Investigation of relationship between Morphometric and Meristic characteristics of *Mugil cephalus* (striped mullet) collected from the coastline of Susa, Libya.

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Abstract

This research examined the interrelations among several morphometric and meristic traits of the striped mullet (Mugil cephalus) sourced from the Susa coastline in Libya. A total of 20 specimens were meticulously analyzed, with measurements taken for parameters including total weight, total length, standard length, body depth, body width, head length, eye diameter, and various fin dimensions. The descriptive statistical analysis indicated that total weight exhibited the highest mean value, whereas eye diameter recorded the lowest. Correlation analysis revealed significant positive associations between body depth and standard length, body depth and total weight, body width and preorbital length, as well as between standard length and total weight, pelvic fin length, and body width. Conversely, certain relationships, such as those between preorbital length and postorbital length, and between preorbital length and second dorsal fin length, were determined to be minimal and statistically insignificant.

الملخص

بحث هذا البحث في العلاقات المتبادلة بين العديد من السمات المورفومترية والتركيبية لسمك البوري المخطط (*Mugil cephalus*) الذي تم جمعه من ساحل سوسة في ليبيا. تم تحليل إجمالي 20 عينة بدقة، مع أخذ القياسات للمعلمات بما في ذلك الوزن الإجمالي والطول الإجمالي والطول القياسي وعمق الجسم وعرض الجسم وطول الرأس وقطر العين وأبعاد الزعنفة المختلفة. وأشار التحليل الإحصائي الوصفي إلى أن الوزن الإجمالي أظهر أعلى قيمة متوسطة، في حين سجل قطر العين أدنى قيمة. وكشف تحليل الارتباط عن ارتباطات إيجابية كبيرة بين عمق الجسم والطول القياسي وعمق الجسم والوزن الإجمالي وعرض الجسم وطول ما قبل الحجاج، وكذلك بين الطول القياسي والوزن الإجمالي وطول الزعنفة الحوضية وعرض الجسم. وعلى العكس من ذلك، تم تحديد علاقات معينة، مثل تلك الموجودة بين طول ما قبل الحجاج وطول ما بعد الحجاج، وبين طول ما قبل الحجاج وطول الزعنفة الظهرية الثانية، على أنها ضئيلة وغير ذات دلالة إحصائية.

Introduction

Mugil cephalus, commonly referred to as the striped mullet, is a marine species that belongs to the Mugilidae family. This species is prevalent in tropical and subtropical regions across the globe, inhabiting the Atlantic, Pacific, and Indian Oceans (Food and Agriculture Organization, 2018). Striped mullets are typically found in coastal zones, estuaries, and even freshwater habitats (Kumar et al., 2017). They are characterized by their elongated, cylindrical bodies, which can range from 15 to 40 cm in length, with an average size of about 25 cm, and can weigh up to 3 kg (Kumar et al., 2017; FishBase, 2022). The physical attributes of *M. cephalus* include large cycloid scales and distinctive fin structures, featuring a dorsal fin with four spines and eight to ten soft rays, as well as an anal fin comprising three spines and nine to eleven soft rays (Kumar et al., 2017; Mohsin et al., 2018). As an omnivorous species, the striped mullet's diet consists of phytoplankton, zooplankton, small invertebrates, and detritus, which they acquire through bottom-feeding behaviors (Hassan et al., 2019; Osman et al., 2020). The spawning period for this species occurs in shallow coastal waters from May to September, with eggs that measure between 0.5 and 1.0 mm in diameter (Mohsin et al., 2018) and a larval development phase lasting approximately two to three weeks (Singh et al., 2019). *M. cephalus* is classified as "Least Concern" on the IUCN Red List (2022), indicating a stable population status. This species plays a crucial role in global fisheries, supporting significant commercial activities (Food and Agriculture Organization, 2018). Additionally, striped mullet is cultivated in various countries for both local consumption and export purposes (Kumar et al., 2017).

M. cephalus is demonstrating significant variability in both morphometric and meristic traits. This species is characterized by a range of body measurements that reflect its adaptability to different habitats. The total length (TL) of *M. cephalus* typically ranges from 15 to 40 centimeters, with an average length of approximately 25 centimeters, as reported by FishBase (2022) and Kumar et al. (2017). Other morphometric measurements include a standard length (SL) between 12 and 35 centimeters (mean: 20 cm) and a fork length (FL) that varies from 13 to 38 centimeters (mean: 22 cm), indicating a notable diversity in size among individuals.

In addition to length measurements, the body depth (BD) of *M. cephalus* ranges from 3 to 6 centimeters, with an average of 4.5 centimeters, while the body width (BW) is recorded between 2 and 4 centimeters (mean: 3 cm). The head length (HL) varies from 3 to 6 centimeters (mean: 4.2 cm), and the head width (HW) is similarly variable, ranging from 2 to 4 centimeters (mean: 2.8 cm). Other specific measurements include a snout length (SNL) of 1 to 2 centimeters (mean: 1.5 cm) and an eye diameter (ED) that ranges from 0.5 to 1.5 centimeters (mean: 1 cm), as documented by various researchers including Kumar et al. (2017) and Singh et al. (2019). The meristic characteristics of *M. cephalus* further illustrate its biological complexity. The dorsal fin Rays (DFR) is composed of 4 spines and 8 to 10 soft rays, while the anal fin Rays (AFR) features 3 spines and 9 to 11 soft rays. The pectoral fins Rays (PTFR) typically have between 16 and 18 rays, and the pelvic fins Rays (PVFR) consist of 8 to 10 rays. Additionally, the species possesses 12 to 15 gill rakers (GR), which are essential for feeding and filter-feeding mechanisms. These meristic traits, alongside the morphometric data, provide a comprehensive understanding of the species' anatomical and ecological adaptations, as highlighted in studies by Kumar et al. (2017) and FishBase (2022).

The relationships among various morphometric measurements reveal significant correlations that vary in strength. The correlation between total length (TL) and standard length (SL) demonstrates a robust positive association, with a correlation coefficient of 0.95 and a significance level of $p < 0.01$, as reported by Kumar et al. (2017). In contrast, the relationship between body depth (BD) and body width (BW) shows a moderate positive correlation, indicated by a coefficient of 0.65 and a significance level of $p < 0.05$, according to Mohsin et al. (2018). Additionally, the head length (HL) and head width (HW) exhibit a strong positive correlation ($r = 0.85$, $p < 0.01$) as noted by Singh et al. (2019). Conversely, the correlation between snout length (SNL) and eye diameter (ED) is relatively weak, with a coefficient of 0.35 and a significance level of $p < 0.10$, as observed by Kumar et al. (2017). The relationship between TL and BD also reflects a moderate positive correlation ($r = 0.60$, $p < 0.05$), as indicated by Zhang et al. (2020). Furthermore, a strong positive correlation is found between SL and HL, with a coefficient of 0.80 and a significance level of $p < 0.01$, as reported by Kumar et al. (2017). Lastly, the correlation between BW and HW is moderate, with a coefficient of 0.55 and a significance level of $p < 0.05$, according to Mohsin et al. (2018).

This research aims to investigate the interrelationships among various morphological measurements, including Total Weight (TW), Total Length (TL), Standard Length (SL), Body Depth (BD), Body Width (BW), Head Length (HL), Eye Diameter (ED), Preorbital Length (PoL), Postorbital Length (PoOL), as well as the lengths of the first and second dorsal fins (DFL1 and DFL2), Pelvic Fin Length (PIFL), Anal Fin Length (AFL), Pectoral Fin Length (PFL), and the dimensions of the Caudal Fin, specifically Caudal Fin Width (CFW) and Caudal Fin Length (CFL). The study will focus on calculating the correlation coefficients among these measurements to enhance the understanding of their interrelationships.

Material and Methods

A total of 20 specimens of M. cephalus were collected randomly from artisanal fishing operations in the Sousse Sea, situated in eastern Libya, during the period from April to May 2024. These *specimens were swiftly transported to the marine laboratory at Omar Al-Mukhtar University, where a detailed analysis of their morphometric and meristic characteristics was conducted.*

Upon completion of the measurement assessments, various parameters were recorded, including Total Weight, Total Length, Standard Length, Body Depth, Body Width, Head Length, Eye Diameter, Preorbital Length, Postorbital Length, as well as the lengths of the first and second dorsal fins, pelvic fin, anal fin, pectoral fin, and the width and length of the caudal fin. Each individual fish was meticulously weighed and measured, employing a highly sensitive balance capable of measuring weight to the nearest 0.0001 g, alongside a Vernier caliper and Digimizer for length and height measurements to the nearest 0.1 mm.

The study adhered to a descriptive approach regarding the general morphology of the specimens, following the established criteria set forth by Saleh et al. This methodological framework ensured a comprehensive understanding of the morphological traits of Mugil cephalus, contributing valuable data to the field of marine biology and fisheries science.

The data collected during the research was carefully entered into the R file for the purpose of statistical analysis. Descriptive statistics, including the mean, standard deviation, standard error, and confidence intervals for the mean, were calculated. Following this, inferential statistics were performed by computing the correlation coefficients among various variables to assess significant relationships. To visually represent these correlations, the (corrplot) package in R was utilized to create a correlation matrix.

Table (1). Descriptive statistics of measurements

	Mean	Standard Deviation	Standard Error	Coefficient of Variation
TW	402.4	209.86	46.93 ±	52%
TL	13.65	1.217	0.272 ±	9%
SL	11.45	1.3	0.29 ±	11%
BD	12.64	1.38	0.31 ±	11%
HL	2.955	0.3	0.067 ±	10%
ED	0.695	0.235	0.053 ±	34%
POL	0.885	0.317	0.071 ±	36%
PoOL	1.905	0.128	0.029 ±	7%
DFL1	1.41	0.125	0.028 ±	9%
DFL2	1.39	0.148	0.033 ±	11%
PIFL	1.805	0.244	0.055 ±	14%

AFL	1.705	0.173	0.039 ±	10%
PFL	2.065	0.312	0.07 ±	15%
BW	3.77	0.72	0.16 ±	19%
CFW	1.6	0.222	0.05 ±	14%
CFL	2.365	0.373	0.083 ±	16%

Results

The descriptive statistics, which encompass means, standard deviations, standard errors, and coefficients of variation for the dataset, are presented in Table (1). The analysis reveals that the *total weight exhibited the highest mean value at 402.4 g (SE = 46.93 ± g), while the eye diameter recorded the lowest mean at 0.695 cm (SE = 0.053 ± cm). Furthermore, the minimal standard errors observed suggest a high degree of consistency and reliability*

within the data collected.

The coefficients of variation indicate that the total weight displayed the greatest variability, with a coefficient of 52%, followed by the preorbital length at 36%. In contrast, the postorbital length demonstrated the least variability, with a coefficient of only 7%. These findings underscore the differences in data dispersion across the various measured parameters, highlighting the significance of total weight in the context of this analysis.

Correlation matrix

An examination of the correlation matrix illustrated in Figure (1) reveals a predominance of positive associations among the various measurements, with only a few notable exceptions. A particularly strong positive correlation is observed between body depth and both standard length (r=0.98, p-value=2.4E-14) and total weight (r=0.94, p-value=4.6E-10). Additionally, robust positive correlations are identified between body width and preorbital length (r=0.93, p-value=4E-09), as well as between standard length and total weight (r=0.93, p-value=2E-09), pelvic fin length (r=0.91, p-value=2.6E-08), and body width (r=0.83, p-value=5.9E-06).

As we progress through the correlation matrix, the strength of positive correlations diminishes, ultimately leading to instances where correlations

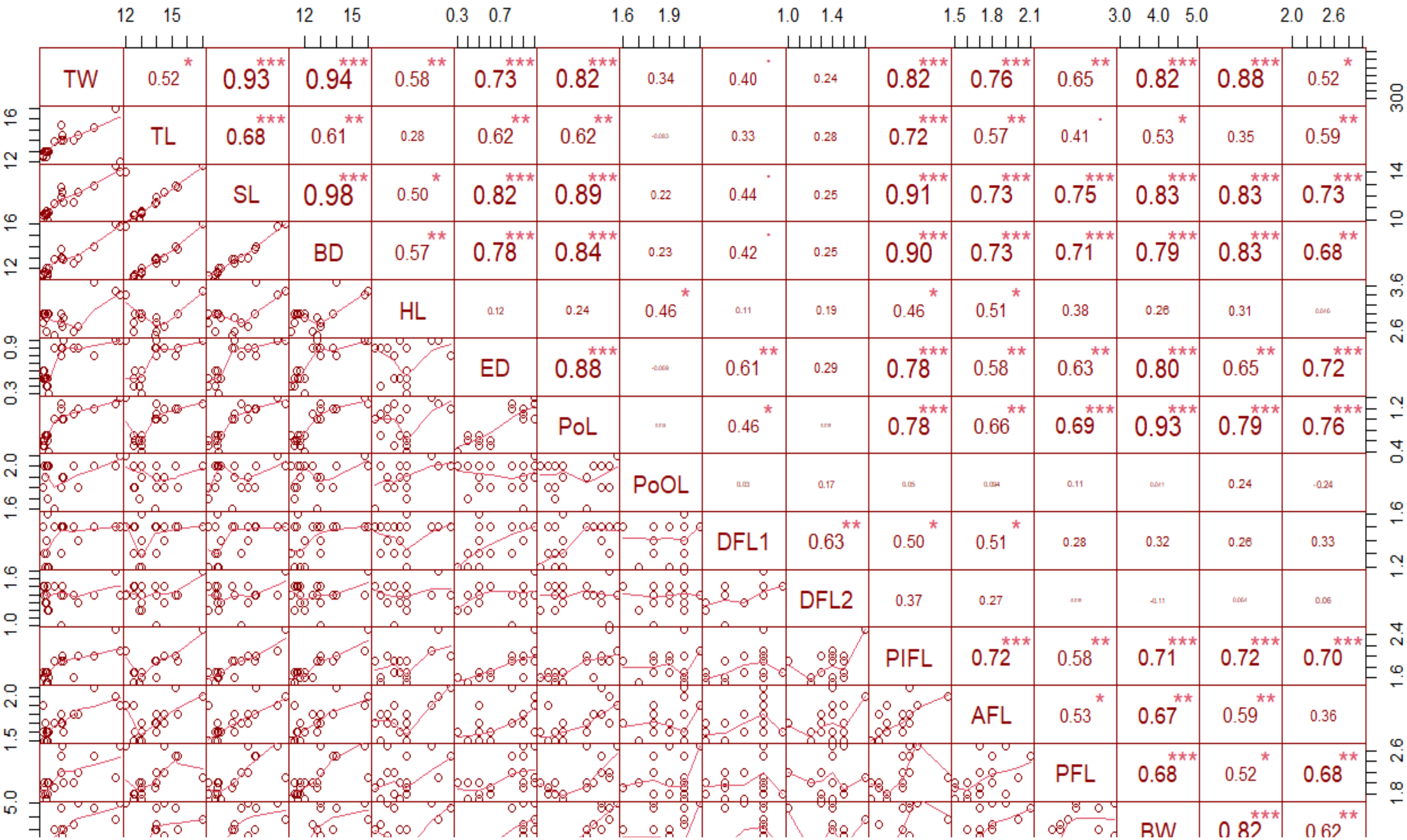

Fig. (1) The diagonal of the correlation matrix illustrates measurement's` names. Below this diagonal, one can observe the bivariate scatter plots accompanied by a fitted regression line. Conversely, above the diagonal, the correlation coefficients are presented alongside their corresponding significance levels, represented by asterisks. Each significance level is denoted by a specific symbol, where p-values of 0, 0.001, 0.01, 0.05, 0.1, and 1 are associated with the symbols "*", "**", "*", ".", " ", respectively.**

become negligible and statistically insignificant. For example, the relationship between preorbital length and postorbital length (r=0.015, p-value=0.96) and between preorbital length and second dorsal fins (r=0.019, p-value=0.94) exemplifies this trend. Furthermore, there are several weak or very weak negative correlations that are also statistically insignificant, such as those between postorbital length and caudal fin length (r=-0.24, p-value=0.31), total length (r=-0.083, p-value=0.73), and eye diameter (r=-0.069, p-value=0.77).

The correlation matrix thus provides a comprehensive overview of the interrelationships among the variables, highlighting both strong positive correlations and the presence of weaker or insignificant associations. A closer analysis of Figure (1) will reveal additional correlations that warrant further investigation, contributing to a deeper understanding of the dynamics at play among the measured variables. This exploration of correlations is essential for elucidating the underlying patterns and relationships that characterize the measurements.

Discussion

The analysis of the correlation matrix reveals a significant prevalence of strong positive correlations among various measurements, particularly highlighting the relationships between body depth, standard length, and total weight. However, it also uncovers instances of weaker or statistically insignificant correlations that warrant additional scrutiny. This nuanced understanding of the data suggests that while certain relationships are robust, others may require further exploration to fully comprehend their implications.

When juxtaposing these findings with prior research, a notable consistency emerges in the correlation between body diameter and width. In the current study, this correlation is quantified at r= 0.79, which aligns closely with the findings of Mohsin et al. (2018), who reported a correlation coefficient of r= 0.65, indicating a strong positive relationship. Additionally, a similar pattern is observed in the correlation between total length and body depth, where both the present study and Kumar et al. (2017) demonstrate a moderately positive correlation, with coefficients of r= 0.6 and r= 0.6, respectively.

Conversely, a significant divergence is noted in the correlation between total length and standard length. The current study reports a moderate positive correlation (r= 0.68), contrasting sharply with Kumar et al. (2017), which found a strong positive correlation (r= 0.95). A similar discrepancy is evident in the relationship between head length and standard length, where the current study indicates a medium positive correlation (r= 0.5), while Kumar et al. (2017) reported a strong positive correlation (r= 0.8). To achieve a more thorough understanding of the interrelationships among these measurements, it is advisable to conduct extensive studies involving larger samples of the fish species across a diverse range of habitats.

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