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Morphometric study and length- weight relationship on the squid *Loligo forbesi* (Cephalopoda: Loliginidae) from the Egyptian Mediterranean waters

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ABSTRACT
Morphometric characters of male and female *Loligo forbesi* were investigated for samples obtained from the commercial shanshola vessels off the coast of Alexandria, Egypt. Samples were collected (548 individuals) between spring 2010 to winter 2011. The regression equations describing the dependence of the relative growth of mantle width, funnel length, funnel width, head length, head width, fin length, fin width, total length, tentacular arm length and arm length on mantle length growth variations were calculated for male and female *Loligo forbesi.* The dependence of shell width on shell length was also calculated.

Differences in slopes for the body parts between sexes were tested for significance by analysis of covariance (ANCOVA). There was a significant difference in all measurements against mantle length in the two sexes ($p<0.05$). Female measurements against mantle length proved to be longer than male, except fin length in which the slope of male was longer than female (B= 0.70, 0.66 respectively).The correlation coefficient (R) of males in the present study was slightly larger than that of females except in case of ML\HW and ML\TL in which the correlation of females was larger than that of males.
Length-weight relationship model equation was calculated for both sexes. Weight exponentially increases with increase of mantle length. The condition factor "K" decreases with increasing length. Data obtained from length- weight relationship study revealed that, there is no significant differences between both sexes until 8 cm and then weight of females were heavier than that of males at the same mantle length.

1. INTRODUCTION
Loliginids play an important role in the marine food chain. They belong to the third trophic level in the food chain. They contain about 500 species of squids in different seas and oceans (Sweeney and Vecchione, 1998). Their sizes range from 1-2 inches in the tiny squids, *Idiosepius pygmaeus*, to 60 feet of the giant squid, *Architeuthis* sp. Squids are divided into two groups; the myopsid and the oegopsid (Sweeney and Vecchione, 1998).

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The myopsid group inhabits the continental shelf regions and has covered eyes; however the oegopsids live in the open ocean. The major exploited family of myopsid squids is Loliginidae, with major genera, *Loligo*, *Photololigo* and *Sepioteuthis*.

Despite the abundance of loliginids in the continental shelf habitats and their commercial and scientific importance, loliginidae classification and phylogeny remain confused (Vecchione *et al*., 1998).

Several attempts were carried out to alleviate this confusion using morphological characteristics; primarily features of the sucker rings and hectocolylus to erect a number of generic and subgeneric groups within Loliginidae.

Cephalopods generally and squids in particular are known to exhibit considerable morphological variations, yet little information is documented on the plasticity of morphological phenotype of squids (Ngolile,1993).

Morphometric and morphological studies help in understanding the systematic and phylogeny of a taxonomical group besides biology, ecology, behavior and fisheries of different species forms (Roper and Voss, 1983; EL-Naggar, 2005; Emam *et al.*, 2007; Doubleday *et al.*, 2009; Gregr *et al.*, 2012; Moreno, 2009; Shea, 2010).

Loligo forbesi is a subtropical and temperate water species, occurring over the shelf in the temperate part of its distributional range, but also found in deeper waters in subtropical areas, and the entire depth ranges from about 100 to 400 m. (Roper *et al*., 1984). *Loligo forbesi* is also found, along the continental shelf and off shore banks at depths of 50-250 m in United Kingdom (UK) waters (Pierce *et al*., 1994), 15-150 m in the North Sea and eastern Atlantic, 150-400 m in the Mediterranean (Mangold-Wirz, 1963) and 100-200 m in Portuguese waters (Moreno *et al*., 1994). Studies carried out in the United Kingdom suggests *Loligo forbesi* to be found in deep waters (100-200 m) along the shelf-edge at the beginning and end of spawning but during peak spawning months are found in shallower waters (<50 m) (Stowasser*et al*., 2005). In the Scottish waters (Pierce, *et al*., 1994; Collins and Pierce, 1996; Stowasser, 2004; Venoverbek, 2008; Bergatad *et al*., 2010; Wangvoralak, *et al*., 2011) studied the food and feeding of squids. Cephalopod catch represents about 10% of the total annual landing from the Egyptian Fishers (Riad and Abd- El- Hafez, 2008).

In Egypt, the squid *Loligo forbesi* is an abundant near–bottom species occurs in Suez bay (Gabr and Riad, 2008).

This work represents the first detailed morphometric study of *Loligo forbesi* in the Egyptian Mediterranean waters, beside evaluating the major characteristic differences\ between both sexes.

2. MATERIALS AND METHODS

Samples of *Loligo forbesi* were collected, frozen and stored for investigation during the period from spring 2010 to winter 2011.The sex was determined by checking the presence of the left arm IV hectocotylized (modified arm) typical of males (Richard, 1967). The total body wet weight (To.Wt) of each specimen was determined to the nearest measured (gm). Fig. (1) illustrates the different morphometric measurements for *Loligo forbesi*.

2.1 Length-weight relationship and condition factor were determined from the relationship between dorsal mantle length and total body weight by the growth equation according to (Bowker, 1995):

$$\mathbf{Y=a\ x^{b}.}$$

Where Y=weight in gram, x=length in cm, a and b are constant.

Calculation of the condition factor (K) was based on the cube law,

$$\mathbf{K = 100\ W / L^{3}}$$ (Le Cren, 1951).

Where W = weight and L = mantle length.

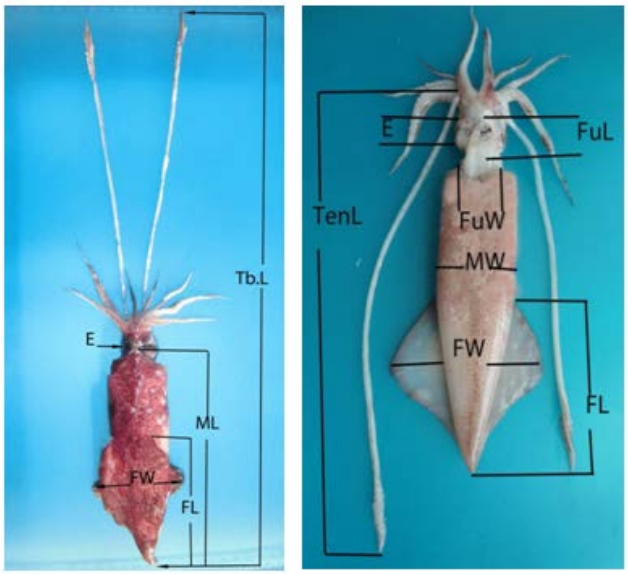

Fig.1a Fig.1b
Fig.1: Photograph of *loligo forbesi* showing the deffrent body measurnent
a- dorsal view b-venteral view

2.2 Morphometric measurements:

1-Mantle length (ML), length of the mantel from the anterior to posterior tip measured on the dorsal side.
2- Head length (HL), from anterior tip of the cartilage to the junction of dorsal arm.
3-Fin length (FL), the distance from the posterior tip of the mantle to the anterior most tip of the fin.
4- Funnel (Fu. L) Siphonlength.
5- Shell length (Sh.L), distance between the anterior to the posterior tips of the pen.
6- Tentacle length (TL), distance from the point of emergence from webbing between arms III and IV to the tip of the tentacle.
7- Arm length (AL), the distance from upper margin of the head to the tip of the longest arm.
8- Mantle width (MW), the largest width of mantle.
9- Head width (HW), the width of the head measured across the anterior edge of the eyes.
10- Fin width (FW), the width of the fins when fully stretched and measured at the greatest width arm length.
11- Funnel (Fu .W), siphon width.
12- Shell width (Sh. W), greatest width of the pen.

The liner regression equation was used to describe the relation between different body measurements as to mantle length.

3. RESULTS

Morphological variability between sexes and similarities between species often hamper precise identification. So, the importance of documenting changes in body measurements within and between species may help to overcome the difficulties of separating species and or sexes especially in the field.

In the Egyptian Mediterranean waters, although squids represent a considerable component of the marine invertebrate population, however many aspects of their life history and structural characteristics are poorly known. In the present study the morphometric characters beside some proportional measurements of the squid *Loligo forbesi* were studied. The body measurements of males and females *Loligo forbesi* are given in Table (1). Most measured body parts showed allometric growth (slope less than 1). Generally, the coefficient of determination (R) was high (0.76 – 0.98) for most measurements, for both sexes.

Table 1: Morphometric characters of male and female *Loligo forbesi.*

Morphometric characters.cm	Males					Females				
	Min.	Max	Mean	SE	N	Min.	Max	Mean	SE	N
Mantle length(ML)	5.1	25	11.98	0.20	310	3.8	17	11.9	0.17	238
Mantle width (MW)	1.8	5	3.28	0.03	308	1.3	5.8	3.43	0.04	235
Shell length (Sh.L)	5.1	25	11.92	0.20	308	3.8	17	11.88	0.21	237
Shell width (ShW)	0.5	2.9	1.52	0.02	303	0.7	2.8	1.71	0.03	232
Funnel length (Fu.L)	1.2	3	2.04	0.02	307	0.8	3	2.11	0.02	233
Funnel width (Fu.W)	1	3.9	2.01	0.02	299	0.7	3.1	2.08	0.03	231
Head length (HL)	1.2	3.2	2.19	0.02	302	1.1	3	2.27	0.02	233
Head width (HW)	1	3.2	2.06	0.02	293	0.9	3.3	2.14	0.03	222
Fine length (FL)	1.6	16	6.78	0.2	306	1.7	10.6	6.66	0.11	236
Fine width (FW)	1.4	10.7	5.98	0.09	305	1.2	10.1	6.22	0.09	229
Total length (To.L)	15.5	52.5	30.35	0.40	269	12.5	46.5	30.36	0.05	196
Tentacular length (TL)	5.1	29.5	16.59	0.21	267	7.4	27	17.11	0.26	195
Arm length(AL)	1.4	10	5.17	0.07	296	1.5	10.5	5.24	0.09	216

Min. = Minimum; Max. = Maximum; SE = Stander error; N = Number.

For the ten significant discriminate factors, the regression equations describing the dependence of the relative growth of mantle width, funnel length, funnel width, head length, head width, fin length, fin width, total length, tentacular arm length and arm length on mantle length growth variations were calculated for male and female *Loligo forbesi.* Also the dependence of shell width on shell length was calculated. The results are given in Table (2) and illustrated in Figs. 2 – 12.

Table 2: Regression equations describing the relative growth of the dimensions of eleven body parts in male and female *Loligo forbesi*.

Variables	Males			Females		
	A	B	R	A	B	R
ML/ MW	1.61	0.14	0.81	0.96	0.21	0.77
Sh.L/ Sh.W	0.56	0.08	0.85	0.16	0.16	0.91
ML/ Fu.L	0.99	0.09	0.85	0.60	0.13	0.88
ML/ Fu.W	0.90	0.09	0.81	0.51	0.13	0.85
ML/ HL	1.24	0.08	0.78	1.01	0.11	0.76
ML/ HW	1.15	0.08	0.70	0.64	0.13	0.76
ML/ FL	-1.58	0.70	0.98	-1.19	0.66	0.95
ML/ FW	1.33	0.39	0.89	0.22	0.50	0.85
ML/ To.L	9.14	1.80	0.92	6.15	2.05	0.84
ML/ TL	7.37	0.78	0.77	3.25	1.17	0.83
ML/ AL	1.85	0.28	0.76	0.75	0.38	0.73

ML = mantle length; MW = mantle width; Sh.L = shell length; Sh.W = shell width; FU.L = funnel length; FU.W = funnel width; HL = head length; HW = head width; FL = fin length; FW = fin width; To.L = Total length; TL = tentacular length; AL = arm length; A= slope; B = intercept.

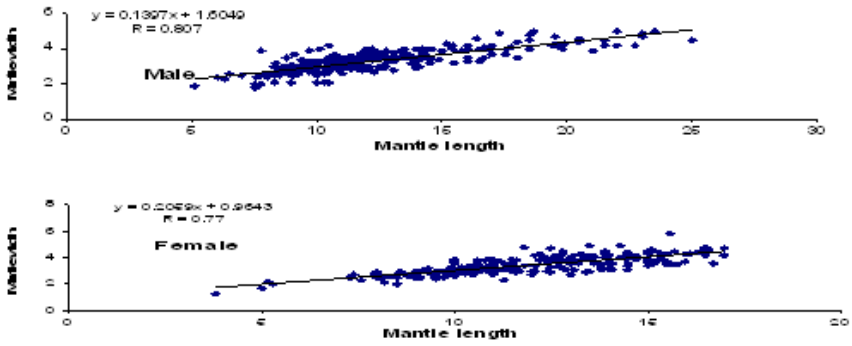

Fig. 2: Relation between mantle length and mantle width for *Loligo forbesi*.

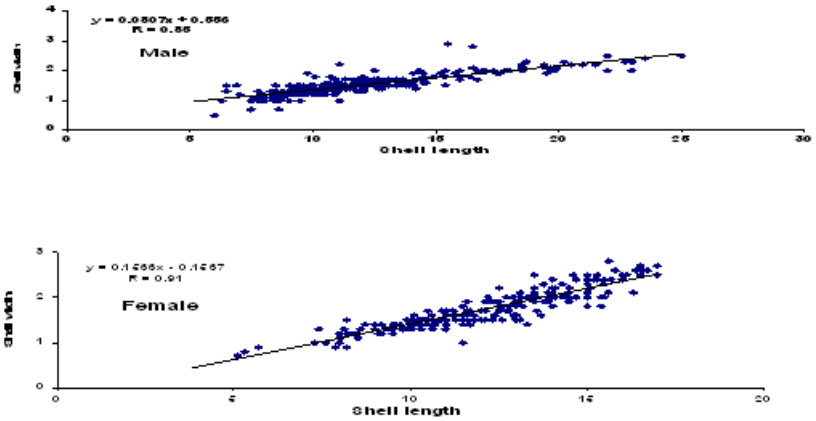

Fig. 3: Relation between shell length and shell width for *Loligo forbesi*

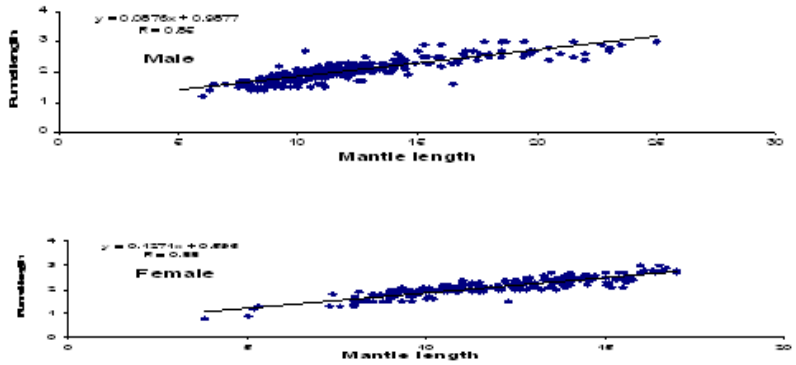

Fig. 4: Relation between mantle length and funnel length for *Loligo forbesi*

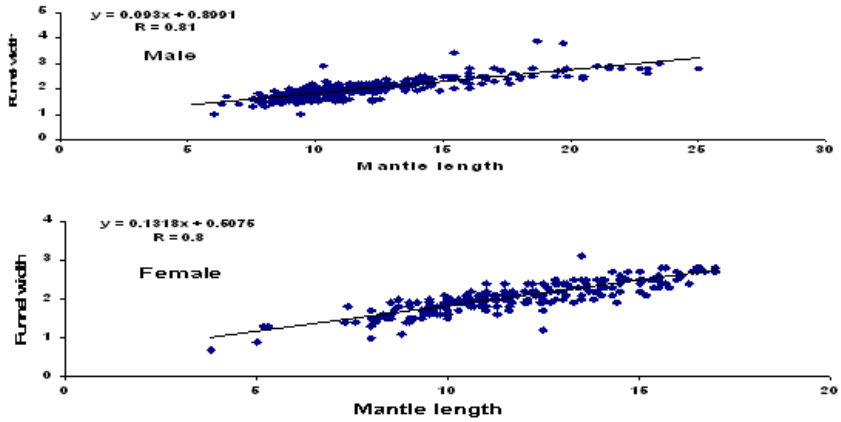

Fig. 5: Relation between mantle length and funnel width for *Loligo forbesi*

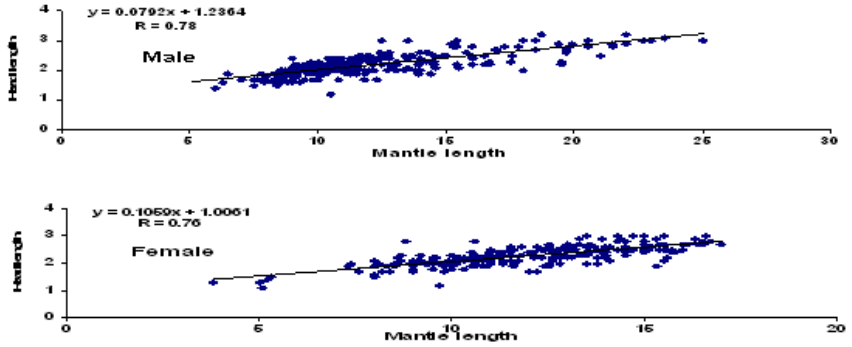

Fig. 6: Relation between mantle length and head length for *Loligo forbesi*.

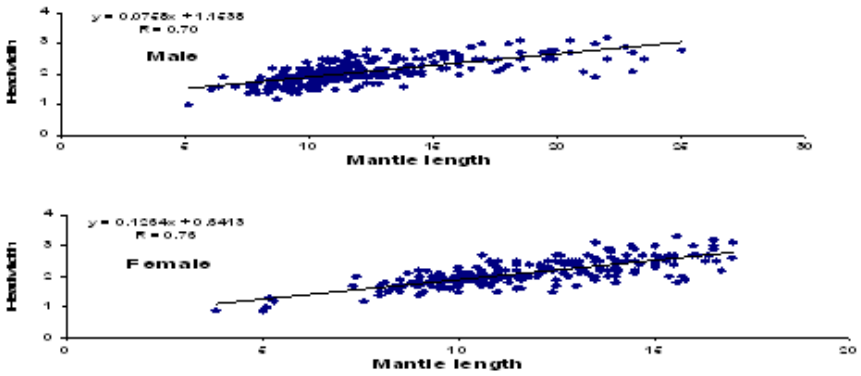

Fig. 7: Relation between mantle length and head width for *Loligo forbesi*.

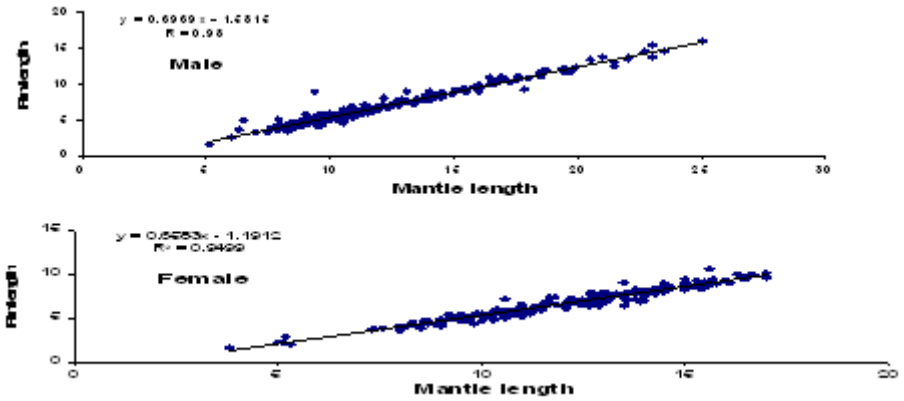

Fig. 8: Relation between mantle length and fin length for *Loligo forbesi*.

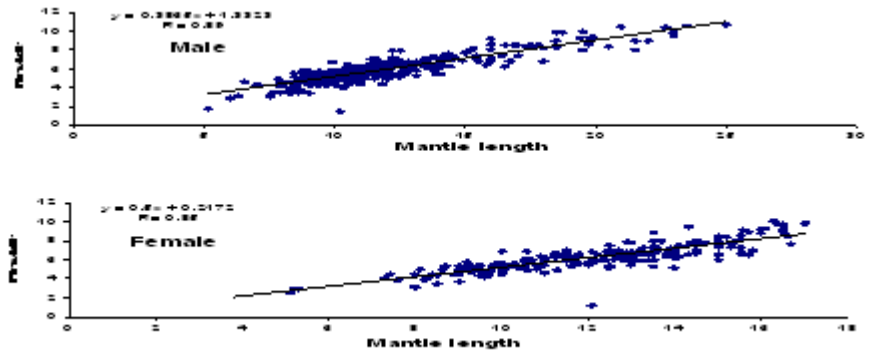

Fig. 9: Relation between mantle length and fin width for *Loligo forbesi*

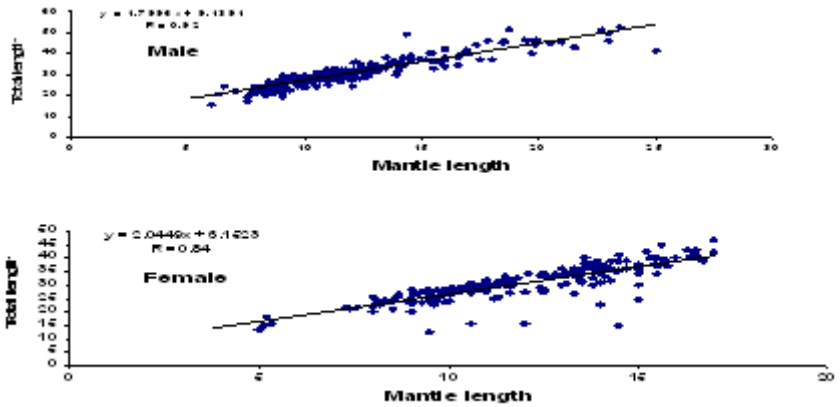

Fig. 10: Relation between mantle length and total length for *Loligo forbesi*.

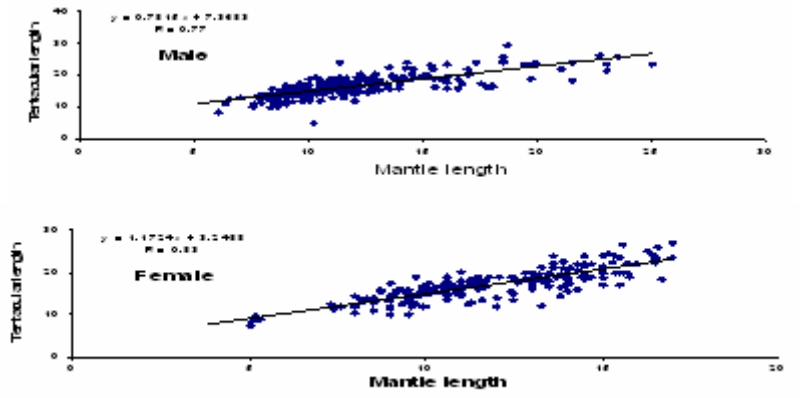

Fig. 11: Relation between mantle length and tentacular arm length for *Loligo forbesi*.

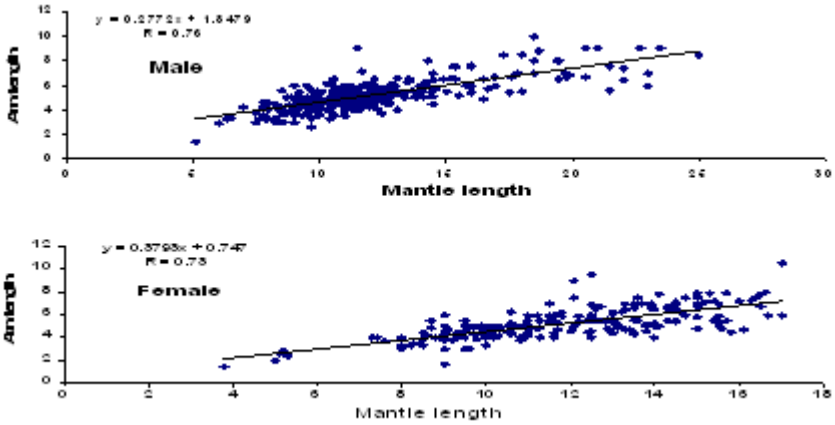

Fig. 12: Relation between mantle length and arm length for *Loligo forbesi*.

Differences in slopes for the body parts between sexes were tested for significance by analysis of covariance (ANCOVA).There was a significant difference in all measurements against mantle length in the two sexes ($p<0.05$). Female measurements against mantle length were longer than in male except fin length in which the slope of male was longer than female (B = 0.70 and 0.66 respectively).

Descriptive statistics for significant differences between some morphometric ratios for male and female *Loligo forbesi* are given in Table (3).

Table 3: Descriptive statistics for significant differences between some morphometric ratios for male and female *Loligo forbesi***.**

Variable	Male									Female								
	Mean	SE	Med	Mode	SD	Range	Min	Max	N	Mean	SE	Med	Mode	SD	Range	Min	Max	N
ML/ MW	3.63	0.03	3.53	3.29	0.60	3.56	2	5.56	308	3.51	0.03	3.43	3.38	0.49	2.55	2.36	4.91	235
ShL/ShW	7.84	0.06	7.69	8	1.13	7.95	4.33	12.29	303	7.06	0.05	7	7.33	0.74	6.1	5.4	11.5	232
ML/ Fu.L	5.83	0.05	5.67	5	0.89	6.50	3.81	10.31	307	5.63	0.04	5.59	5	0.59	4.12	4.08	8.2	233
ML/FuW	5.91	0.05	5.74	5	0.91	5.85	3.55	9.4	299	5.75	0.05	5.61	5	0.72	6.42	4	10.42	231
ML/ HL	5.44	0.06	5.18	5	0.98	5.58	3.42	9	302	5.25	0.05	5.19	5	0.79	5.16	2.92	8.08	233
ML/ HW	5.79	0.07	5.57	5	1.15	7.89	3.42	11.32	293	5.58	0.06	5.5	5	0.85	4.97	3.70	8.67	222
ML/ FL	1.82	0.01	1.8	2	0.18	2.14	1.04	3.19	305	1.81	0.01	1.79	2	0.14	1.07	1.45	2.52	236
ML/ FW	2.03	0.02	1.96	2	0.39	5.87	1.41	7.29	305	1.98	0.04	1.9	2	0.58	8.63	1.45	10.08	229
ML/ToL	0.39	0.003	0.38	0.37	0.04	0.34	0.27	0.61	269	0.39	0.005	0.38	0.4	0.07	0.68	0.29	0.97	196
ML/ TL	0.71	0.009	0.68	0.63	0.14	1.53	0.47	2	267	0.70	0.007	0.67	0.67	0.09	0.58	0.51	1.09	195
ML/ AL	2.34	0.02	2.28	2	0.43	2.56	1.28	3.84	296	2.32	0.03	2.24	2	0.44	3.98	1.32	5.29	216

Legend: SE= Standard error; Med= Median; SD= standard deviation; Min= Minimum; Max= Maximum; N= Numb

Length-weight relationship and condition factor:

The average weight for each length group for both sexes of *Loligo forbesi* is given in Table (4). The mantle length ranged from 5 cm. to 25 cm. for males and 3 cm. to 17 cm. for females. The weight of the males ranged from 3.5 gram to 134.6 gram, while for females, it ranged from 1.8 gram to 99.1 gram. The length-weight relationship was determined from scattered diagrams representing *Loligo forbesi* males and females (Fig. 13). Applying the growth equation:

$$\mathbf{y = a\,x^{b}}$$

Where y = total weight, x = mantle length, a and b are constants. The "b" values for males and females through the year cycle were found to be 2.01 and 2.55, respectively. The resulting equations are as follows:

$$\mathbf{y = o.2532x^{2.0108}} \quad \textbf{(Males)}$$

$$\mathbf{y = o.o764x^{2.5458}} \quad \textbf{(Females)}$$

Table 4: Average total weight and condition factor for each length group of male and female *Loligo forbesi.*

Male					Female				
Length group	Numbers of sample	Average total weight		K	Length group	Numbers of sample	Average total weight		K
		Observed	Calculated				Observed	Calculated	
5	1	3.50	6.35	5.08	3	1	1.75	1.32	4.88
6	3	14.70	9.16	4.24	5	4	4.48	4.85	3.88
7	9	14.28	12.49	3.64	7	4	14.39	11.43	3.33
8	24	17.44	16.34	3.19	8	16	17.19	16.07	3.14
9	54	23.93	20.70	2.84	9	30	25.38	21.70	2.98
10	59	29.43	25.58	2.56	10	34	31.33	28.39	2.84
11	45	35.25	30.98	2.33	11	32	38.19	36.19	2.72
12	31	42.14	36.91	2.14	12	28	46.82	45.19	2.62
13	16	49.27	43.35	1.97	13	31	58.26	55.42	2.52
14	18	54.85	50.31	1.83	14	22	65.12	66.95	2.44
15	8	65.91	57.79	1.71	15	24	76.80	79.82	2.37
16	11	68.77	65.80	1.61	16	10	99.31	94.10	2.30
17	6	81.66	74.33	1.51	17	2	99.11	109.83	2.24
18	6	78.10	83.38	1.43					
19	7	96.12	92.95	1.36					
20	2	100	103.04	1.29					
21	3	109.71	113.66	1.23					
22	3	122.45	124.80	1.17					
23	3	137.73	136.46	1.12					
25	1	134.58	161.36	1.03					

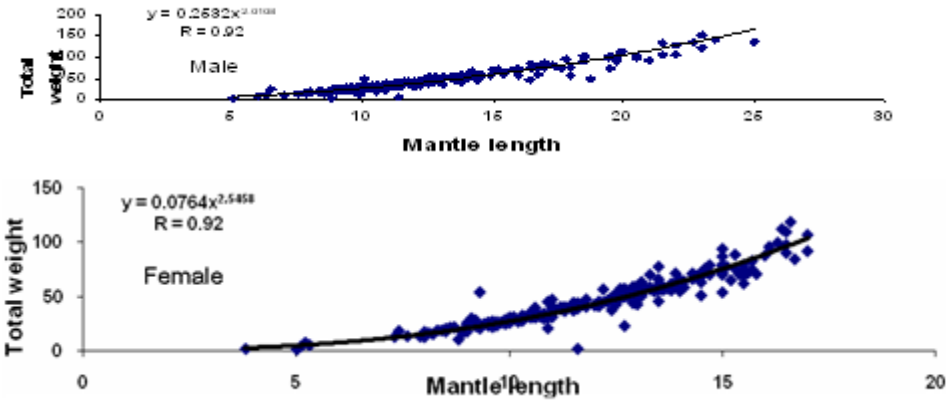

Fig. 13: Relation between mantle length and total weight for *Loligo forbesi.*

The cube length- weight relationship, i.e. $\mathbf{y = a\ x^3}$, where growth is assumed to be isometric serves best in the study of "condition", the value of "a" which is equal to $\mathbf{Y / x^3}$ is rounded and expressed as the "condition factor"

$\mathbf{K = 100\ y / x^3}$

Thus, the condition factor is measuring the degree well, being changes according to length, weight, age, sex, state of maturity, month, locality, etc. Carful inspection of the calculated weight of males and females (Table 5) shows that males are heavier than females at the same mantle length at the early stage, while the females are heavier than males starting from 9 cm. mantle length. The difference in weight between sexes increases parallel to length increase and is maximal at 17 cm. mantle length exceeding 35 gm. in weight. This trend is also indicated by the value of condition factor for both sexes (Table 5). In general the "K" values are observed to decrease with increasing length. These values encountered in male individuals with mantle length between (5 – 10 cm.), (11 – 17 cm.) and (18 – 25 cm.), "K" values ranged between (5.o8 – 2.56), (2.33 – 1.51) and (1.43 – 1.03) with an average of 3.59, 1.87 and 1.23, respectively. The range of "K" values for the first two length intervals in female individuals with mantle length between (3 – 10 cm.) and (11 – 17 cm.) are (4.88 – 2.84) and (2.72 – 2.24) with an average of 3.51and 2.46, respectively.

Table 5: Comparison between the present regression models of male and female *Loligo forbesi* fitted lines and those calculated by Gabr and Riad (2008) for the same species from Suez Bay, Red Sea, Egypt.

	Male						Female					
	No. of individual		Correlation coefficients		" B " constant		No. of individual		Correlation coefficients		" B " constant	
	Gabr & Riad,	Present study	Gabr & Riad,	Present study	Gabr&Riad, 2008	Present study	Gabr&Riad, 2008	Present study	Gabr& Riad, 2008	Present study	Gabr&Riad, 2008	Present study
ML/HL	323	302	0.56	0.78	0.08	0.08	240	233	0.62	0.76	0.13	0.11
ML/HW	323	293	0.75	0.70	0.08	0.08	240	222	0.79	0.76	0.13	0.13
ML/FL	323	305	0.99	0.98	0.71	0.70	240	236	0.97	0.95	0.63	0.66
ML/FW	323	305	0.89	0.89	0.45	0.39	240	229	0.85	0.85	0.57	0.50
ML/TL	323	267	0.83	0.77	1.07	0.78	240	195	0.78	0.83	1.63	1.17

4. DISCUSSION

Table (5) shows a comparison between the present regression models of male and female fitted lines and those calculated by Gabr and Riad (2008) for the same species from Suez Bay, Red Sea, Egypt. In the present study, the (B) constant for females was slightly larger than that of males, except in the equation of ML/FL in which (B) constant in males was larger than females. Gabr and Riad (2008) indicated the same results.

The correlation coefficient (R) of males in the present study was slightly larger than that of females except in case of ML/HW and ML/TL, the R value of females was larger than that of males, while the results of Gabr and Riad (2008) indicated inverse result except in case of ML/FL and ML/FW in which R of males was slightly larger than that of females.

Morphometic characters of *Loligo forbesi* have been thoroughly investigated in various locations. Pierce *et al.* (1994) stated that multivariate analysis of morphometric characters for samples collected in the Scottish waters over 12 months revealed no consistent differences between localities. In contrast, there were marked differences between *Loligo forbesi* from the Azores and those from UK waters, there were significant between area differences in regression slopes for the majority of variables. Comparison of 'size-in' and 'size-out' canonical variants analyses indicated that differences between Azores and UK samples are accentuated by inclusion of body size, but even with effects of size removed (as far as possible), the Azores sample is well-separated from the UK samples in its score on the first canonical axis. The differences are apparent for both males and females, from both body and beak measurements.

Pierce *et al.* (1994) added that in *Loligo forbesi* it was apparent that the effect of body size on body shape could not easily be regressed out. Relationships between pen length and other measurements were, however, sufficiently close to linear that simple transformations invariably produced curvilinear relationships. *Loligo forbesi* has a very wide range of adult body size, particularly in males, with animals reaching a larger size in the Azores than elsewhere. Martins (1982) and Boyle and Ngoile (1993) found differences in body form of *Loligo forbesi* from different regions of Scottish and British coast, but no clear evidence of separate populations; maybe a highly mobile species is free movement among all parts of the Scottish coast, so that separate regional populations are unlikely. Kristensen (1982) attempted to control for differences in body size by using ratios between pen length and other measurements. This is a generally less satisfactory procedure if there is any allometry (Thorpe, 1976).

In the present study, males and females of *Loligo forbesi* in the samples constituted 56.57 % and 43.43 %, respectively of the specimens collected. Length-weight relationship for males and females in the

present study remains more or less similar until the specimens reach approximately 9 cm. in length. Beyond this size, females begin to become gradually heavier than males of the similar lengths. This weight difference occurs during the latter phase of sexual maturation of the species and is probably due to the large egg mass of the females, while the reproductive system of the mature male weights is much lesser (Haefner, 1959). The larger weight of the female may be related to the fact that the mass of the gonad and accessory reproductive organs constitute a greater proportion of the body mass in females than in males at the larger sizes, thus for a given length, a female will be heavier than male (Gabr and Riad, 2008). This observation is not in agreement with that recorded by Fields (1950, 1965) for *Loligo opalescens* and Squires (1957) for *Illex illecebrosus*. The growth equations during the present work showed that females of *Loligo forbesi* assume a higher slope than males. Among *Loligo forbesi* "b" values were 2.01 for males and 2.55 for females.

These values agree to a great extent with those calculated by other workers. The "b" values for males and females given by these authors were as follows: 2.29 and 2.43 for *Loligo forbesi* (Holme, 1974); 2.23 and 2.32 for *Loligo forbesi* (Howard, 1979); 2.08 and 2.18 for *Loligo forbesi* (Martins, 1982); 2.44 and 2.57 for *Loligo forbesi* (Guerra and Roch, 1994); 2.29 and 2.43 for *Loligo forbesi*, (Pierce *et al.*, 1994a). It is worth to note that similar values have been observed in other Loliginids. The "b" value for males and females *Loligo peale*is were 2.11 and 2.26, respectively (Macy, 1980). Baddyr (1991) stated that females of *Loligo vulgaris* were heavier than males above 10 cm. mantle length. Augustyn (1990) recorded different "b" values for *Loligo vulgaris* male and female, from different localities; in Jeffrey's Bay (2.89 and 2.96); Mainland river (2.44 and 2.68); Krum Bay (2.30 and 2.40) and Seal Bay (2.42 and 2.44). In accordance with the higher slope "b" for males than females, Fields (1950, 1965) clarified that males attain a greater weight than females at comparable lengths longer than 12 cm. mantle length of *Loligo opalescens.*

The present work results accord with those authors in that females are heavier than males. The exponent "b" in the growth equation measures the ratio of instantaneous rates of increase in weight and length, whereas the value of "a" depends on fatness, being high in fat individuals and low in thin ones (Brown, 1957). Males were found to decline in relative weight as they mature, while females increase in relative weight. There is evidence that timing of breeding and size at maturity is related to environmental variations (Pierce *et al.*, 2005). Length-weight relationship indicates that males from the Azores show much lower allometric coefficient (b) than other samples; this is in agreement with previous morphological studies (Pierce *et al.*, 1994b). Length- weight relationship varies according to maturity stage, and a decrease in size-adjusted mantle weight in later maturity stages indicates the diversion of resources from somatic to reproductive growth (Pierce *et al.*, 1994a).

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