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Research article

Estimation of biometric characters, relative growth and sex ratio of cuttlefish, *Sepia officinalis* Linneus, 1758 (Cephalopoda: Sepioidea) off the coast of Lagos, Southwest, Nigeria

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Abstract

The biometric characters, relative growth and condition factor (K) with sex ratio were investigated of the common cuttlefish (*Sepia officinalis*) off the Lagos coast (Nigeria) between August 2018 and January 2020. In total, 1,082 cuttlefish were analyzed for biometric parameters, measured to the nearest 0.01 cm using a measuring board. To record the body weight, samples were blotted dry and weighed on an electronic balance up to the nearest gram. The correlation coefficient (R) for various biometric characters against mantle length ranged between 0.253 and 0.823, indicating a high degree of relationship among the characters compared. The highest value of R (0.823) and hence the highest correlation was between the dorsal mantle length and total weight. The strongest positive association was with the length of arms, mantle breadth, head width, cuttlebone and total weights. The linear regression equation for both sexes using a log-transformed length-weight relationship revealed negative allometric growth ($b < 3$), reflecting a comparatively slower growth rate in total weight than in mantle length throughout the species ontogeny. The highest K value (4.44) was recorded for the largest size group (24.98–27.60 cm), while females had a higher K value than males. Out of the 1,082 specimens, the incidence of males (799) was significantly ($p < 0.05$) much higher than for females (283), resulting in a sex ratio of 1:0.35. This statistic suggested a strong indication of skewed sex ratio within the cuttlefish population off the Lagos coast.

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Introduction

Cephalopods are ancient marine mollusks characterized by bilateral body symmetry, a prominent head and a set of arms or tentacles modified from the primitive mollusk foot (Siddique et al., 2016). Living cephalopods include the nautilus, squid, octopus and cuttlefish (Wood and O'dor, 2000). The cuttlefish is a type of marine mollusk that belongs to the family Sepiidae of the class Cephaopoda. Owing to the appearance of fins, it is referred to as a cuttlefish. It undergoes internal fertilization, have a high fecundity and growth rate, but has a short life span of 1–2 years (Beasley, 2017). According to Duysak et al. (2014), cuttlefish can exhibit variations in its life cycle, living for approximately 2 yr before exhibiting mass mortality of adults following a spring spawning period. Currently, more than 120 species of cuttlefish are known and are mainly bottom-dwellers in a variety of environments, including rocks, sea grass, seaweed, coral reefs and sandy and muddy substrates (Reid et al., 2005). The contribution of cuttlefish species to local fisheries varies by location, with commercial catches of 1,163.3–841.6 t in the Mediterranean Ocean, 321.4 t in the Aegean Sea and 0.3 t in the Marmara Sea (Duysak et al., 2014). The common cuttlefish, *Sepia officinalis* (L. 1758) is commonly found in the Atlantic, from the North Sea to the Cape of Good Hope, through the English Channel and the eastern coast of Africa to Mozambique and is one of the most important demersal marine invertebrates inhabiting the continental shelf (Lawal-Are et al., 2018).

Study of the length-weight relationship is a basic biostatistical approach in fish biology, where the mathematical expression between length and weight is used to determine the other where either is unknown, and this expression serves as an indication of factors, general well-being and development (Getso et al., 2017). In some cases, it is easier to take measurements of weight rather than length, such as for cephalopods, and then the weight data can be converted to length using the length-weight relationship. Length and weight measurements in conjunction with age data can provide information on maturity, life span, mortality, growth and reproduction (Kumar et al., 2014). According to Mishra et al. (2012), this relationship serves three purposes: 1) to determine the type of the mathematical relationship between two variables so that if one variable is known the other can be computed; 2) the relative condition can be estimated to assess the general wellbeing of the fish and type of growth (isometric or allometric); and 3) it helps in the estimation of the potential yield per recruit in studies of fish population dynamics. The morphometric characters and their allometric relationship are to a large extent influenced by the age, local environmental conditions and pollution density of the species (Ramasamy et al., 2013).

Biometric traits in various aquatic mollusks at different locations have been used by many researchers to predict the live weight of the animals (Moruf and Lawal-Are, 2015; Moruf et al., 2018; Akinjogunla and Moruf, 2019). Biometric characters in cephalopods involve relationships between various parameters such as dorsal mantle length, dorsal body breadth and total weight; with cuttlefish, length of the mantle from the anterior-most point on the dorsal side to the posterior body tip is considered as the 'standard' and is termed the dorsal mantle length (Sundaram and Khan, 2010). Several studies have been carried out on different features of cuttlefish in different parts of the world. For example, Siddique et al. (2016) reported the morphometric relationships of three semi-tropical cephalopods from the coastal waters of Bangladesh, while Tuanapaya and Nabhitabhata (2017) reported the morphological phylogeny of *Sepia pharaonis* in Thai waters. However, investigations regarding the biometrics of *S. officinalis* in African waters remain scarce. Consequently, the present study was conceived to provide useful information concerning the biometric characters, length-weight relationship, condition factor and sex ratio of *S. officinalis* off the Lagos coast, Nigeria.

Materials and Methods

Description of study area

The study area, off the Lagos coast, is a marine environment extending from the Badagry to the Ibeju-Lekki Local Government Areas of Lagos State, Nigeria. It is located between 6°20'N–6°34'N and 2°45E'–3°60'E and falls within the barrier lagoon complex (200 km). Eight notable stations were selected as sampling points for this research based on representing the entire length of Lagos State off the coast of Lagos, Nigeria (Fig. 1). The dominant ocean currents operating within the region include the Benguella, Guinea, Equatorial and the Equatorial counter currents (Akanmu and Onyema, 2020). These currents, which are associated with intense coastal upwelling and tropical sea surface temperatures, feed the westward North and South Equatorial Currents, respectively (Longhurst et al., 2005).

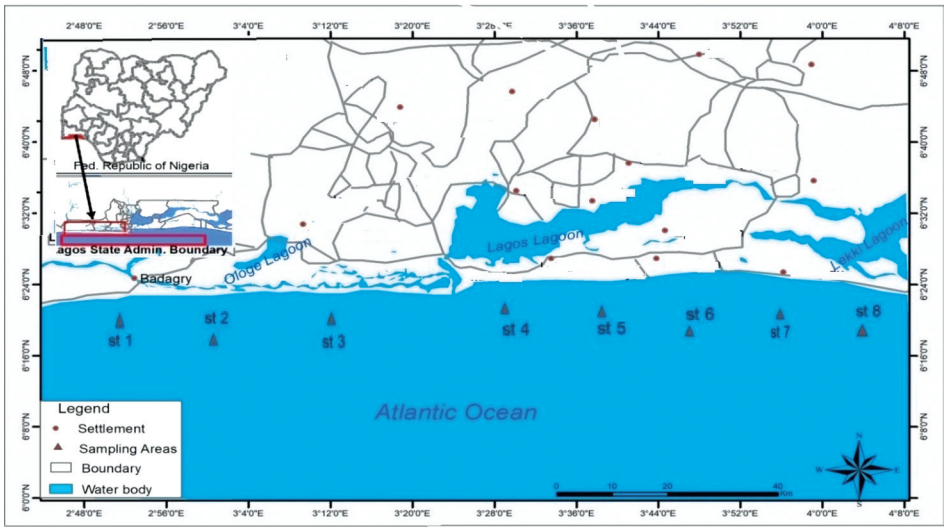

Fig. 1 Map of Lagos coast showing eight sampling locations (1st– 8th)

Data collection and length-weight relationship

In total, 1,082 samples of cuttlefish (Fig. 2) were collected randomly between 1,000 hrs and 1,200 hrs over a period of 18 mth (August 2018 to January 2020) from 8 stations off the Lagos coast Nigeria. The specimens were immediately identified, sorted and sexed, after which the biometric parameters were measured in fresh condition. The sex of each cuttlefish was determined using physical examination (presence of the left arm four [IV] hectocotylized [modified arm] typical for males).

The dorsal mantle length (DML) and other morphometric measurements were taken using a divider and measuring board to the nearest centimeter (Central Marine Fisheries Research Institute, 1995). After recording lengths, the cuttlefish were blotted dry and weighed on an electronic balance up to the nearest milligram and this was recorded as the body weight (WT). The cuttlebone weight was recorded after removing it from the mantle cavity. Thereafter, relationships between the various body measurements to the dorsal mantle length were calculated using the mean and standard deviation.

Fig. 2 Dorsal view of common cuttlefish (*Sepia officinalis*) collected off Lagos coast, Nigeria

The relationships between the characters were determined using a modified linear regression formula, shown in Equation 1 (Pauly, 1983), while the cubic relationship between length (L) and weight (W) was natural logarithm-transformed into a straight-line (Parsons, 1978) as shown in Equation 2:

$$W = aL^b \quad (1)$$

$$\log W = \log a + b \log L \quad (2)$$

where W is the body weight (measured in grams), L is the dorsal mantle length (measured in centimeters), log is the natural (Euler's) logarithm, a is the regression constant (intercept) and b is the regression coefficient (slope).

The length-weight relationship was determined separately for males, females and the pooled data. Length and weight data were used to determine the condition factor, K (Equation 3) according to Bannister (1976):

$$K = \frac{100W}{L^3} \quad (3)$$

where W is the body weight (measured in grams), Lis the dorsal mantle length (measured in centimeters)

Data analysis

Analysis of covariance was conducted to test for a significant ($p < 0.05$) difference in the values of b between males and females. The χ^2 test of fitness was applied to determine a departure from the expected or theoretical 1 to 1 ratio between males and females (Equation 4):

$$\chi^2 = \frac{\Sigma_i(o_i - E_i)^2}{E_i} \quad (4)$$

where: Σ_i is the summation of values, O_i is the observed ratio and E_i is the expected ratio. The calculated and tabulated χ^2 values were compared at $\alpha = 0.05$ to determine the level of significance.

Data were analyzed using the Excel 2010 (Microsoft; USA) and SPSS (Version 21; IBM; USA) software packages.

Results and Discussion

Biometric and growth pattern of cuttlefish

The descriptive data of biometric characters are compiled in Table 1. There were 17 biometric characters estimated for *S. officinalis,* which was more morphometric features recorded than in most other cuttlefish species; Muchlisin et al. (2014) measured 13 biometric characters for *Sepioteuthis lessoniana* while Tehranifard and Dastan (2011) described 15 characters for *S. pharaonis*. In the present study, the dorsal mantle length was in the range 6.50–27.60 cm while the total weight was in the range 19.20–1,376.40 g. Duysak et al. (2014) reported mantle lengths in the range 4.8–19.2 cm, while Valeri et al. (2016) reported values in the range 10.0–29.7cm and Akyol et al. (2011) in the range 5.5–22.4 cm. The mantle lengths in the present study were higher than those reported by Siddique et al. (2016), who reported 135 mm and 82 mm as the maximum dorsal mantle length for needle cuttlefish and spineless cuttlefish respectively. *S. officinalis* reaches 30 cm and 2 kg in subtropical waters and can be as high as 45 cm and 4 kg in temperate waters (Food and Agriculture Organization of the United Nations, 2017). These differences could be due to environmental, nutritional and genetic variations.

In the present study, dorsal mantle length (DML) was used in the length-weight relationship (DMLWR). The DMLWR obtained in the present study were: male *S. officinalis*, log TW = 0.33+2.46 log DML (correlation coefficient, $R^2 = 0.697$; Fig. 3A; female *S. officinalis*, log TW = 0.10+2.25 log DML ($R^2 = 0.701$; Fig. 3B) and combined sexes, log TW = 0.26+2.39 log DML ($R^2 = 0.607$; Fig. 3C).

The results showed a strong relationship between the two parameters where over 60% (based on the correlation coefficient) of the change in weight was explained by the increase in length, irrespective of sex. Similar results were reported for Côte d'Ivoire *S. officinalis*, where the length-weight equation was log TW = 0.203+2.77 log DML ($R^2 = 0.97$; $p < 0.01$; Valeri et al., 2016). According to Vasconcelos et al. (2018), abiotic and biotic key factors that influence growth features are certainly also responsible for both temporal and spatial variation in the length-weight relationships and relative growth of *S. officinalis*.

In the present study, the values for the b (slope coefficient) of 2.46, 2.25 and 2.39 for the males, females and combined sexes, respectively, of S. *officinalis* revealed a negative allometric growth ($b < 3$), reflecting a comparatively slower growth rate in total weight than in mantle length throughout the species ontogeny. The present results were comparable to the respective b values of 2.588±0.008, 2.696±0.010 and 2.641±0.007 for male, female and combine sexes, respectively, for *S. officinalis* from the Algarve coast, Southern Portugal (Vasconcelos et al., 2018). Siddique et al. (2016) estimated b values of 2.504 for needle cuttlefish and 1.979 for spineless cuttlefish.

Table 1 Descriptive biometric data of *Sepia officinalis* off Lagos coast, Nigeria (n = 1,082)

Parameter	Range		Mean±SD
	Minimum	Maximum	
Dorsal mantle length (cm)	6.50	27.60	13.47±0.12
Eye diameter (cm)	0.30	11.60	1.16±0.03
Fin length (cm)	0.20	90.10	12.75±0.24
Fin width (cm)	0.40	30.00	2.39±0.09
Head length (cm)	1.00	66.10	4.72±0.13
Head width (cm)	2.10	13.40	7.08±0.06
Mantle breadth (cm)	2.00	23.40	11.60±0.12
Funnel length (cm)	1.00	680	3.81±0.09
Funnel width (cm)	0.70	5.50	2.75±0.03
Length of first arm (cm)	0.10	25.00	8.90±0.11
Length of second arm (cm)	2.70	19.30	7.43±0.09
Length of third arm (cm)	0.30	15.60	7.03±0.08
Length of fourth arm (cm)	0.50	17.60	7.10±0.09
Cuttlebone length (cm)	4.00	342.00	13.82±0.45
Cuttlebone weight (g)	0.90	100.10	20.12±0.55
Cuttlebone width (cm)	1.00	30.00	5.47±0.07
Total weight (g)	19.20	1376.40	348.53±8.68

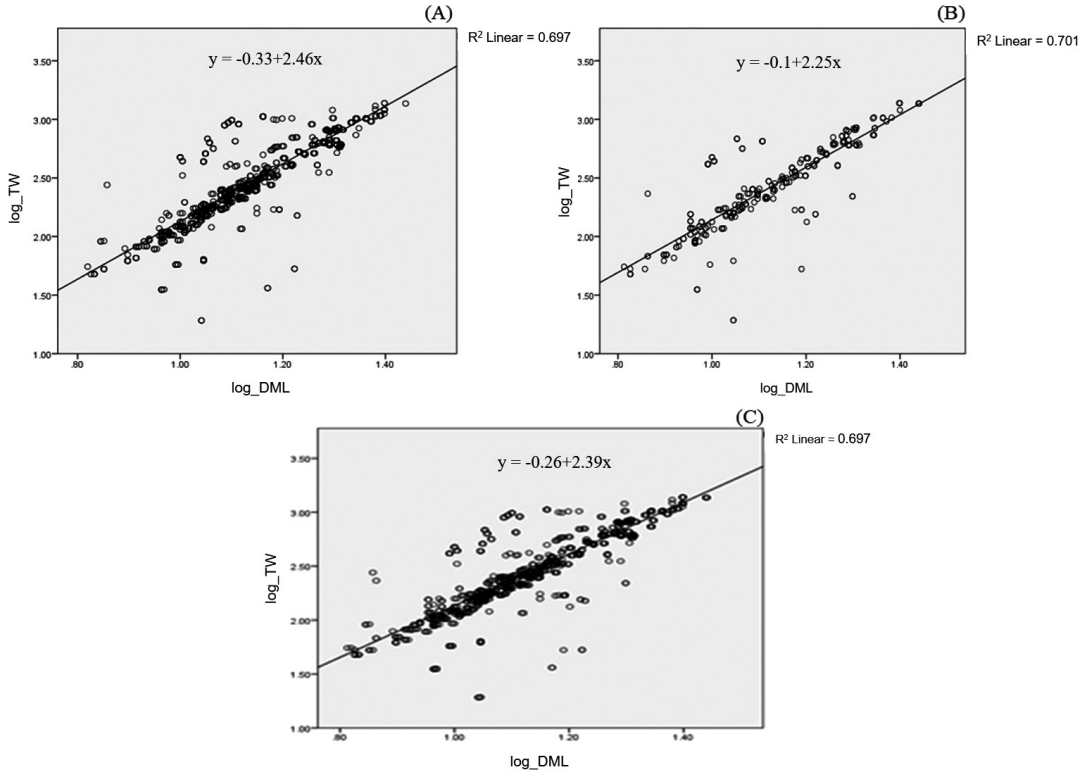

Fig. 3 Length-weight relationship of *Sepia officinalis* off Lagos coast, Nigeria: (A) males; (B) females; (C) combined sexes, where log is the natural (Euler's) logarithm, TW = total weight and DML = dorsal mantle length and R^2 = correlation coefficient

The R values for the various biometric characters against DML were in the range 0.253–0.823, indicating a high degree of interdependence for these compared characters (Table 2). The highest value of R (0.823) was between DML and TW, indicating the highest correlation. This was similar to the findings of Riad et al. (2016), who reported a strong relationship for body measurements against mantle length, with value of R in the range 0.945–0.996 for *S. pharaonis* in the Suez Gulf, Egypt. In the present study, the biometric characters increased with an increase in the mantle length. The regression equations for the body measurements revealed the dependence of the growth of different body parts on the mantle length. Tehranifard and Dastan (2011) studied the morphometric characters on the same species but from Iranian waters and concluded that sexual dimorphism was not distinct. According to Vasconcelos et al. (2018), the differential growth pattern in total weight between the sexes of *S. officinalis* was due to the greater development and weight of the reproductive organs in females compared to males. Indeed, approaching maturation, females invest more energy resources in reproduction than in somatic growth. At maturity, the weight of the gonads and accessory reproductive organs may represent 10–16% of female TW but only 4–5% of male TW (Pereira et al., 2019). Consequently, while the female reproductive organs become comparatively heavier at maturity (thus increasing the total weight), female growth slows down at a faster rate than male growth (Domingues et al., 2003).

Condition factor of cuttlefish

The variations in condition factor (K) by size and sex of *S. officinalis* off the Lagos coast are illustrated in Table 3. In studies of population dynamics, high K values of a fish show favorable environmental conditions such as habitat and prey availability (Moruf et al., 2018). The present research work had mean K values for males, females and combined sexes in the ranges 1.40–4.35, 1.40–4.44 and 1.40–4.39, respectively. The highest K value (4.44) was recorded for the largest size group (24.98–27.60 cm), while the females had the higher K-value, implying that females did better in terms of fatness and robustness. The K values reported in the present study were higher than for *Uroteuthis duvauceli*, which were in the range 0.49–1.4 (Mishra et al., 2012).

Table 2 Regression analysis of dorsal mantle length (DML, independent variable) against biometric variables of *Sepia officinalis* off Lagos coast, Nigeria (n = 1,082)

Morphometric character	R	R^2	SE of estimated R
DML and Eye diameter	0.253	0.064	0.914
DML and Fin length	0.478	0.229	7.045
DML and Fin weight	0.222	0.049	2.917
DML and Head length	0.266	0.071	3.481
DML and Head width	0.732	0.535	1.430
DML and Mantle breadth	0.616	0.380	3.095
DML and Total weight	0.823	0.677	163.578
DML and Funnel length	0.134	0.018	3.029
DML and Funnel width	0.432	0.187	0.811
DML and Length of first arm	0.628	0.394	2.741
DML and Length of second arm	0.678	0.459	2.138
DML and Length of third arm	0.684	0.468	1.925
DML and Length of forth arm	0.600	0.361	2.424
DML and Cuttlebone length	0.271	0.073	10.689
DML and Cuttlebone weight	0.729	0.531	12.440
DML and Cuttlebone width	0.634	0.402	1.796

R = coefficient of determination

Table 3 Condition factor (K) by sex and size of *Sepia officinalis* off Lagos coast, Nigeria

Dorsal mantle length (cm)	Male				Female				Combined sex			
	N	DML (cm)	TW (g)	K	N	DML (cm)	TW (g)	K	N	DML (cm)	TW (g)	K
4.45–6.99	36	6.75	49.03	1.40	5	6.66	50.26	1.40	12	6.71	49.59	1.40
7.00–9.77	139	8.84	90.77	1.83	61	8.87	97.86	1.86	171	8.85	93.3	1.84
9.78–11.11	169	10.55	163.16	2.21	49	10.58	204.98	2.28	189	10.56	174	2.22
11.12–15.04	92	12.9	322.58	2.71	83	12.97	298.8	2.71	411	12.91	317.82	2.71
15.05–17.05	92	16.04	459.1	3.14	29	16.11	363.65	3.04	92	16.06	429.01	3.11
17.06–19.69	107	18.67	621.83	3.54	27	18.66	631	3.55	105	18.67	624.19	3.54
19.70–22.33	78	20.66	777.73	3.79	19	20.91	715.3	3.73	68	20.73	760.28	3.77
22.34–24.97	45	23.75	1057.89	4.16	4	23.45	1013.25	4.12	20	23.69	1048.97	4.15
24.98–27.60	41	25.31	1260.58	4.35	6	26.3	1341.32	4.44	14	25.74	1295.18	4.39
Total	799				283				1082			

N = number of cuttlefish; DML = dorsal mantle length; TW = total weight

Sex ratio

Of the total of 1,082 specimens in the present study, the number of males (799) was substantially higher than females (283), resulting in a sex ratio of 1.00:0.35 (male:female), as shown in Table 4. The calculated monthly χ^2 test showed that males were significantly more abundant than females off the Lagos coast. Furthermore, the monthly sex ratio shows that the male *S. officinalis* was more abundant than females in both the dry months (Nov.–Apr.) and wet months (May–Oct.) seasons throughout the sampling period. The results differed from those reported in İskenderun Bay, where out of the 2,006 *S. officinalis* examined, 992 (49.45%) were females, and 1,014 (50.55%) were males (Duysak et al., 2014). Similarly, Sujit and Sushant (2018) reported female *S. pharaonis* were dominant in their study, with a male-to-female sex ratio of 1:1.24. It has been reported that environmental factors can influence the sex ratio of aquatic organisms either directly or indirectly (Moruf, 2020).

The study supported the theory that growth is allometric in cephalopods. S. *officinalis* had a negative allometric growth ($b < 3$), reflecting a comparatively slower growth rate in total weight than in mantle length throughout the species ontogeny. A strong relationship between length and weight was observed and over 60% (based on the coefficient of determination) of the change in weight could be explained by the increase in length, irrespective of sex. Males were significantly more abundant than females off the Lagos coast, and the habitat conditions were favorable for their year-round growth. The present study, for the first time, has provided detailed bioinformation on the mantle length and weight of *S. officinalis* off the coast of Lagos. This information should assist in alternative culture pilot studies and the management of wild common cuttlefish around the Nigerian Atlantic coast region.

Table 4 Monthly variation in sex ratio of *Sepia officinalis* Lagos coast, Nigeria ($\chi^2_{(0.05,\ d.f.\ =\ 1)} = 3.841$)

Period	Males	Females	Total	Sex ratio	χ^2
Aug 2018	59	20	79	1.00:0.34	19.2532
Sept 2018	44	26	70	1.00:0.59	4.6286
Oct 2018	55	13	68	1.00:0.24	25.9412
Nov 2018	52	16	68	1.00:0.31	19.0588
Dec 2018	35	11	46	1.00:0.31	12.5217
Jan 2019	32	7	39	1.00:0.22	16.0256
Feb 2019	24	9	33	1.00:0.38	6.8182
Mar 2019	18	17	35	1.00:0.94	0.0286
Apr 2019	21	11	32	1.00:0.52	3.1250
May 2019	49	18	67	1.00:0.37	14.3433
Jun 2019	51	19	70	1.00:0.37	14.6286
Jul 2019	67	12	79	1.00:0.18	38.2911
Aug 2019	64	22	86	1.00:0.34	20.5116
Sep 2019	69	15	84	1.00:0.22	34.7143
Oct 2019	47	21	68	1.00:0.45	9.9412
Nov 2019	51	16	67	1.00:0.31	18.2836
Dec 2019	43	13	56	1.00:0.30	16.0714
Jan 2020	18	17	35	1.00:0.94	0.0286
χ^2 total	799	283	1083	1.00:0.35	246.0776

Conflict of Interest

The authors declare that there are no conflicts of interest.

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