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LENGTH-WEIGHT RELATIONSHIP OF TIGER CUTTLEFISH *Sepia pharaonis* (Ehrenberg, 1831)

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Abstract

As an animal grows, the resultant increase in size or shape and volume can be measured as length and weight respectively. When an animal grows, the shape increases in size considerably and the volume can be measured as length and weight respectively. Hence, the variability in weight increases as the length of the fish increases. Since, weight of an organism is a linear function of its length, it was observed that the length - weight relationship could be expressed by the hypothetical cube law, $W = CL^3$ (W = Weight; L = Length and C = a constant). The insight on length - weight relationship in mollusca particularly in cephalopod has both pragmatic and intrinsic value. The length-weight relationship studies on various cuttlefishes showed an exponential relationship. Hence, the present study has been aimed at providing useful information on the length weight relationship of tiger cuttlefish, *Sepia pharaonis* from Puducherry, South east coast of India. The functional regression 'b' value (2.4951 and 2.4252) represents the body form and it is directly related to the weight affected by ecological factors indicating males being heavier than females in the present study. The exponential values 'b' of the total length total weight relationship of male and female *Sepia pharaonis* were calculated as 2.4951 and 2.4252 respectively, indicating thereby nearly an isometric pattern of growth exists. The correlation coefficient 'r' value is very high showing that there is a good linear association and high degree of positive correlation existing. The regression coefficient 'a' and 'b' values supporting the healthy condition and the correlation coefficient 'r' values indicating a significant and high degree of positive correlation exist between the total length and total weight of both male and female of this species.

Key words: Length - weight relationship, *Sepia pharaonis*, Correlation coefficient, Regression coefficient and Allometric growth.

1. Introduction

The molluscs constitute a natural resource of sizable magnitude in many parts of the world. They are an age old group represented among the early fossils, a group of great diversity in size, distribution, habitat and utility Phylum Mollusca is the second largest phylum of the animal kingdom that contains soft bodied animals, represented by 100000 living species which have adapted very well to the dynamic marine ecosystems. Biometric studies are very important not only in differentiating species but also populations within a species and are significant in taxonomic studies (Mc Hugh, 1951; Collette and Chao, 1975; Iwata, 1975). The identity of a fish stock can be often ascertained by morphometric and meristic studies (Marr, 1955). Recent studies on several species have demonstrated that the range of variation in characters used for identification is of considerable importance.

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The length - weight relationship (LWR) is an important tool in the biological study of fishes and their stock assessments. When an animal grows, the shape increases in size considerably and the volume can be measured as length and weight respectively. Le Cren (1951) trusted upon the length - weight relationship mainly for two reasons: a) to determine the mathematical relationship between the variables namely, length and weight, so that if one variable is known, the other could be computed; b) to measure the variations from the expected weight for individual fishes or group of fishes as indication of fatness, general well - being, general development, rate of feeding, degree of parasitization etc. This relationship is helpful for estimating the weight of a fish of a given length and can be used in studies of gonad development, rate of feeding, metamorphosis, maturity and condition (Le Cren, 1951).

The main objective here has been to derive appropriate mathematical formulae, correlating the two variables length and weight, for calculating one from the other within a certain range of error (Jhingran, 1952). Further, the length weight relationship helps to evaluate the condition, reproductive history, life cycle and the general health of fish species (Pauly, 1983) and is also useful in local and inter-regional, morphological and life historical comparisons in species and populations. Analysis of its length against weight relationship has become a standard practice in fishery studies (Ricker, 1973). Bal and Rao (1984) suggested that the knowledge of the length-weight relationship has a vital role in fishery as it is not only helps in establishing the yield, but in converting one variable to another. In some cases, it is easier to take measurements of weight rather than length, such as in cephalopods (Bello, 1991) and then weight data can be converted to length by using the LWR. The size/structure of a fish population at any point of time can be considered as a ‘snapshot’ that reflects the interactions of the dynamic rates of recruitment, growth and mortality (Neumann, 2001). However, the length - weight parameters of the same species may be different in the same or different population because of feeding, reproductive activities and fishing etc. Therefore, it becomes imperative to study the length-weight relationship of fish which are captured at a given place in a particular period of time. Since, the length-weight relationship (LWR) is an important factor in the biological study of fishes, their stock assessment and standard results of fish sampling programs (Morato *et al*., 2001; Abdurahiman *et al*., 2004; Mendes *et al*., 2004) for many species, a nationwide system of relative weight indices has been developed (Murphy *et al*., 1991). Such data are essential for a wide number of studies, for example estimating growth rates, age structure and other aspects of fish population dynamics. They are important component of Fish Base (Froese and Pauly, 1998).

2. Materials and Methods

Totally 224 specimen comprising of 113 male and 111 female of *Sepia pharaonis* were purchased at random from Thengaithittu landing centre of Puducherry (Lat. 11° 54’ 44”N ; Long. 79° 49’ 13” E) from April 2010 to March 2011. The collected specimen was identified using the publications of Roper *et al*. (1984), Silas (1985b), Jothinayagam (1987) and Shanmugam *et al*. (2002). After bringing the specimen to the laboratory, they were thoroughly cleaned with tap water. Then, the cuttlefishes were measured using a scale corrected to the nearest centimeter for studying their total length (TL) and the values were recorded. All the cuttlefishes were weighed using a weighing balance (Docbel-Braun) corrected to the nearest gram after removing all adhering water from the body using a blotting paper.

Methods to describe the length-weight relationship are described by Pauly (1983). Since, weight of an organism is a linear function of its length; it is observed that the length-weight relationship could be expressed by the hypothetical cube law,

$$W = CL^3$$

Where, W = Weight; L = Length and C = a constant

Martin (1949) suggested that most of the fishes change their form or shape as they grow and in such cases the exponent may be altered.

Hence, the formula was modified and expressed by the equation for nearly all species of fish:

$$W = a L^n$$

Where 'W' and `L' are weight and length respectively, 'a' a constant equivalent to `C' and `n' is another constant to be calculated empirically, from the data.

Values of 'W' usually have been calculated from the logarithmic (base 10) equivalent

$$\text{Log } W = \log a + b.\log L$$

A graph of log W against log L forms a straight line with a slope of b and a. Y-axis (log W) intercept of log 'a'. Invariably, 'b' is close to 3.0 for almost all species of fin-fishes (James *et al*., 2000). Also it is well known that the functional regression 'b' value represents the body form and it is directly related to the weight affected by ecological factors such as temperature, food supply, spawning conditions and other factors such as sex, age, fishing time and area and fishing vessels (Ricker, 1973).

The length-weight (TL x TWt) relationships (LWR) was calculated separately for male and female *S. pharaonis* by the method of least squares using the logarithmic forms of the exponential equation

$$W = aL^{\mathbf{b}},$$

Where W = weight; L = length; ` a' and `b' are constants.

For this purpose, the observed values of length and weight of individual cuttlefishes were transferred into logarithmic values and regression analysis was carried out to calculate the ` a' and `b' values as:

$$\text{Log } W = \log a + n \log L \text{ i.e., } Y = a + bx$$

Where, a = log a; b = n; y = log n and x = log L which is a linear relationship between y and x.

The correlation coefficient `r' was determined to know the degree of association of the two variables involved. The variation between the regression coefficient `b' in male and female *Sepia pharaonis* was calculated using ANOVA (Analysis of variance).

3. Results

A comparative data on Mean, Standard deviation and Range values, LWR coefficients and the regression coefficient of male and female was presented in Tables 1 - 3. A scatter diagram each for male and female in respect to *Sepia pharaonis* was obtained by plotting the length against weight of individual cuttlefishes (Figs. 1 and 2). From the closeness of the scatter and from the parabolic nature of the plot, it is clear that there is a good relationship between length and weight, as also the suitability of fitting the exponential formula $W= a\ L^b$ to the data. The whole of the data were pooled and the individual regression equations derived for male and female of *Sepia pharaonis* are:

Male (Total length - Total weight): Log W = 0.162 + 2.4951 Log TL

Female (Total length- Total weight): Log W = 0.167 + 2.4252 Log TL

The coefficient of correlation 'r' obtained for the total length - total weight of males and females were nearly equal to 1 (0.9620 and 0.9847 respectively) indicating that the values were highly significant and hence, a high degree of positive correlation existed between total length- total weight in this species.

The exponential values 'b' of the total length - total weight relationship of male and female *Sepia pharaonis* were calculated as 2.4951 and 2.4252 respectively, indicating thereby nearly an isometric pattern of growth. The data were analyzed using ANOVA and the results were found to be highly significant ($P<0.001$) which are shown in the Tables 1 to 3.

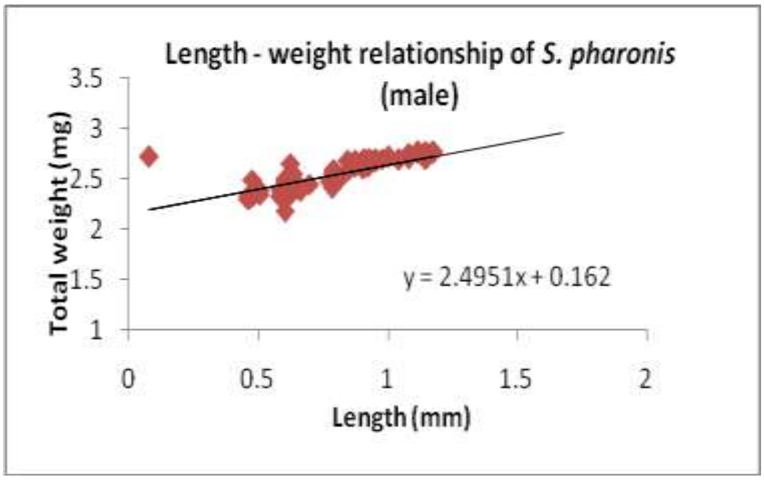

Figure – 1: Scatter diagram of Length - Weight relationship of *Sepia pharaonis* (Male)

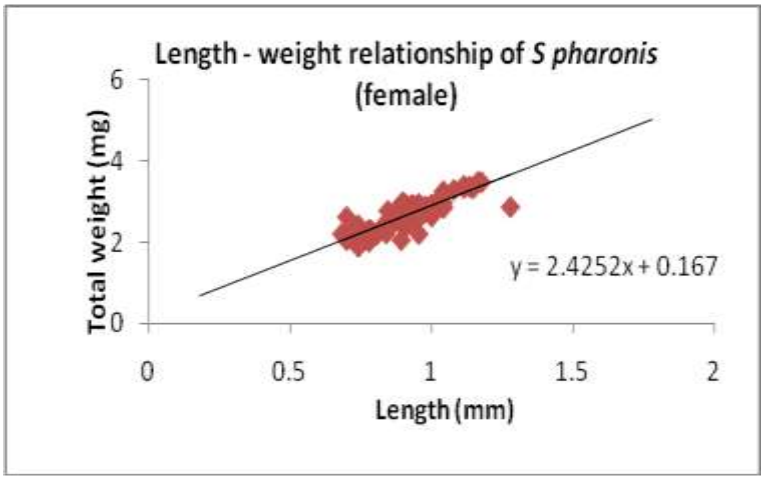

Figure - 2: Scatter diagram of Length - Weight relationship of *Sepia pharaonis* (Female)

Table – 1: Sum of squares and products of the Total length – Total weight relationship of male and female animals of *Sepia pharaonis*

Sex	'a'	'b'	'r'	ΣX	ΣY	ΣX^2	ΣY^2	ΣXY
Female	0.0785	2.4252	0.9847	71.6648	168.7343	128.8694	714.6282	303.4546
Male	0.0724	2.4951	0.9620	71.7741	168.9644	129.031	715.194	303.758

Table – 2: Regression data of the Total length – total weight relationship of male and female animals of *Sepia pharaonis*

Category	Df	x2	Xy	Y2	b	Df	SS
Female	111	102.9308	242.3823	570.834	2.397862	110	0.070234
Male	113	103.014	242.5091	571.0073	2.361221	112	0.107221
Total	224	205.9447	484.8914	1141.841	4.759083	222	0.177455

df – degrees of freedom; X^2, XY, Y^2= Corrected sum of squares and products; b = regression co-efficient; ss - Sum of squares

Table - 3: Analysis of covariance for male and female animals of *Sepia pharaonis*

Source of Variation	Df	Sum of Squares	Mean square	Observed 'F'
Deviation from individual regression within sexes	224	0.17745	0.002113	0.010887
Difference between regression	1	0.000023	0.000023	

4. Discussion

According to Ogle (2010), the relationship between the length and weight of a sample of fish has two important characteristics. Firstly, the relationship is not linear. This can be explained intuitively by thinking of length as a linear measure and weight as being related to volume. Thus as the organism adds a linear amount of length it is adding a disk of volume with a commensurate weight. Secondly the variability in weight increases as the length of the fish increases i.e., in the scatter diagram the points increases from left- to- right.

Gabr *et al.* (1999) reported that the regression equations for males and females did not differ significantly and both the sexes increased similarly in weight per unit gain in mantle in *S. pharaonis*. Whereas Silas *et al.* (1985) observed an increase in weight in relation to length differences that vary for both male and female *Sepia pharaonis*, *Sepia lessoniana* and *Loligo duvauceli* and the regression equations also differ for male and female.

Comparison of the relationship between the length and weight of *Illex coindettii* in different regions of the Mediterranean and eastern Atlantic (space), as well as a comparison of different years (time) indicated a positive allometry (b>3) in males and negative allometry (b<3) in females (Sanchez, 1981; Ragonese and Jereb, 1992). Mohamed Kasim (1988) calculated the length- weight relationship in *Sepia inermis* using the pooled data of male and female and found it as W= -2.0564 + 2.0013 Log L.

The power function ($y = ax^b$), fitted to the empirical points of this relationship, is used in studies of relative growth. The constant `a' represents the degree of fattening (condition factor), of a species. The exponent `b' represents the weight gain, which can be isometric (b = 3), negatively allometric (b<3), or positively allometric (b>3) (Hartnoll, 1982). In allometric length-weight relationship, the most interesting component is the equilibrium constant 'b', the variations of which from hypothetical unity suggested physiological deviations in condition (Mudigere *et al.*, 2009). The LWR parameters 'a' and 'b' of the fish are affected by a series of factors such as season, habitat, gonad maturity, sex, diet, stomach fullness, health, preservation techniques and annual differences in environmental conditions (Bagenal and Tesch, 1978; Moutopoulos and Stergion, 2002). Pauly (1983) reported that 'b' values must be equal to 3 if fishes have to maintain their shape as they grow but there is no theory that says in which case the estimated 'b' values can be expected to be negatively or positively allometric.

In the present study, the value of exponent 'b' was found to be 2.4951 and 2.4252 for male and female *Sepia pharaonis* respectively. These values for the slope falls in the range mentioned for the cephalopod species and other cuttlefish species available. When the slope of the length-weight relationship is equal to '3' the weight is considered to be increasing as the cube of the length and indicating the isometric body growth (Ricker, 1973). However for an ideal organism which maintains its shape throughout, without any change the value of `b' will be '3' (Allen, 1938). When the slope is not equal to 3, growth is said to be allometric. But in a number of organisms the value of 'b' lies between 2.5 and 4.0 (Hile, 1936). Whereas Meiyappan *et al*. (1993) and Nair *et al*. (1993) reported, that the relationship between length and weight of Indian cephalopods were found to be allometric with the 'b' values of the regression near to 2 rather than 3, as also the values of *Sepia pharaonis* in which the 'b' values of total length-total weight were found to be 2.4951 and 2.4252 for male and female *Sepia pharaonis*, respectively.

The length-weight relationship studies on various cuttlefishes showed an exponential relationship. The result of the present investigation indicated that the pharaoh cuttlefish, *Sepia pharaonis* shows an allometric growth as observed by various authors in other cuttlefish species (Silas *et al*., 1985; Meiyappan *et al*., 1993; Nair *et al*., 1993; Gabr *et al*., 1999); Abdurahiman *et al*., 2004; Abdussamad *et al*., 2004; Sivashanthini *et al*., 2009). Gabr *et al*. (1999) reported that the regression equations for females and males did not differ significantly and both sexes increased similarly in weight per unit gain in mantle in *Sepia pharaonis*. Silas *et al*. (1985) found an increase in weight in relation to length difference in male and female of *Loligo duvauceli*, *Sepia lessoniana* and *Sepia pharaonis*. Usually this allometric growth is due to the result of differential growth of the arms and tentacles with respect to mantle (Forsythe, 1984).

Further in the present study, the difference in 'b' value between male and female indicated that there is a variation observed in growth, though statistically it is not significant. The variation between the sexes may be due to the gonadal maturity and weight of the gonads, which will be at a higher side in female when it attains maturity. Forsythe and Van Heukelem (1987) also suggested that within the cephalopod species the slower growing sex weighs more at a given mantle length than its counterpart. Silas *et al*. (1985) studied in *Sepia pharaonis* a size of 109.4 mm, 186.1mm, 239.7mm, 277.3 mm, 303.6mm and 322.0 mm for males and 119.9 mm,197.8 mm, 248.3mm, 281.2 mm, 302.5 mm and 316.3mm for females six, twelve, eighteen, twenty four, thirty and thirty six months respectively. Further they also added that, probably this has some developmental implications since the slower growing sex will always be a bit older by the time when a given mantle length is reached.

Whereas the 'b' values calculated for the length-weight relationship of cuttlefishes were found with variations *i.e.*, Unnithan (1982) calculated the 'b' values of LWR as 1.9320 and 2.3208 for male and female *Sepia inermis*, Manfrin and Giovanardi (1984) estimated it as 2.773 for male and female *Sepia officinalis*, Silas *et al*. (1985a) reported it as 2.5058 and 2.5478 for male and female *Sepia pharaonis* and 1.0671 and 2.7427 for male and female of *Sepia aculeata*, Mohamed Kasim (1988) calculated the length-weight relationship in *Sepia inermis* using the pooled data of male and female and found it as W= -2.0564 + 2.0013 Log L, whereas, Appannasastry (1989) estimated it as 2.2808 and 2.3016 for male and female *Sepia inermis*, Nair *et al*. (1993) calculated the 'b' value as 2.5997 and 2.6286 for male and female of *Sepia pharaonis*, Gabr *et al*. (1999) reported it as 2.60 and 2.65 for male and female *Sepia pharaonis* and Abdurahiman *et al*. (2004) calculated the 'b' value as 2.649 and 2.855 for male and female of *Sepia aculeata*.

The length-weight relationship parameters estimated for *Sepia pharaonis* by previous studies expressed 'b' = 2.5058 and 2.5478 for male and female respectively (Silas *et al*., 1985); 2.5997 and 2.6286 for male and female by Nair *et al*. (1993) and 2.60 for male and 2.65 for female (Gabr *et al*., 1999). The exponential values 'b' in the present study of the total length - total weight relationship of male and female *Sepia pharaonis* were calculated as 2.4951 and 2.4252 respectively, indicating thereby nearly an isometric pattern of growth exists.

The correlation coefficient 'r' is a measure of linear association between two quantities both of which are subjected to random variation (Sparre and Venema, 1998). The correlation coefficient 'r' value in the present study is very high between length and weight for the male (0.9620) and female (0.9847). This result shows that there is a good linear association existing between two parameters. In general, the value of '1' and '-1' for correlation indicates a perfect and positive relationship between the two parameters. Like any natural population this relationship was found to vary in space and time for this species as well (Jha *et al*., 2005). This study has tried to give some baseline information about the pharaoh cuttlefish, *Sepia pharaonis* from Puducherry, regarding the length- weight parameters and supporting the healthy condition of this species by regression coefficient 'a' and 'b' values of the present study. The correlation coefficient 'r' values indicate that a significant and high degree of positive correlation existing between the total length and total weight of both male and female *Sepia pharaonis.*

5. Conclusion

The 'b' values obtained for *Sepia pharaonis* in the present study is slightly lower (2.4951 and 2.4252 for male and female) than the previous studies. However, the growth pattern remains the same as that of previous studies by Silas *et al*. (1985), Meiyappan *et al*. (1993) and Mohamed (1996). From the observation, the linear plot based on the calculated values suggested that there is a direct relationship in total length and total weight between male and female *Sepia pharaonis*. The tendency of *Sepia pharaonis* males being heavier than females in the present study is confirmed with the earlier observation of Silas *et al.* (1985); Meiyappan *et al*. (1993) and Mohamed (1996). In morphometric studies, the coefficient of correlation 'r' obtained for the total length-total weight of male and female *Sepia pharaonis* were nearly equal to 1 (0.9620 and 0.9847 respectively) indicating that the values were highly significant at $P<0.001$ and hence, a high degree of positive correlation exists between total length- total weight in this species. In general, the value of '1' and '-1' for correlation indicates a perfect and positive relationship between the two parameters.

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