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Morphological features and morphometric structure of the Sepia elegans along the coast of Sousa, eastern Libya

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A B S T R A C T

The aim of this study was to determine the morphological characteristics of female and male ***S. elegans*** in the Sousa region, located in eastern Libya. A total of 30 specimens were randomly collected, and 13 morphometric measurements were taken for each specimen. The mean values of these morphological measurements were determined. The maximum total length was 15.10 cm, and the maximum weight was 275 g, while the minimum total length and weight were 11.50 cm and 161 g, respectively. No statistically significant differences were observed between males and females. High R^2 values, ranging from 0.790 to 0.799, indicated that the results of linear, logarithmic, and exponential regressions for the WW–DML relationship were very good. The logarithmic regression was the most accurate, achieving the highest R^2 values among the three regressions for both males and females. The regression constants “a” and “b” were statistically significant in most cases. The “b” value for the power regression was 1.50, which is less than 3, indicating a negative allometric growth pattern. Additionally, the condition of the squid improved with growth, as shown by the regression models (logarithmic, linear, and power) for C^F with DML, which had high coefficients of determination (R^2). This indicates that the WW/DML ratio increased with cuttlefish growth. Pairwise correlations between morphometric measurements were generally good; some were statistically significant, while others were not.

الخصائص المورفولوجية والبنية المورفومترية لـ Sepia elegans على طول ساحل سوسة، شرق ليبيا

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الـمُخلص

هدفت هذه الدراسة إلى تحديد الخصائص المورفولوجية لكل من ذكور وإناث S. elegans في منطقة سوسة الواقعة شرق ليبيا. جُمعت عشوائيًا 30 عينة، وأُخذت 13 قياسًا مورفومتريًا لكل عينة، ثم حُددت القيم المتوسطة لهذه القياسات المورفولوجية. بلغ الحد الأقصى للطول الكلي 15.10 سم، والحد الأقصى للوزن 275 جم، بينما بلغ الحد الأدنى للطول الكلي والوزن 11.50 سم و161 جم على التوالي. لم تُلاحظ فروق ذات دلالة إحصائية بين الذكور والإناث.أظهرت قيم R^2 المرتفعة، والتي تراوحت بين 0.790 و0.799، أن نتائج الانحدارات الخطي واللوغاريتمي والأسي لعلاقة WW–DML كانت جيدة جدًا. وكان الانحدار اللوغاريتمي الأكثر دقة، حيث حقق أعلى قيم R^2 بين أنواع الانحدار الثلاثة لكل من الذكور والإناث. كما كانت ثوابت الانحدار "a" و"b" ذات دلالة إحصائية في معظم الحالات. بلغت قيمة "b" في الانحدار القُدْري 1.50، وهي أقل من 3، مما يشير إلى نمط نمو تباينيي سلبي (Negative Allometric Growth).بالإضافة إلى ذلك، تحسنت الحالة الجسمية للحبار مع النمو، كما أوضحت نماذج الانحدار (اللوغاريتمي والخطي والقُدْري) لعلاقة CF مع DML، والتي أظهرت معاملات تحديد (R^2) مرتفعة. ويشير ذلك إلى أن نسبة WW/DML ازدادت مع نمو الحبار. وكانت معاملات الارتباط الثنائية بين القياسات المورفومترية جيدة بشكل عام؛ إذ كانت بعض العلاقات ذات دلالة إحصائية، في حين لم تكن الأخرى كذلك.

الكلمات المفتاحية: سيبيا، القياسات المورفومترية، سوسة، الأحياء البحرية، علاقة الطول بالوزن، النمو ألتبايني.

1 Introduction

Fish production in Libya is relatively low, despite the country possessing a coastline of approximately 1,970 km that is rich in marine resources (Abu Madina, 2008). Nets and hooks are the most commonly used fishing methods from boats. Nets are divided into two types: trawl nets and gillnets, while hooks include longlines and handlines (Abu Madina, 2008).

Within this context, cephalopods—particularly cuttlefish of the genus Sepia—are among the most abundant species in the Mediterranean Sea. Cuttlefish have significant economic value due to the high demand for them in both international and local markets. They also play an important role in the marine food chain, acting as both predators and prey. The family *Sepiidae* is widely distributed across oceans and seas at various depths and includes approximately 100 species belonging to the genus *Sepia* (Lu & Reid, 1997). Cuttlefish can inhabit depths of up to 1,000 meters along the upper slopes and continental shelf. They are capable of living in diverse environments, including algae, coral reefs, sandy and muddy substrates, and seagrass beds. Cuttlefish are also influenced by temperature changes, which drive their seasonal migrations. During the breeding season, they aggregate in shallow waters (Boletzky, 1983). Therefore, studying the morphological characteristics of cuttlefish is essential for understanding their biology, improving fish stock assessment models, and supporting fisheries, as well as the sustainable exploitation of marine resources in Libya.

2 Materials and Methods

Morphological structure refers to the numerical, morphometric, and morphogenetic characteristics of living organisms. When formulating a specific policy for the management of environmental resources and ecosystems, morphological structure—together with the length–weight relationship and condition factor—constitutes essential input parameters for developing population models (Suarez & Conde, 2002). In the context of evaluating ecological stock models, it is necessary to refer to morphological traits, as the length–weight relationship enables the conversion of growth rates in length into growth rates in weight, which are subsequently utilized within the assessment model (Atar & Selçuk, 2003).

Objectives of the Study

- To determine the morphological structure of ***Sepia elegans*** in Sousa.
- To compare the morphological characteristics of male and female ***Sepia elegans*** in Sousa region.
- To employ linear and exponential regression models in order to relate the derived traits to total mantle length and to examine whether these traits undergo changes throughout the growth process.

Study Sampling Site

Sousa Study Area

The Sousa study area is located in northeastern Libya. It is characterized by a variety of natural landscapes and the presence of historical Greek archaeological remains. The area is also rich in commercially important fish species, which are marketed in nearby small towns. Geomorphologically, it consists of a rocky tidal zone interspersed with sandy beaches.

The morphological measurements taken

Samples were randomly collected from the Sousa area using traditional fishing boats during the study period. The sex of each cuttlefish specimen was identified; the sample consisted of 16 females and 14 males. Their descriptive characteristics were recorded, and thirteen main morphometric measurements were taken using a ruler to the nearest millimeter. Weights were measured using a sensitive balance with a precision of 0.01 g, as shown in Table 1.

Length –weight relationship

The length – weight relationship was described by a power relationship based on (Le Cren, 1951):

$$W = aL^b$$

Where:

W= total weight (g).

L= dorsal mantle length (cm)

a and b = constants

The condition factor

Fulton's (1902) condition factor (K_F) is calculated as follows:

$$K\_F = 100\ (Wt / DML^3)$$

Where:

Wt= total weight (g).

DML= dorsal mantle length (cm).

Statistical Procedures

Statistical analyses were performed using IBM SPSS Statistics and Microsoft Excel. Descriptive statistics, regression analysis, and Pearson correlation coefficients were calculated.

- Descriptive statistics for the measured morphometric parameters of the cuttlefish.
- Examination of the relationship between dorsal mantle length and wet weight.
- Calculation of Pearson's bivariate correlation coefficients for the morphometric measurements and the condition factor of the cuttlefish.
- Regression analysis relating mantle length to the various morphometric measurements.
- Independent t-tests were applied to the morphometric measurements of male and female cuttlefish to assess the effect of sex. The level of statistical significance was set at $p < 0.05$.

Table1.The morphometric measurements recorded for male and female cuttlefish during the study.

NO.	Code	Measurements
1	G	Gender
2	TW	Total weight
3	DML	Dorsal mantle length
4	FL	Fin length
5	HW	Head width
6	HL	Head length
7	AL	Arm length
8	VML	Ventral mantle length
9	MW	Mantle width (ventral)
10	FW	Fin width (ventral)
11	FNL	Funnel length
12	CL	Club length
13	CW	Club width

3 Results

Morphological Structure of the Elegant Cuttlefish (***Sepia elegans***) In this study, cuttlefish samples were collected from the Sousa area, totaling 30 specimens, to determine the morphological characteristics of this species. Thirteen main morphometric measurements were recorded. The maximum length reached 15.10 cm with a wet weight of 275.00 g, while the minimum length was 11.50 cm with a wet weight of 161.00 g. No statistically significant differences were observed between females and males, as shown in Table 3.

Table 2. Morphometric measurements of *Sepia elegans* (weights in grams, lengths in centimeters) recorded in this study.

PARAMETER	Minimum	Maximum	Mean	Std. Error
Total weight	161.00	275.00	196.2000	8.26882
Dorsal mantle length	11.50	15.10	13.1733	0.27438
Fin length	9.90	15.00	12.3200	0.33183
Head width	5.00	8.00	6.3267	0.25828
Head length	2.00	5.50	3.6533	0.26635
Arm length	6.00	12.00	8.6067	0.41833
Mantle length (ventral)	10.10	13.00	11.6533	0.22208
Mantle width (ventral)	8.00	10.00	8.7333	0.13721
Fin width (ventral)	10.00	13.00	11.4333	0.24215
Funnel length	1.00	2.80	1.8400	0.14236
Club length	.00	14.60	12.0133	0.89165
Club width	3.90	6.00	4.8533	0.14171

Table 3. Average morphometric measurements by sex (female and male) for weight and length of *Sepia elegans*.

PARAMETER	Gender	Mean
Total weight	F	193.1000
	M	202.4000
Dorsal mantle length	F	13.3500
	M	12.8200
Fin length	F	12.3300
	M	12.3000
Head width	F	6.2000
	M	6.5800
Head length	F	3.4800
	M	4.0000
Arm length	F	8.5700
	M	8.6800
Mantle length (ventral)	F	11.5300
	M	11.9000
Mantle width(ventral)	F	8.5000
	M	9.2000
Fin width (ventral))	F	11.2600
	M	11.7800
Funnel length	F	1.8900
	M	1.7400
Club length	F	13.0700
	M	9.9000
Club width	F	4.9300
	M	4.7000

Dorsal mantle length–wet weight relationships

The relationship between dorsal mantle length and wet weight in both males and females of ***Sepia elegans*** was examined using linear, exponential, and logarithmic regression models, as illustrated in Figure 3. The results showed that the coefficient of determination (R^2) ranged from 0.790 and 0.799. However, the logarithmic regression model provided the best fit, as it exhibited the highest R^2 value among the three models for both males and females. Furthermore, most of the regression constants *("a" and "b")* were found to be statistically significant. The value of the exponent *b* in the exponent regression model was 1.50, which is less than 3, indicating negative allometric growth.

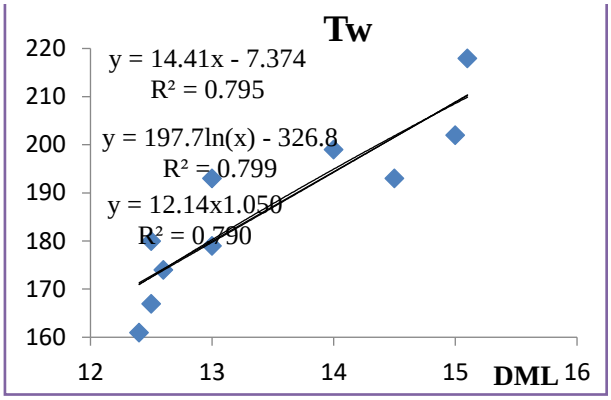

Fig. 1 Regression of wet weight (WW) of male and female *Sepia elegans* with Dorsal mantle length (DML)

The condition factor of Sepia elegans

The condition factor of Sepia elegans was analyzed in this study through regression of the condition factor against dorsal mantle length (DML), showing a high coefficient of determination (R^2). The results indicate that the condition of Sepia elegans improves as it grows, meaning that the ratio of wet weight (WW) to dorsal mantle length (DML) increases with growth.

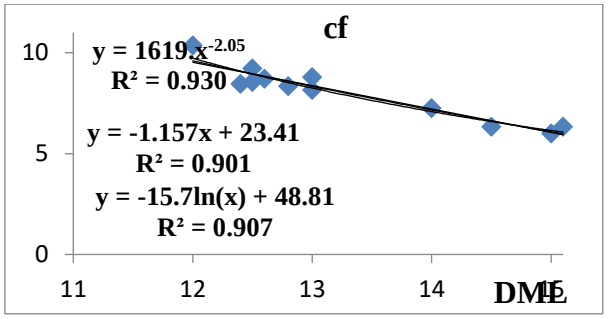

Fig. 2. Regression of condition factor of Sepia by length

Correlation Among Morphometric Measurements

The relationships among morphometric measurements showed that some pairwise correlations were statistically significant, while others were not, indicating variability in the degree of association between different measurement parameters.

Correlations												
para	**Tw**	**DML**	**FL**	**HW**	**HL**	**AL**	**VML**	**MW**	**FW**	**FNL**	**CL**	**CW**
Tw	**1**											
DML	**.396**	**1**										
FL	**.589***	**.644****	**1**									
HW	**.865****	**.477**	**.530***	**1**								
HL	**.276**	**.669****	**.652****	**.457**	**1**							
AL	**.099**	**.396**	**.114**	**.178**	**.363**	**1**						
VML	**.522***	**.195**	**.170**	**.423**	**.143**	**.292**	**1**					
MW	**.599***	**.167**	**.485**	**.512**	**.437**	**.345**	**.648****	**1**				
FW	**.290**	**.131**	**.594***	**.359**	**.554***	**.291**	**.379**	**.691****	**1**			
FNL	**-.324-**	**.487**	**.219**	**-.037-**	**.544***	**.251**	**.000**	**-.112-**	**.196**	**1**		
CL	**.241**	**.524***	**.231**	**.206**	**.149**	**.433**	**-.213-**	**-.138-**	**-.300-**	**.043**	**1**	
CW	**.149**	**.624***	**.307**	**.346**	**.286**	**.184**	**-.075-**	**-.161-**	**.000**	**.240**	**.117**	**1**

4 Discussion

The wet weight (WW) and dorsal mantle length (DML) of ***Sepia elegans*** in this study ranged from 161.00 to 275.00 g and from 11.50 to 15.10 cm, respectively, with mean values of 196.20 ± 8.27 g and 13.17 ± 0.27 cm. Another study reported that the dorsal mantle length ranged between 63 and 133 mm in males and between 67 and 110 mm in females, while total weight ranged from 35.5 to 192.9 g in males and from 37.3 to 103.5 g in females (Guerra, 2019). The higher values observed in this study may be attributed to variations in environmental conditions, particularly within Libyan coastal waters. Several key factors play a crucial role in determining growth patterns, including salinity, food availability, and water temperature. The Libyan coast is characterized by relatively warm waters and seasonal productivity, which may enhance feeding efficiency and growth rates in cephalopods. These findings were supported by high coefficients of determination (R^2), which ranged from 0.795 to 0.799. However, the logarithmic regression model proved to be the most accurate, yielding the highest R^2 value among the three regression models for both males and females. This may be attributed to energy allocation, as larger individuals tend to invest a substantial portion of their energy in reproduction rather than somatic growth. The regression constants "a" and "b" were statistically significant in most cases. The value of *b* in the power regression (1.50) was less than 3, indicating negative allometric growth. In the Libyan marine environment, this pattern may be influenced by environmental stressors, including fishing pressure and limited nutrient availability, which can constrain optimal weight gain in smaller individuals. Additionally, in Libyan waters, cuttlefish tend to shift their diet from small crustaceans during early life stages to larger invertebrates and fish as they grow older. According to (Froese, 2006), growth is considered negative when the value of b is less than 3, suggesting that organisms tend to become more elongated as size increases or that smaller individuals may have experienced poor nutritional conditions. Gonadal maturity is influenced by the length–weight relationship, particularly in females (Cisneros-Mata, 1991). All regression models (linear, logarithmic, and exponential) describing the relationship between the condition factor (CF) and dorsal mantle length (DML), with high coefficients of determination (R^2), indicated that the condition of cuttlefish improves with growth. In other words, the ratio of total weight to dorsal mantle length (TW/DML) increases as the organism grows. This suggests that cuttlefish enhance their ability to acquire food as they increase in size, particularly when their diet becomes more carnivorous with growth. This improvement may be attributed to increased feeding efficiency and enhanced metabolic capacity in larger individuals. In Libyan coastal ecosystems, larger individuals are better able to exploit a wider range of available nutrients, thereby gaining a competitive advantage. The potential pairwise correlations among the morphometric measurements of cuttlefish were generally strong; some were statistically significant, while others were not. This may be attributed to the influence of local currents and environmental

heterogeneity in coastal areas of eastern Libya (such as the Sousa region), which can lead to morphological variations among individuals.

5 Conclusions

This study aimed to investigate the morphometric characteristics and length–weight relationship of Sepia elegans collected from the Sousa region in eastern Libya. The results showed differences in morphometric measurements among the specimens. These findings provide basic biological information that may contribute to future studies related to marine biology and fisheries in Libyan waters.

Conflict of interest: No conflict of interest.

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Enclose the references list at the end of the manuscript accordingly to the APA (American Psychological Association) style (5th to 7th) edition.

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