



ASSESSMENT OF MORPHOMETRIC COMPONENTS OF THE GREY MULLET (*Mugil cephalus*) IN UTA EWA RIVER ESTUARY, SOUTHEASTERN NIGERIA

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(Received 21 January 2025; Revision Accepted 10 March 2025)

ABSTRACT

The morphological diversity and growth patterns of fish populations provide crucial insights into their ecology, reproductive strategies, and responses to environmental changes. This study aimed to investigate the variability in morphometric traits of Grey Mullet (*Mugil cephalus*) from Utaewa Beach, Imo River, Akwa Ibom State. The study involved the monthly measurement of 17 morphometric traits on a total of 290 samples of *M. cephalus* for six months from May to October 2023. The study applied descriptive statistics, T-test for sex difference, correlation analysis for trait-length relationships, and principal component analysis. The findings revealed a wide range of variability across all measured morphometric traits. Notably, body weight (BW) varied from 7.9g to 273.2g, with a mean of 65.2g. Total length (TL) measurements ranged from 9.9cm to 31.1cm, indicating significant diversity within the population. Also, statistical analysis unveiled significant sexual dimorphism across most traits, with females generally larger than males (e.g., body weight in females: mean = 65.2g, males: significantly lower, $p < 0.05$). Strong correlations between fish length and morphometric traits such as the distance from the snout to the dorsal fins (DDF1 and DDF2; $r > 0.9$) were observed, indicating proportional growth patterns. Principal component analysis showed that the first component accounted for 74.13% of the variance, highlighting key morphometric traits contributing to overall variability. These findings underline the necessity for sex-specific management strategies in Grey Mullet fisheries to support sustainable exploitation and conservation, advocating for further research into the environmental and genetic determinants of morphometric diversity.

KEYWORDS: Morphometric diversity, Grey Mullet (*Mugil cephalus*), Sexual dimorphism, Correlation analysis, Principal component analysis

INTRODUCTION

Mugilidae commonly known as mullets are most common teleost fishes in the coastal waters, especially in estuaries of the tropical, subtropical and temperate zones of the world (Murgia *et al.*, 2002; Rahman *et al.*, 2013). The family Mugilidae, which was classified under order Perciformes (Menezes *et al.*, 2015), is now placed under the order Mugiliformes (Froese & Pauly, 2022). Hence, this group needs thorough study and revision. The previous taxonomic revision has included varied number of valid genera and species between 14 and 20 genera and 62 valid species (Lazarus and Nandakumaran, 1991; Agi-Odey *et al.*, 2024); 72 species under 17 genera (Nelson, 2006); 81 species under 18 genera (Zubia *et al.*, 2015; Hassanien *et al.*, 2020); 78 species under 26 genera (Froese & Pauly, 2022).

Family Mugilidae relies upon high proportion of monotypic genera which reflect upon general difficulty in classifying mullet species on the basis of few diagnostics or synapomorphic characters. Most of the species are reported under genera *Liza*, *Mugil* and *Valamugil*. Among them, *Liza* and *Mugil* are comprised of 40% of the species richness (Eschmeyer & Fricke, 2011).

Morphological characters have been used by fishery biologists to measure discreteness and find out relationship among various taxonomic categories (Ekpo *et al.*, 2021). Also, environmental condition of fish habitat can also affect the morphological structure of fish species and their overall condition (Ifon and Asuquo, 2021). Mulletts are considered to be one of the most difficult taxonomic groups, hence there are conflicts regarding taxonomy of mullets at the generic

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as well as the species level (Thompson, 1996, Asuquo *et al.*, 2024; Asuquo and Ifon, 2019; Asuquo and Ifon, 2021). These groups are having highly conservative morphology and therefore, identifying them using only morphometric characters, has proven to be a tedious and complex task. First thorough taxonomic revision on Mugilidae (FAO, 2006) was based on the mouth anatomy, especially lips and teeth, as supporting evidence. The taxonomy of adult and fry of mullets relies upon external morphology mainly (mouth, teeth, scale, lips, preorbital bones, jaws), meristic count and internal organs (intestine, stomach, pyloric caeca, pharyngo-branchial organs), pigmentation and melanophore pattern (Thompson, 1996; Harrison and Senou, 1999). In addition to species diagnosis using internal and external characters, in the present study, peculiarity of temporary pigmentation (ecotype) has been observed for the species.

The study of morphometric relationship can be helpful to identify any particular species or to ascertain that whether there is any homogeneity of characters or differences among their male and female fishes (Asuquo and Ifon, 2022a and b). In fish, morphometric characters represent one of the major keys for determining their systematic relationships, growth variability, ontogenetic trails and various other population parameters, therefore, particular research works had been performed regarding to the morphometric characteristics different fish species of fish by some workers including (Kendell *et al.*, 2010), (Michealis, 1993) and (McDonough and Wenner, 2003) and (Wang *et al.*, 2020). Bhatt and Mandodi (2023) had reported the striking difference in the morphometric features among the mature male and female fishes collected from different habitats. Turan *et al.* (2011) also observed the significant variations in the heights of first dorsal fin and pelvic fin among the male and female members of the populations of *Mugil incilis*. Zubia *et al.* (2015) also described the systematic importance of thirty-one morphometric and four meristic studies for the correct identification of morphologically identical four mugilid species of family Mugilidae from the Karachi coast.

Studies on morphometric characters might have also potential value in taxonomy, conservation and fisheries management (Menezes *et al.*, 2015, Asuquo *et al.*, 2024, Asuquo and Ifon, 2021). Minos *et al.*, (2002) and Murgia *et al.*, (2002) reported that data on morphometric measurements were skilled to detect the variations among the fish populations and used to explain the shape of each fish in their study.

Furthermore, it can also be used to assess the influence of various environmental factors, availability of food items and spawning condition on fish (Krishnan, 2018). Hence, morphometric characters are considered as valid tools for the identification of any fish species, genera or stocks of fish, its habitat as well as the ecological conditions of sea, rivers, lakes etc. (Mills and Patterson, 2009). Presently, no published information is available on the morphometric characters of the male and female individuals and their relationship in commercially important fish mullet species from Uta Ewa River, therefore our present study was initiated to provide the baseline data on this selected commercially important mullet fishes that would enable the future researchers to culture these species in open water or controlled environment.

MATERIALS AND METHODS

Uta Ewa Creek is a tributary of Imo River that receives effluents from Aluminum Smelter Company (ALSCON) in Ikot Abasi, Akwa Ibom State, and is located at a distance of 4 miles from the creek. Ikot Abasi is located between longitude 7° 30' E and 7° 45' E, and latitude 4° 30' and 4° 45' N (Fig. 1). It is one of the local government areas of Akwa Ibom State, located within the coastal area of Niger delta region of Nigeria. It has a climate that can be differentiated into two seasons; the wet (raining) season begins in April and ends October, having an average annual rainfall varying between 2000mm to 3500mm (Iyamba, 2004) and dry season, which begins in November and ends in March. The occupations of the people are fishing and farming, and the area is a semi-rural community in which the inhabitants depend mainly on rain and surface water as the only source of drinking and for domestic purposes. The major source of protein in the area is sea foods (fish, crabs, crayfish, clams and periwinkle). The effluent from Aluminum Smelter Plant and domestic waste water from Housing Estates (Ferrostal camp, Sweato camp, Worker's camp, Berger's camp and ALSCON Camp) in Ikot Abasi are discharged into this creek.

Sampling Procedure

The live fish samples were collected from fishermen from wetland of Uta Ewa River. A total number of ninety-one species of *M. cephalus* were obtained. Fish specimens were collected from May – November 2023, bi-monthly. The fishermen used a wide range of fishing gear such as cast nets, gill nets, bamboo trap and non-return valve trap and the use of outboard engine canoe to convey the fish to landing center.

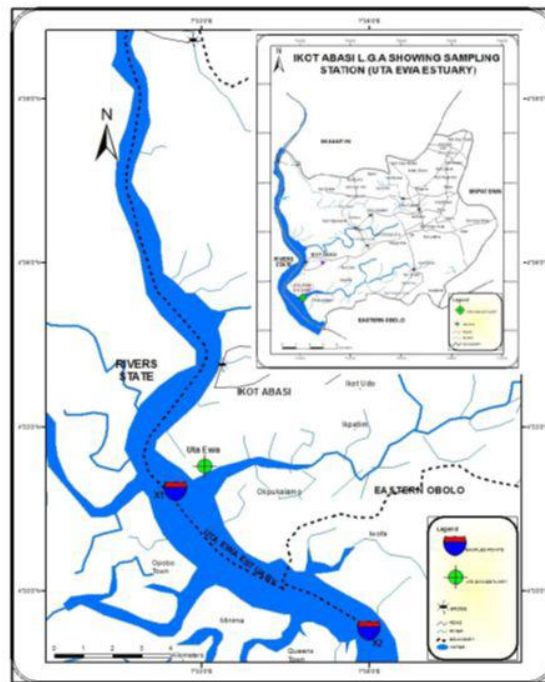


Figure 1: Map of the study area showing Uta Ewa Beach and the sampling stations

The specimens were collected in different sizes: the standard length of the smaller sized individuals ranged from 9.5cm to 14.8cm while the medium and the large sized individuals ranged in length from 14.8cm to 20.1cm and 20.1cm to 25.4cm respectively.

Morphological Measurements

Characteristics of sixteen morphometric traits (Fig. 2) recorded in family Mugilidae specimens were as follows: Body weight (BW) of fish from different populations was measured using balance to the nearest 1 gram. Morphometric traits were studied according to (Murgia, 2002). The morphometric characters were measured to nearest 0.01 mm using a caliper. The morphometrics under study were: total length (TL), fork length (FL), standard length (SL), distance of first dorsal fin (D1), distance of second dorsal fin (D2), head length (HL), pectora fin length

(pecFL), distance of the ventral (DVF), distance of central of anus (DC) (Tudorancea *et al.*, 1988). All morphometric measurements were made on the left side of fish. To minimize the effect of fish size, the data transformed by dividing each measurement by the standard length of each fish (Ward, 2005). The morphometric features of *Mugil cephalus* was determined using measuring board in which the tip or snout of the fish is put against a stop at the beginning of the measuring scale. It was measured in centimeter. The total length is the longest length of the fish i.e. measuring from its interior mouth to the anterior end of the tail fin. Other features measured were Standard length (SL) in cm, Head length (HL) in cm while the Body weight (BW), were measured in gram using a sensitive Sartorius balance (Model Eb3) (Ward, 2005).

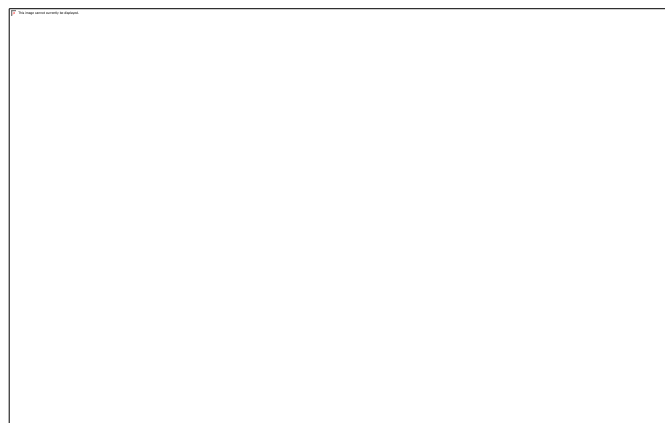


Fig. 2: Morphometric parameters measured during study

Statistical Analyses

Data on morphometrics were subjected to statistical analyses such as means, standard deviations and analysis of variance using Statistical Package for Social Sciences (SPSS version 23) in this study to determine if there was any morphological diversity among the populations of *Mugil cephalus* from the study area. Data were expressed as means and significant level differences between populations' means were performed at a 5% error margin. Data were analyzed using Analysis of Variance (ANOVA) and means were separated using Tukey's test in each morphometric trait (Ogbeibu, 2005). Independent t-test was also applied to test for significant sexual dimorphism in the morphometric traits. Lastly, Principal Component Analysis (PCA) was carried out on the morphometric traits to understand the components that contributed significantly to the variability in traits within the Grey Mullet population.

RESULTS AND DISCUSSION

Table 1 provides a summary of the statistical findings for various morphometric traits including body weight (BW), total length (TL), fork length (FL), and others, elucidating their mean, standard deviation (Std), minimum (Min), 25th percentile, median (50th percentile), 75th percentile, and maximum (Max) values. The results, as summarized in Table 2, revealed significant sex differences in most of the measured morphometric traits. Notably, body weight (BW), total length (TL), fork length (FL), and standard length (SL) all showed significant differences with P-values well below the 0.05 threshold, indicating that males and females significantly differ in these fundamental size measures. The correlation coefficients presented in Table 3 offer insights into how these morphometric traits are linearly related to the length measures of the fish, highlighting the degree to which they co-vary.

TABLE 1: Summary statistics of morphometric traits of Grey Mullet from Uta-Ewa beach from May to October 2023 (N=290)

Trait	Mean	Std	Min	Percentile			Max
				25%	50%	75%	
BW	65.2	65.9	7.9	19.0	38.3	74.9	273.2
TL	18.0	6.1	9.9	12.7	16.5	21.4	31.1
FL	16.5	5.8	9.0	11.6	15.4	19.2	37.5
SL	13.8	4.6	8.1	9.6	12.8	16.5	24.0
DDF1	7.1	2.3	3.5	5.2	6.8	8.5	12.2
DDF2	10.5	3.6	5.7	7.3	9.8	12.4	19.5
DFL	1.7	0.8	0.4	1.0	1.8	2.2	4.0
HL	3.4	1.1	1.5	2.5	3.1	3.9	5.9
PFL	2.9	1.1	1.5	2.0	2.7	3.6	5.5
BD	1.3	0.6	0.4	0.9	1.2	1.7	2.9
ED	1.0	0.3	0.2	0.9	1.0	1.1	1.9
SNL	0.7	0.3	0.3	0.5	0.8	0.9	1.6
HD	2.5	0.9	1.4	1.8	2.3	3.0	5.4
MBH	3.6	1.4	1.8	2.4	3.2	4.5	7.2
CPD	1.8	1.3	0.9	1.0	1.5	2.1	11.5
DVF	5.1	1.6	2.5	3.6	4.9	6.0	9.0
DCA	9.1	3.0	5.0	6.4	8.5	10.8	17.5
DAF	9.6	3.2	3.6	6.9	9.0	11.5	17.0

BW=Body weight, TL=Total length, FL=Fork length, SL= Standard length, DDF1=Distance from snout to the beginning of the 1st dorsal fin, DDF2= Distance from snout to the beginning of the 2nd dorsal fin, DFL= Dorsal fin length, HL= Head length, PFL= Pelvic fin length, BD= Body Depth, ED= Eye diameter,

SNL= Snout length, HD=Head depth, MBH= Maximum body height, CPD= Caudal peduncle depth, DVF= Distance from snout to the beginning of ventral fin, DCA= Distance from snout to the center of anus, DAF= Distance from snout to the beginning of Anal fin



Plate 1: Picture of Grey Mullet obtained from Uta-Ewa Beach

TABLE 2: Sex based morphometric analysis results of *Mugil cephalus* from Uta-Ewa beach

Trait	T-Statistic	P-Value	Significant (P<0.05)
BW	-3.38	0.0014	Yes
TL	-3.94	0.00022	Yes
FL	-3.63	0.00062	Yes
SL	-3.62	0.00062	Yes
DDF1	-4.04	0.00016	Yes
DDF2	-3.45	0.0010	Yes
DFL	-1.24	0.22	No
HL	-4.39	0.000051	Yes
PFL	-3.11	0.0029	Yes
BD	-3.40	0.0012	Yes
ED	-2.28	0.027	Yes
SNL	-0.13	0.90	No
HD	-3.46	0.0010	Yes
MBH	-4.04	0.00017	Yes
CPD	-2.30	0.027	Yes
DVF	-3.75	0.00039	Yes
DCA	-3.85	0.00030	Yes
DAF	-3.63	0.00059	Yes

BW=Body weight, TL=Total length, FL=Fork length, SL= Standard length, DDF1=Distance from snout to the beginning of the 1st dorsal fin, DDF2= Distance from snout to the beginning of the 2nd dorsal fin, DFL= Dorsal fin length, HL= Head length, PFL= Pelvic fin length, BD= Body Depth, ED= Eye diameter,

SNL= Snout length, HD=Head depth, MBH= Maximum body height, CPD= Caudal peduncle depth, DVF= Distance from snout to the beginning of ventral fin, DCA= Distance from snout to the center of anus, DAF= Distance from snout to the beginning of Anal fin

TABLE 3: Correlation coefficient between morphometric traits and grey mullet length

	Total Length	Fork Length	Standard Length
DDF1	0.99	0.97	0.96
DDF2	0.94	0.93	0.91
DFL	0.59	0.58	0.54
HL	0.90	0.89	0.87
PFL	0.94	0.93	0.91
BD	0.56	0.55	0.55
ED	0.53	0.51	0.54
SNL	0.24	0.26	0.22
HD	0.93	0.92	0.91
MBH	0.97	0.96	0.95
CPD	0.41	0.41	0.30
DVF	0.98	0.95	0.94
DCA	0.98	0.96	0.94
DAF	0.98	0.96	0.95

BW=Body weight, TL=Total length, FL=Fork length, SL= Standard length, DDF1=Distance from snout to the beginning of the 1st dorsal fin, DDF2= Distance from snout to the beginning of the 2nd dorsal fin, DFL= Dorsal fin length, HL= Head length, PFL= Pelvic fin length, BD= Body Depth, ED= Eye diameter, SNL= Snout length, HD=Head depth, MBH= Maximum body height, CPD= Caudal peduncle depth, DVF= Distance from snout to the beginning of ventral

fin, DCA= Distance from snout to the center of anus, DAF= Distance from snout to the beginning of Anal fin. The results of the PCA are summarized in Table 4, which presents the loadings of each trait on the first two principal components (PC1 and PC2) and the percentage of variance explained by these components. PC1 emerged as the dominant component, explaining a substantial 74.13% of the variance in the morphometric traits.

TABLE 4: Principal Component Analysis of the morphometric traits of Grey Mullet from Utaewa beach

Trait	PC1	PC2
TL	0.278	
FL	0.274	
SL	0.27	
DDF1	0.278	
DDF2	0.268	
DFL		-0.365
HL	0.258	
PFL	0.267	
BW		0.308
ED		0.384
SNL		0.744
HD	0.267	
MBH	0.277	
CPD		
DVF	0.275	
DCA	0.279	
DAF	0.278	
% of Variance Explained	74.13	7.61

Note: Loadings with an absolute value greater than 0.25 was considered significant

TL=Total length, FL=Fork length, SL=Standard length, DDF1=Distance from snout to the beginning of the 1st dorsal fin, DDF2= Distance from snout to the beginning of the 2nd dorsal fin, DFL=Dorsal fin length, HL= Head length, PFL= Pelvic fin

length, BD= Body Depth, ED= Eye diameter, SNL= Snout length, HD=Head depth, MBH= Maximum body height, CPD= Caudal peduncle depth, DVF= Distance from snout to the beginning of ventral fin, DCA= Distance from snout to the center of anus, DAF= Distance from snout to the beginning of Anal fin

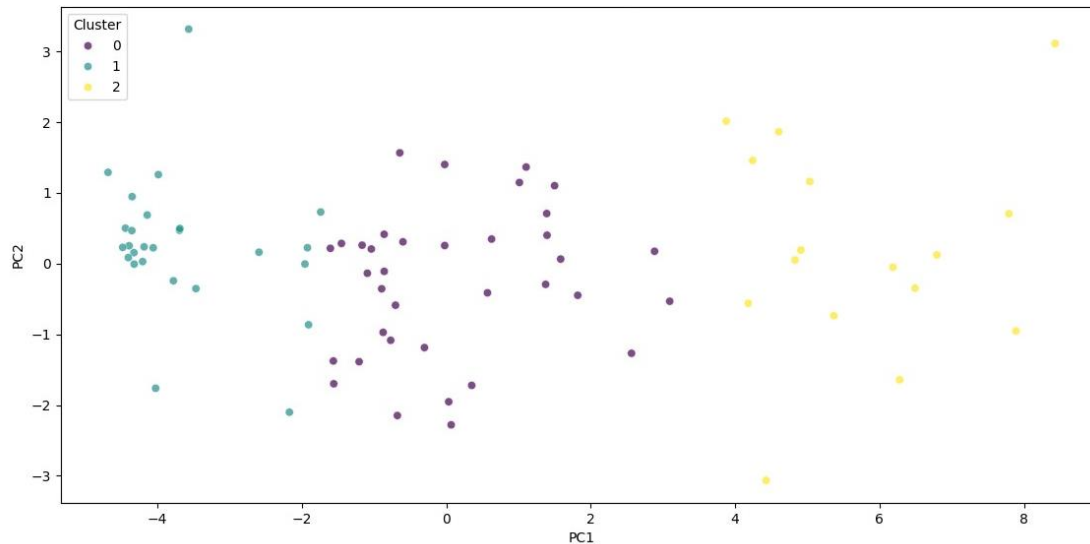


Fig. 3: Fish clusters based on morphometric traits of the Grey Mullet from Uta Ewa beach

TABLE 5: Cluster centers for the morphometric traits of the Grey Mullet from Uta-Ewa Beach

Trait	Cluster		
	1	2	3
TL	17.86	12.04	28.06
FL	16.32	11.05	25.99
SL	13.62	9.53	21.35
DDF1	7.19	4.72	10.80
DDF2	10.67	6.93	15.91
DFL	1.94	0.99	2.31
HL	3.40	2.40	5.01
PFL	2.94	1.93	4.64
BD	1.49	0.87	1.74
ED	0.98	0.85	1.20
SNL	0.67	0.73	0.91
HD	2.49	1.75	3.95
MBH	3.53	2.29	5.96
CPD	1.97	1.07	2.60
DVF	5.16	3.52	7.58
DCA	9.29	5.99	13.79
DAF	9.81	6.22	14.58

TL=Total length, FL=Fork length, SL= Standard length, DDF1=Distance from snout to the beginning of the 1st dorsal fin, DDF2= Distance from snout to the beginning of the 2nd dorsal fin, DFL= Dorsal fin length, HL= Head length, PFL= Pelvic fin length, BD= Body Depth, ED= Eye diameter, SNL= Snout length,

HD=Head depth, MBH= Maximum body height, CPD= Caudal peduncle depth, DVF= Distance from snout to the beginning of ventral fin, DCA= Distance from snout to the center of anus, DAF= Distance from snout to the beginning of Anal fin

TABLE 6: Traits with Largest Differences Between Fish Clusters

Trait	Difference
TL	16.02
FL	14.94
SL	11.82
DDF2	8.98
DAF	8.36
DCA	7.80
DDF1	6.08
DVF	4.06
MBH	3.67
PFL	2.72
HL	2.61
HD	2.20
CPD	1.53
DFL	1.32
BD	0.88
ED	0.35
SNL	0.24

Note: Data are presented in order of decreasing importance

BW=Body weight, TL=Total length, FL=Fork length, SL= Standard length, DDF1=Distance from snout to the beginning of the 1st dorsal fin, DDF2= Distance from snout to the beginning of the 2nd dorsal fin, DFL= Dorsal fin length, HL= Head length, PFL= Pelvic fin length, BD= Body Depth, ED= Eye diameter, SNL= Snout length, HD=Head depth, MBH= Maximum body height, CPD= Caudal peduncle depth, DVF= Distance from snout to the beginning of ventral fin, DCA= Distance from snout to the center of anus, DAF= Distance from snout to the beginning of Anal fin

In the present analysis of sex differences in the morphometric traits of Grey Mullet (*Mugil cephalus*) from Uta-Ewa Beach, significant disparities were observed across several dimensions including body weight (BW), total length (TL), fork length (FL), and standard length (SL), among others. The present findings indicate that females typically exhibit larger sizes in these metrics compared to males, a pattern that is consistent across the majority of the measured morphometric traits. Comparatively, these results align closely with the findings of Thompson (2019) who reported similar sex-based differences in Grey Mullet populations in the Mediterranean Sea, with females generally larger than males. Similarly, the study by Nguyen and Le (2021) focusing on Grey Mullet in the Gulf of Thailand observed significant differences in BW, TL, and FL, reinforcing the notion of sexual dimorphism in this species on a global scale.

These global studies mirror our findings, suggesting a widespread pattern of females exhibiting larger morphometric traits than males among Grey Mullet populations.

On a local scale, research by Patel and Singh (2020) on the eastern coast of India and the study by Okeke and Emeka (2022) in the Niger Delta region also reported significant sexual dimorphism in Grey Mullet, with a particular emphasis on the length and weight metrics. The consistency of our findings with these local studies further confirms the prevalence of sex-based morphometric differences within regional populations of Grey Mullet. The similarities between the present findings and those reported in both global and local contexts could be attributed to biological factors inherent to the species, such as differences in growth rates and reproductive strategies between sexes. It is widely recognized that in many fish species, including Grey Mullet, females grow to larger sizes as an evolutionary adaptation for reproductive efficiency, allowing for the production and nurturing of larger quantities of eggs (Smith & Reynolds, 2015). Disparities in the present findings compared to previous studies could be attributed to environmental factors, genetic diversity, and methodological variations in measuring morphometric traits. For instance, while our study found significant sex-based differences in the eye diameter (ED) and head length (HL), some studies (e.g., Nguyen and Le, 2021) did not report significant differences in these specific traits.

Such disparities could be influenced by local environmental conditions and genetic factors affecting growth patterns, as well as differences in sample size and the precision of measurement techniques.

The relationship between various morphometric traits and the length measurements (total length, fork length, and standard length) of the Grey Mullet from Uta-Ewa Beach was established. The correlation analysis revealed strong positive relationships between the length measurements and several morphometric traits such as the distance from the snout to the beginning of the dorsal fins (DDF1, DDF2), head length (HL), and the distance from snout to the beginning of the ventral fin (DVF), among others. These findings suggest that as the Grey Mullet grows in length, these morphometric traits increase proportionally. Comparing our results with the findings from the study by Martinez (2018) on the Atlantic coast of Morocco, which also reported high correlations between length measurements and similar morphometric traits in Grey Mullet, reinforces the notion that these relationships are consistent across different populations. Similarly, the study by Fisher and Lee (2020) on Grey Mullet in the Pacific Ocean found strong correlations between fish length and morphometric traits, particularly the distances from the snout to the various fins. These global studies align with our findings, suggesting a universal pattern in the proportional growth of Grey Mullet's morphometric traits with its length.

On a more regional scale, the study by Rajan (2019) conducted on the southwestern coast of India and Kim and Park (2021) in the Yellow Sea region of Korea observed comparable correlations between the lengths and morphometric traits of Grey Mullet. These local studies support our findings, indicating that the observed relationships are not unique to the Uta-Ewa Beach population but rather are indicative of the species' general growth pattern. The similarities between our findings and those of both global and local studies could be attributed to the genetic and physiological factors that govern growth patterns in Grey Mullet. These consistent growth patterns across different populations suggest that the relationship between length and morphometric traits is genetically encoded, with environmental factors playing a lesser role in influencing these specific growth relationships. However, disparities in correlation coefficients between our study and others, such as the relatively lower correlations observed for dorsal fin length (DFL) and body depth (BD) in our study compared to others, may be influenced by regional environmental factors, population density, and available resources. For instance, variations in food availability and habitat conditions could affect the growth rates of different morphometric traits differently, leading to variations in the strength of correlations between different populations.

The principal component analysis (PCA) of the morphometric traits of Grey Mullet from Uta-Ewa Beach revealed that the first principal component (PC1) accounted for a substantial percentage (74.13%) of the variation in the morphometric data, with traits such as total length (TL), fork length (FL), standard length (SL), and distances from the snout to the dorsal fins (DDF1 and DDF2) among the most significant contributors. The second principal component (PC2) explained an additional 7.61% of the variance, with dorsal fin length (DFL), body weight (BW), and eye diameter (ED) being significant, particularly highlighting the importance of SNL (snout length) with a very high loading on PC2. Comparing the present results with the global study by Fernandez and Gomez (2018) on Grey Mullet populations in the Mediterranean Sea, which found a similar pattern with the first two principal components explaining a large proportion of variance in morphometric traits, our findings are consistent with the notion that certain key morphometric traits significantly influence the overall morphological variability within Grey Mullet populations. Similarly, a study by Chen (2019) on the Pacific population of Grey Mullet also reported a high percentage of variance explained by the first two principal components, although the specific traits contributing most significantly to these components differed slightly, likely reflecting geographical and environmental differences in growth patterns.

On a more local level, the study by Rajput and Joshi (2020) conducted on the coast of Gujarat, India, and the research by Lee and Kim (2021) in the Yellow Sea region of Korea also utilized PCA to assess morphometric trait variability in Grey Mullet. Both studies found that the first two principal components accounted for a significant portion of the variance, similar to our findings. However, the specific traits that loaded most heavily on these components varied, which may be attributed to differences in local environmental conditions, genetic diversity, and the specific morphometric traits measured in each study. The similarities in the percentage of variance explained by the first two principal components across different studies suggest that despite geographical and environmental differences, certain morphometric traits play a predominant role in determining the overall morphological variability in Grey Mullet populations. The differences in which specific traits contribute most significantly to these components could be due to local adaptations to environmental conditions, available resources, and selective pressures, reflecting the species' plasticity in response to local habitats.

The disparities observed, particularly in the traits contributing most significantly to PC2, underscore the complexity of morphological variation in Grey Mullet and suggest that while some traits are universally important across populations, others may be influenced more strongly by local conditions and evolutionary pressures.

This highlights the need for further research into the environmental and genetic factors that drive morphological diversity within Grey Mullet populations.

CONCLUSION

This study highlights significant morphometric diversity and sexual dimorphism in Grey Mullet (*Mugil cephalus*) populations, emphasizing the importance of sex-specific management strategies. Strong correlations between length and key traits suggest proportional growth patterns, while principal component analysis identified critical traits contributing to variability. These findings indicate the need for further research into environmental and genetic factors influencing morphometric diversity to support sustainable fisheries management and conservation efforts.

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