61,9	61,9	57,1	52,4	47,6	42,9	38,1	33,3	33,3	33,3	33,3	28,6
A-B	+	+	+	+	+	+	-	-	+	+	-	-	-	+	+
A-C	+	+	-	+	-	+	+	+	+	+	-	+	+	+	-
A-D	+	+	-	+	-	+	-	+	+	+	-	+	+	+	-
B-C	+	+	-	+	-	+	+	+	+	+	-	+	+	-	-
B-D	+	+	+	-	-	+	+	+	-	-	+	+	+	-	-
C-D	-	+	-	+	+	-	+	-	+	-	-	+	+	-	-
C-E	+	+	-	+	+	-	-	-	+	+	+	-	-	-	+
C-F	-	-	+	+	-	-	-	+	-	-	-	-	-	-	-
D-E	-	-	+	+	+	-	-	+	+	-	-	-	-	-	+
D-F	+	+	+	-	+	-	-	+	+	-	-	+	-	-	+
E-F	-	-	-	+	+	-	-	+	-	-	-	-	-	-	-
E-G	-	+	-	-	+	+	+	-	-	-	-	+	-	+	+
E-H	-	-	+	+	-	-	+	+	-	+	-	-	-	-	-
F-G	+	-	-	-	+	-	+	-	-	-	+	-	-	-	-
F-H	+	+	+	-	+	+	+	-	-	-	-	-	-	-	-
G-H	+	-	+	+	-	-	+	-	+	-	-	-	+	+	-
G-I	+	+	+	-	+	+	+	-	-	-	+	-	-	-	-
G-J	+	+	+	-	+	+	+	-	-	-	-	-	-	+	+
H-I	+	+	+	+	+	+	-	-	-	+	+	-	-	-	-
H-J	+	+	+	-	+	+	-	-	-	+	+	-	-	-	-
I-J	-	-	+	+	-	+	-	+	-	-	+	-	+	+	-

*Explanation: + = similar - = not similar.

Morphometric character similarity in the genus Chelon was five characters (23.8%) in B- D, G- I, H- I, H- J, and I- J. The genus Chelon has many similarities, mostly in the position of the tail. *Moolgarda engeli*, *C. subviridis*, and *C. melinopterus* had the highest morphometric similarities, with 66.7% in the head and tail. *Mugil cephalus* and *C. macrolepis* had the biggest differences, 71.4 %, which were on the head and back side of the body following the first dorsal.

The similarity of morphometric characters in the genus Chelon is mainly found on the posterior part, an interval from the second dorsal fin to the upper caudal fin, an anal fin to the upper caudal fin, anal fin to lower caudal fin, depth on caudal peduncle. The other similarity was an interval from the mandible's posterior edge to the gill cover's edge (Table 5). The species with a high degree of similarity in morphometric character are *Moolgarda engeli*, *C. subviridis*, and *C. melinopterus*, which are 66.7% similar in the head and tail parts. The species with the highest differences are *Mugil cephalus* and *C. macrolepis*, with 71.4% on the anterior, dorsal, and posterior after the first dorsal.

Fig. (7) depicts the relationships between mullet species based on truss morphometric character similarities. The morphometric character relationships between mullets were tested using cluster analysis, and the results were presented in the form of a dendrogram. The closeness of the morphometric character relationship describes the possibility of a genetic relationship between the mullets inhabiting the estuaries of Yogyakarta Special Territory. The closer the relationship, the greater the potential for crossbreeding.

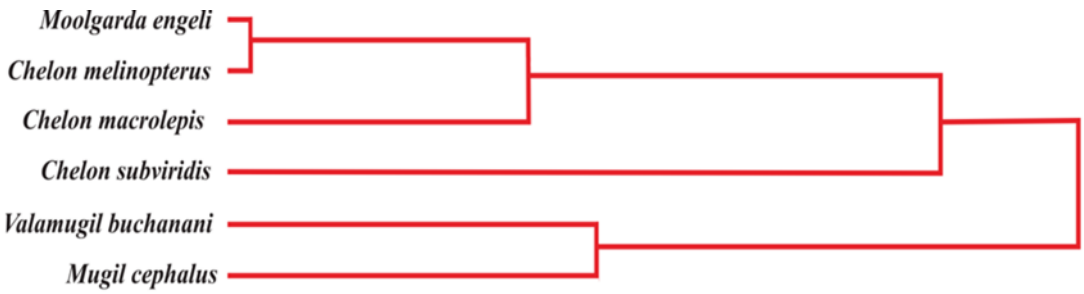


Fig. 7. The morphometric character relationships between mullets inhabiting the estuaries of Yogyakarta Special Territory

The dendrogram is divided into four branches: The first branch consists of *Moolgarda engeli* and *C. melanopterus*, with a relationship distance of 16.467. The first branch is connected to the second branch i.e., *Moolgarda engeli* and *C. melanopterus* with *C. macrolepis*. Moreover, the second branch relates to the third branch, i.e., *C. subviridis*. On the other branches, there are *V. buchanani* and *Mugil cephalus*, with a relationship distance of 29.761 (Table 6).

Table 6. The relationship distance between mullets in the estuaries of Yogyakarta Special Territory

Species	Squared Euclidean Distance					
	C. sub	*Mo. eng*	*C. me*	*C. ma*	*V. bu*	*M. ce*
C. sub	.000					
Mo. eng	**25.052**	.000				
C. me	38.939	**16.467**	.000			
C. ma	68.239	**28.363**	**27.782**	.000		
V. bu	52.163	42.451	77.240	66.075	.000	
Mu.ce	48.048	**18.996**	40.041	50.384	**29.761**	.000

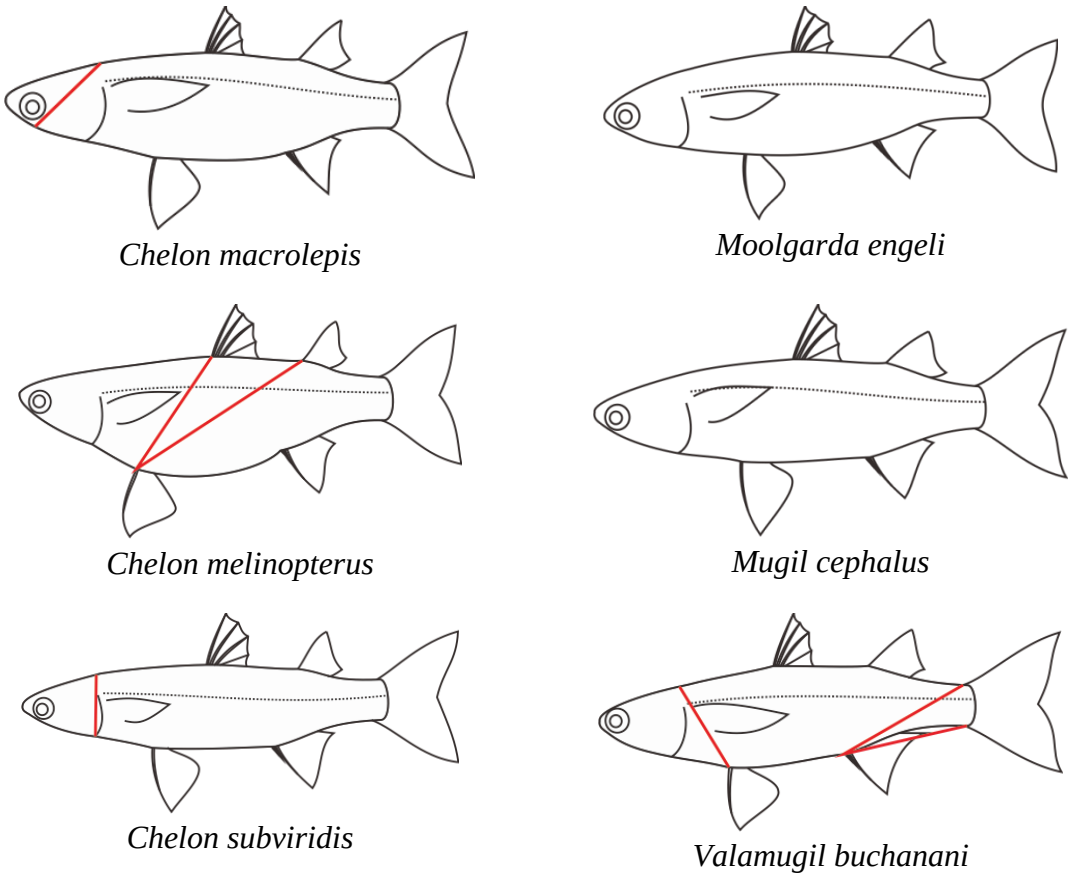


Fig. 8. The specific character differences of mullets in the estuaries of Yogyakarta Special Territory (---)

DISCUSSION

This research found six species of four genera of mullets inhabiting estuaries in Yogyakarta Special Territory. The mullet has generallya fusiform and bilaterally symmetric body shape, such as a flathead at the top, a small mouth, protruding and located in a terminal position, the body is silvery on the ventral side and tends to be dark on the anterior, more than one lateral line, and ctenoid-shaped scales. The meristic character of the mullet shows a difference in the number of lateral line scales, while the other meristic characters are not significantly different. The similarity of meristic characteristics in the number of fin bones shows that the six mullets found in the Yogyakarta estuary belong to the Mugilidae family. Differences between each mullet were found in the number of scales, which can be used to determine species diversity. Meristic variation was influenced by a derivative of the parent genotype **(Brett, 1979)**, while meristic variation number is determined by environmental conditions during egg and larval development with the aim of showing geographic differences between populations during early life stages, which is useful as an information for stock identification **(Cadrin *et al.*, 2014)**. Many authors mention that the meristic character approach to identifying the morphological character of a fish species is not quite prominent **(Samaradivakara *et al.*, 2012)**.

Morphometric variations were analyzed in detail for each mullet species to determine the specific distinguishing characteristics of the Mugilidae. The discriminant analysis shows that the main distinctive character between mullet species lies in the distance between the anterior dorsal and the edge of the gill cover (C- D). Another prominent distinguishing characteristic was the body's inner side and the caudal fin's height (Fig. 5). A study by **Turan *et al.* (2011)** using nine types of mullets from four genera explained that the main distinguishing features lie in the gap between the anterior dorsal and the first dorsal fin, the gap between the first dorsal fin and the ventral fin, and the interval from the snout to the posterior edge of the mandible.

The distribution of morphometric characters of mullets is divided into three groups: *C. melinopterus and C. macrolepis* concentrated in quadrant II, *Mugil cephalus*, *Moolgarda engeli*, and *V. buchanani* concentrated in quadrant III, and *C. subviridis* concentrated in quadrant IV (Fig. 6). While *C. melanopterus* and *C. macrolepis* show morphometric similarities; *Mugil cephalus* and adjacent *Moolgarda engeli* show a similarity value of 61.9% (13 characters) in Duncan's analysis. The Duncan test, *Moolgarda engeli* and *C. subviridis*, has a similarity value of 66.7% (14 characters). The cladogram shows that they are in different quadrants, meaning that *M. engeli* and *C. subviridis* are other species. The two species differ between the anterior and second dorsals (Table 5).

The comparison of the mullet's morphometric characters revealed that 21 morphometric characters were significantly different (Duncan, $P< 0.05$). The correlation

of morphometric characters among mullet species shows similarities in several characters (Table 5). *M.engeli* with *C. melanopterus* and *C. subviridis* with *M. engeli* have as many as 14 characters (66.7%), indicating the two species are morphometrically more closely linked, but in the classification, they originate from a different genus. A study by **Muchlisin *et al.* (2013)** mentioned that one type of mullet (*Mugil cephalus*) examined at four different locations had six characters different from the 18 characters tested. Morphometric character differences are not the primary determinant of species differences during identification since other characters (qualitative data) are unique characteristics of a species.

The difference in morphometric characteristics of mullets ranged from 33.3-71,4%. *Chelon macrolepis* differs from other species in the interval between the end of the mouth and the anterior dorsal fin (B- C), *Chelon melinopterus* differs in the interval between the first dorsal fin and the ventral fin (E- F) and the interval between the ventral fin and the second dorsal fin (F- G), and *Chelon subviridis* differs in the interval between the end-skull and the gill cover. In contrast, *M. engeli* and *Mugil cephalus* have no distinct differences from other mullet fish species (Fig. 8). The *C. macrolepis-C. melanopterus,* and *C. melanopterus-M. engeli* show 13 character similarities, and the *C. macrolepis-Moolgarda engeli* shows 14 character similarities. In general, it can be concluded that these three species have a close relationship, and when correlated in detail in the Duncan analysis, *C. macrolepis*, *C. melanopterus*, and *Moolgarda engeli* have the same characters as many as eight (38.1%) in AB, DF, FH, GH, GI, GJ, HI, and HJ (Table 2). The cluster analysis results also revealed a match relationship between *C. macrolepis* and *C. melinopterus* at 27.782, between *C. melanopterus* and *Molgarda engeli* at 16.467, and between *C. macrolepis* and *Molgarda engeli* at 28.363 (Table 6). The smaller the value in the cluster analysis, the closer the relationship between the two species.

The habitat where fish live can affect the shape and structure of the body. Fish can adapt to their environment so that fish habitat can affect the morphometric characteristics of fish populations **(D'Iglio *et al.*, 2021)**. In general, eight morphometric characters can distinguish mullet populations caught in the coastal waters of the Yogyakarta Special Territory into three groups. The first group is *C. melinopterus* and *C. macrolepis,* the second is *C. subviridis,* the third is Moolgarda engeli, *V. buchanani,* and *Mugil cephalus*. Among these distinguishing characters, the morphometric characters on the head and tail have the highest value. High morphometric character values for the head and tail are related to feeding habits and adaptation to currents or habitat foraging. *C. melinopterus* and *C. macrolepis* populations can inhabit river mouths or channels where the water is salty and go downstream to find food. The type of food consists of tiny algae, diatoms, benthic polychaetes, crustaceans, molluscs, organic matter and detritus **(Froese & Pauly, 2023)**, which are abundant in the estuaries to the lower reaches of the river. The second group is the population of *C. subviridis*, which can inhabit lagoons and enter rivers and fresh waters. Both groups were caught by nets and cast nets in lagoons and river estuaries

at a depth of 0.5- 2.0m **(Djumanto *et al.*, 2013)**. The third group is the mullet population that inhabits coastal to offshore waters and enters lagoons or river mouths during the dry season when the water's salinity is brackish. The group is often caught in coastal waters and rarely in lagoons or estuaries. The results of this study are supported by **Muchlisin *et al.* (2013)**, who found variations in morphometric characters in the heads and tails of mullet populations in Aceh waters.

The phylogenetic tree shows that *C. melanopterus* and *Moolgarda engeli* have the closest relationship, followed by *C. macrolepis* and *C. subviridis*. It should be in 1 genus in one close family group, but *Moolgarda engeli* is in the Chelon genus group. Similar to the result shown by **Turan *et al.* (2011)**, the truss morphometric approach reveals that *Chelon labrosus, Liza lamada,* and *Oedalechius labeo* have closer relationship than *Liza aurata, Liza subviridis, Liza abu,* and *Liza carinata*. This situation shows that more in-depth research is needed to complement morphometric observations, such as researching down to the genetic level. The closeness of the relationship allows for cross-breeding between species. Quantitative morphometric studies have three benefits: Differentiating sex and species, describing patterns of morphological diversity between populations or species, and classifying and predicting phylogenetic relationships **(Strauss & Bond, 1982)**. Morphometric analysis can also identify differences in fish populations, detect differences between groups, and distinguish similar species **(Mojekwu & Anumudu, 2015)**.

Based on the study results, the diversity of mullet species found in DIY's estuary waters was six; there may be other mullet species that have not been identified. It is necessary to carry out a longer follow-up study to obtain more complete data since **Harrison and Senou (1999)** estimated that about 17 species of mullet fish migrate through the southern sea of Java. Dominant mullet species such as *C. subviridis* and *Moolgarda engeli* are expected to be immediately managed for cultivation by building ponds around the river estuaries to increase mullet production in Yogyakarta Special Territory.

CONCLUSION

The mullets found in the Yogyakarta Special Territory's estuary are *Chelon macrolepis, Chelon melinopterus, Chelon subviridis, Moolgarda engeli, Mugil cephalus,* and *Valamugil buchanani.* The main differences in morphometric characters were: The interval between the anterior dorsal and the edge of the gill cover, the interval between the first dorsal and ventral fins, and the interval between the anterior dorsal and the ventral fins. The morphometric variations among the mullet were between 33.3- 71.4%.

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