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RESEARCH ARTICLE

Relationship between length-weight, total length-carapace length and total length-abdominal length and relative condition factor in the deep water mud shrimp *Solenocera melantho* (de Man, 1907) off Visakhapatnam coast.

Myla. S. Chakravarty* and P. R. C. Ganesh

Department of Marine Living Resources, Andhra University, Visakhapatnam – 530 003, Andhra Pradesh, India.

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Corresponding Author

Myla. S. Chakravarty

Abstract

The relationship between length-weight, the total length-carapace length and total length-abdominal length and relative condition factor of the deep water mud shrimp *S. melantho* were studied for a period of two years (Nov'2004 – Oct'2006). In length – weight the estimated slope value (b) for male was found to be 2.7377, for female 2.9569 and for sexes combined was 3.1962. The regression equations calculated was $W = 0.000010931\ L^{2.7377}$ (r=0.87) for male, was $W = 0.000012419\ L^{2.9569}$ (r=0.94) for female and for sexes combined was $W = 0.000012017\ L^{3.1962}$ (r=0.94). The regression equations for total length-carapace length relationship of males, females and sexes combined were CL = -0.6003 + 1.0117 TL (r = 0.93), CL = -0.8592 + 1.1567 TL (r = 0.96) and CL = -1.0058 + 1.2276 TL (r = 0.86) respectively. The regression equations for the total length – abdominal length relationship for male was AL = -0.1244 + 0.9953 TL (r = 0.99), for female was AL = -0.0253 + 0.9398 TL (r = 0.99) and for sexes combined was AL = 0.0288 + 0.9137 TL (r = 0.98). Analysis of covariance confirmed significant difference between males and females in the regression coefficients between length - weight, total length - carapace length and total length-abdominal length. The relative condition factor in males and females of *S. melantho* was highest in the size groups of 101-105 mm and 106-110 mm respectively indicating the maturity of both the sexes. In both the sexes combined the peak value is found at 56-60mm. Peak values were observed in March and July for males and October for females and January and August for sexes combined.

Introduction

Growth in shrimps is manifested as an increase in body size or weight and is usually measured by its total length, from the tip of the rostrum to the tip of the telson. It has been proved mathematically that there is a relationship between total length and weight of the body of the organisms (Le Cren, 1951). Length-weight relationship is usually to obtain the knowledge of the growth. A study of length-weight relationship helps obtaining the yield estimates by analytical models (Rao, 1988). Information on the relationship between total length and carapace length is needed for the purpose of comparison of data from different sources. This helps compilation of uniform and more reliable data on catch statistics of commercial landings of individual species.

Huxley (1932) has made a mention of the allometric equation of the relationship between body weight and carapace length in both the sexes of *Solenocera melantho* off Japanese coast. Le Cren (1951) contends that the length-weight is calculated primarily with two fold aims, first to determine the mathematical relationship between the two variables, length and weight, that if one is known other could be computed and secondly to measure the variations from the expected weight for length of an individual (or) group of individuals as an indication of increase

in muscle. The length-weight relationship of *S. crassicornis* from Bombay waters has been carried out by Sukumaran (1978). Ramamurthy (1994) has studied the length-weight relationship of *Parapenaeopsis stylifera*, *Metapenaeus affinis, S. crassicornis* and *M. monoceros* of the North West coast of India. Ohtomi and Irieda (1997) have derived the relationship between body weight and carapace length for both sexes in *S. melantho* of Kagoshima Bay. Dinesh Babu and Manissery (2007) have observed morphometric relationships between total length - total weight, carapace length - total weight and total length-carapace length in *S. choprai* on the south west coast of India.

Individual variations in length–weight relationship which has been considered as the general condition of the organism will be analysed by means of condition factor or k-factor or ponderal index (Le Cren, 1951). The condition of a shrimp is influenced by the environment, season, feeding, moulting, gonadal maturity etc., (Le Cren, 1951). The other investigators who have contributed on these lines are Sarada (2010), Lakshmi Pillai *et al.*, (2012) and Lawal-Are and Akinjogunula (2012). An attempt is made in the present study to derive the relationship between length and weight, total length and carapace length, total length and abdomen length and the relative condition factor during different months of the study period and in different size groups in *S. melantho* for two successive years *i.e.*, 2004 to 2005 and 2005 to 2006.

Material and methods

Samples of *S. melantho* were collected fortnightly from the commercial trawl catches at Visakhapatnam fishing harbour during Nov' 2004 to Oct' 2006. In both the years of sampling the month, May was declared as the period of ban or closed periods (fishing holiday) in both years and hence there was no sampling. Shrimps were washed thoroughly and were blotted with filter paper to remove excess water. The weights of shrimps were taken upto 0.1g and the total length, carapace length and abdominal length were measured to the nearest 0.1mm with a fine pair of dividers. Total length was taken from the tip of the rostrum to the tip of the telson while carapace length was measured from the orbital angle to posterior mid- dorsal edge of carapace with the help of dividers. Abdominal length was measured from the edge of the first abdominal segment to the tip of the telson. Data of both the years were pooled.

A total of 493 males measuring 60-110 mm and 541 females were with 54-114 mm were used for the study. The data was processed by following formula

$W = c\ L^n$ (Kunju, 1978).

Where, W = weight (g), L= Length (mm) and c and n are constants

or its logarithmic expression log W = log c + n log L, for the determination of the length-weight relationship in shrimps in comparison with the cube law was expressed as

$k = W/L^3$, Where k = Growth coefficient, W = Weight (g) and L = Length (mm)

In the present study, the data for total length and total weight showed an exponential relationship between the two parameters and a linear relationship between total length- carapace length and total length–abdominal length. Therefore logarithmic form of the expression $\log_e W = \log_e a + b \log_e L$ was used for determining the relationship between length- weight, where W (g) is the weight, L (mm) is the length and a and b are constants representing the intercept and the slope (regression coefficient) respectively. The expression $\log_e$ denotes the natural logarithm. The linear equation derived was converted into the exponential form i.e.,

$W = a\ L^b$,

Where W = Weight (g), L = Length (mm), 'a' = a constant equivalent to 'c' and 'b' = a constant.

The relationship between total length – carapace length and total length – abdominal length was calculated by the least square method using individual measurements. To determine the significance of the regression coefficients of the relationship in males and females, analysis of covariance (ANCOVA) of Snedecor and Cochran (1968) was used.

Condition factor (K) and relative Condition factor (Kn)

The condition factor was computed by the formula

$$K = \frac{W \times 10^5}{L^3}$$

Where K = condition factor,

W = weight (g) and L = length (mm).

The effect of length on K can be eliminated by computing the relative condition factor based on the emperical length–weight relationship and is calculated by the formula

$Kn = W/\bar{w}$ Where

Kn = Relative condition factor,

W = observed weight and $\bar{w}$ = calculated weight.

The Kn values calculated for individual shrimp were pooled for different months, as well as each size-group, for both the sexes combined separately.

Results

Length- weight relationship

The observed values of length and weight of males, females and sexes combined were plotted in fig.1. The regression lines fitted to the data indicated a straight-line relationship between the two variables. The regression coefficient calculated using the method of least squares for males, females and sexes combined gave the following equations:

Males $W = 0.000010931\ L^{2.7377}$ (r=0.87); Log W = -4.4698 + 2.7377 Log L (r=0.87)

Females $W = 0.000012419\ L^{2.9569}$ (r=0.94); Log W = -4.8368 + 2.9569 Log L (r=0.95)

Sexes combined $W = 0.000012017\ L^{3.1962}$ (r=0.94); Log W = -5.3248 + 3.1962 Log L (r=0.95)

Analysis of covariance (F-test) revealed significant difference at 5% level in males, females and sexes combined (Table 1).

Total length-carapace length relationship

The ANCOVA indicated that there was significant difference in the regression coefficients of males and females (Table 2 & Fig. 2). The regression equations obtained were

Males CL = -0.6003 + 1.0117 TL (r = 0.93)

Females CL = -0.8592 + 1.1567 TL (r = 0.96)

Sexes combined CL = -1.0058 + 1.2276 TL (r = 0.86)

Total length - Abdominal length relationship

The difference of length between the total length and carapace length was taken as the abdominal length. There was a significant difference in the regression coefficients of males, females and sexes combined (Table 3 & Fig. 3).

Males AL = -0.1244 + 0.9953 TL (r = 0.99)

Females AL = -0.0253 + 0.9398 TL (r = 0.99)

Sexes combined AL = 0.0288 + 0.9137 TL (r = 0.99)

Relative condition factor (Kn values)

The average Kn values for males, females and sexes combined were calculated separately every month. Kn values were also estimated with increasing size groups of 5mm.

Month-wise mean Kn values

Males showed peak values in March, July and September of the study period and moderate values in February, June, August and October and low values in January and April. Whereas females showed a peak value in October, higher values in September, moderate values in August, January, July and February and low values in other months. In case of the sexes combined the values showed peak values in January and August, higher values in December, February, September, March and June and the rest showed lower values (Fig. 4).

Size-group wise mean Kn values

The mean Kn values of males showed a peak value in 101-105 mm size group and higher values in 86-90 mm, and 96-100 mm size-groups, in rest of the size groups a steady increase in mean kn values with lowest value at a size group of 56-60mm. In case of females the peak values were recorded at 106-110mm, higher at 76-80mm, 96-100mm, the lowest in 51-55mm size group and the rest of groups at moderate levels. When sexes combined a peak value was found at 56-60mm and the rest showed a downward trend with a lowest value of 106-110mm, higher value at 51-55mm and the remaining sizes showed moderate values (Fig.5).

Table 1 Comparison of regression lines of length - weight relationship in males, females and sexes combined of *S. melantho*.

Sex	Corrected sums of squares and products				Regression coefficient (b)	Deviations from Regression		
	d.f	ΣX^2	ΣXY	ΣY^2		d.f	S.S	M.S.S
Males	492	0.57745	1.43768	5.61833	2.7377	491	1.29029	0.002627
Females	540	1.23165	1.92529	11.79645	2.9569	539	1.02815	0.0019075
Pooled(within)						1030	2.31844	0.0022509
Combined	1032	1.8091	3.36297	17.41478	3.1962	1031	2.87784	0.0027913
Slopes						1	0.5594	0.5594

Slopes, F = 248.522 (d. f ; 1,1030) Significant at 5% level

d. f = Degrees of freedom; ΣX^2, ΣXY,ΣY^2 = corrected sum of squares and products S.S = Sum of Squares; M.S.S = Mean Sum of Squares

Table 2 Comparison of regression lines of the relationship between total length and carapace length in males, females and sexes combined of *S. melantho*.

Sex	Corrected sums of squares and products				Regression coefficient (b)	Deviations from Regression		
	d.f	ΣX^2	ΣXY	ΣY^2		d.f	S.S	M.S.S
Males	492	0.57745	2.53698	0.67659	1.00176	491	0.0971	0.000197
Females	540	1.23165	2.78399	2.15000	1.15678	539	0.3685	0.000683
Pooled(within)						1030	0.4656	0.000452
Combined	1032	1.8091	5.32097	2.82659	1.2276	1031	1.4356	0.0001392
Slopes						1	0.97	0.97

Slopes, F = 697.454 (d. f ; 1,1030) Significant at 5% level

d. f = Degrees of freedom; ΣX^2, ΣXY, ΣY^2 = corrected sum of squares and products S.S = Sum of Squares; M.S.S = Mean Sum of Squares

Table 3 Comparison of regression lines of the relationship between total length and abdominal length in males, females and sexes combined of *S. melantho*.

Sex	Corrected sums of squares and products				Regression coefficient (b)	Deviations from Regression		
	d. f	ΣX^2	ΣXY	ΣY^2		d. f	S.S	M.S.S
Males	492	0.57745	3.38492	3.14832	0.9953	491	0.01165	0.00002372
Females	540	1.23165	3.58424	3.32247	0.9398	539	0.01718	0.00003187
Pooled(within)						1030	0.02883	0.00002799
Combined	1032	1.8091	6.96916	6.47079	0.9137	1031	0.05826	0.00005651
Slopes						1	0.02943	0.02943

Slopes, F = 1051.44 (d. f ; 1,1030) Significant at 5% level

d. f = Degrees of freedom; ΣX^2, ΣXY,ΣY^2 = corrected sum of squares and products S.S = Sum of Squares; M.S.S = Mean Sum of Squares

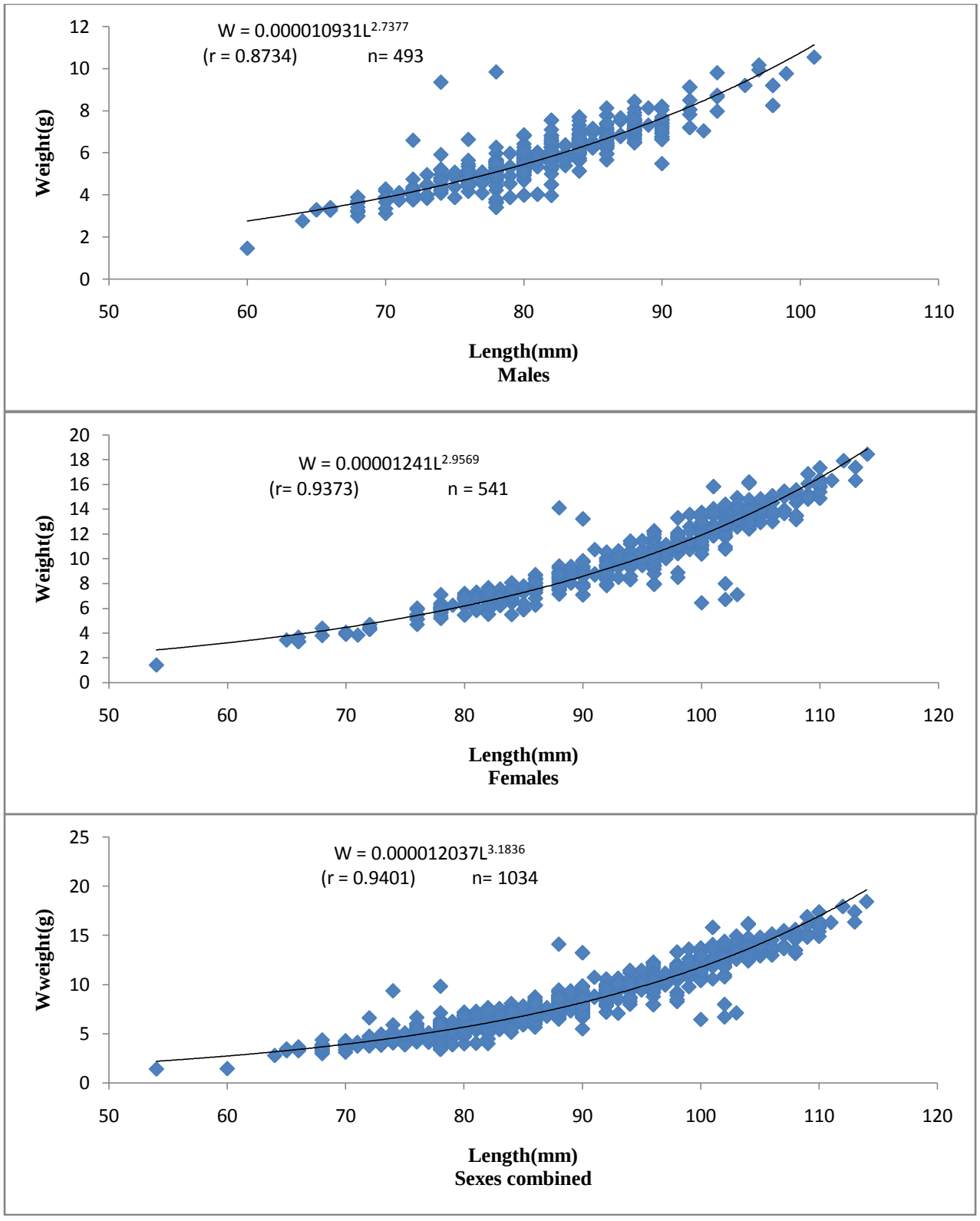

Fig. 1 Scatter diagram showing length-weight relationship of *S. melantho* in males, females and sexes combined.

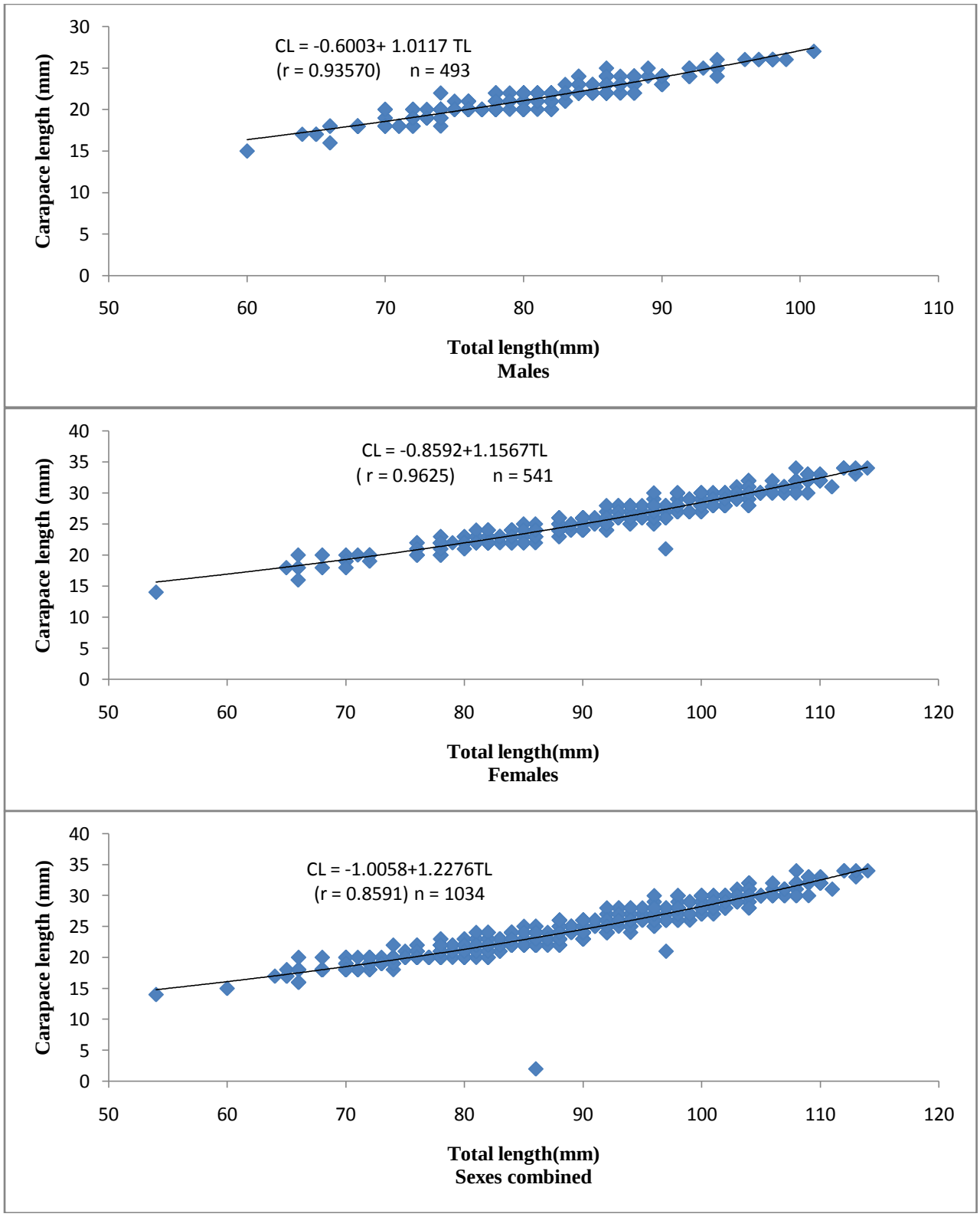

Fig. 2 Scatter diagram showing total length - carapace length relationship of *S. melantho* in males, females and sexes combined.

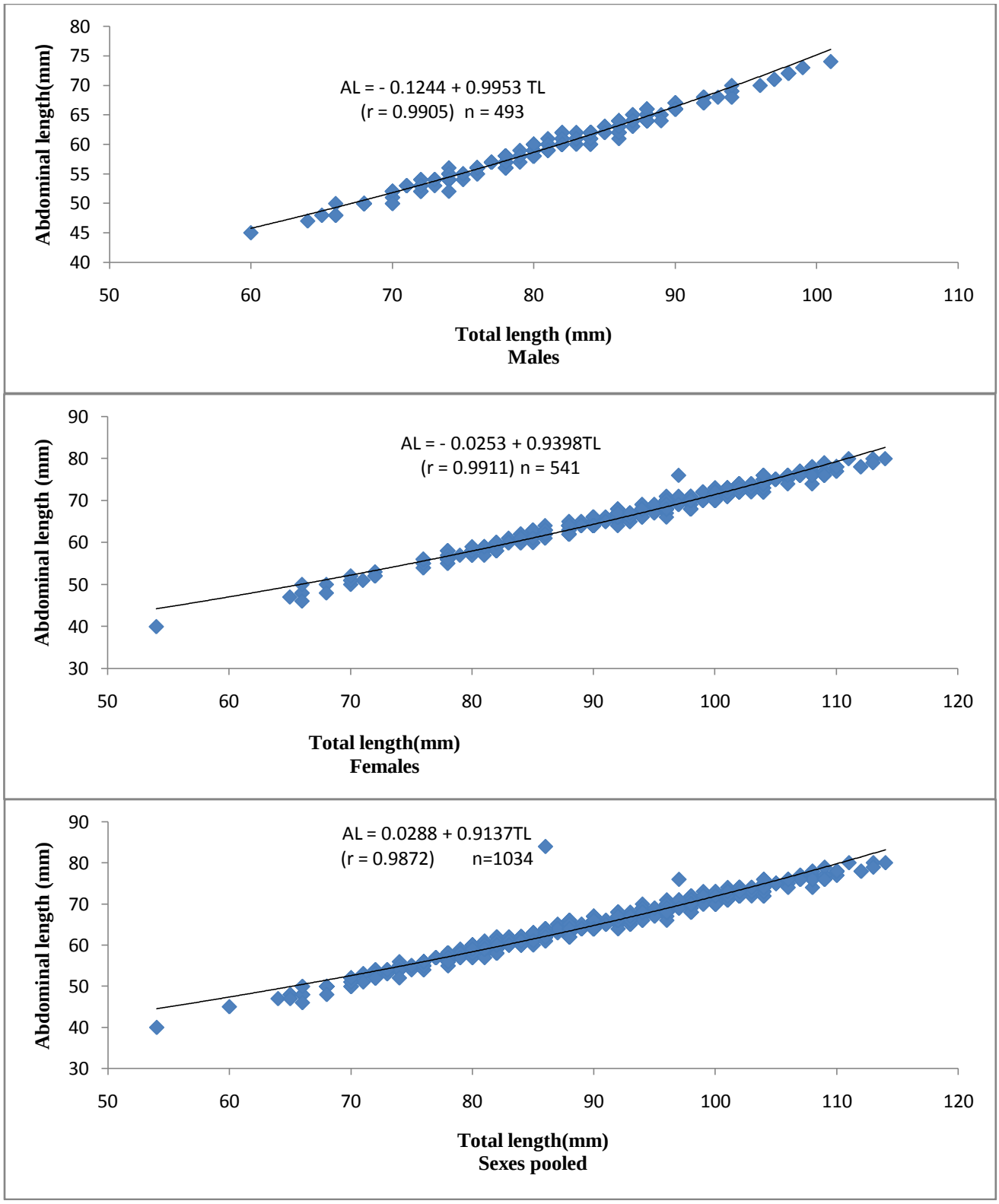

Fig. 3 Scatter diagram showing total length - abdominal length relationship of *S. melantho* in males, females and sexes combined.

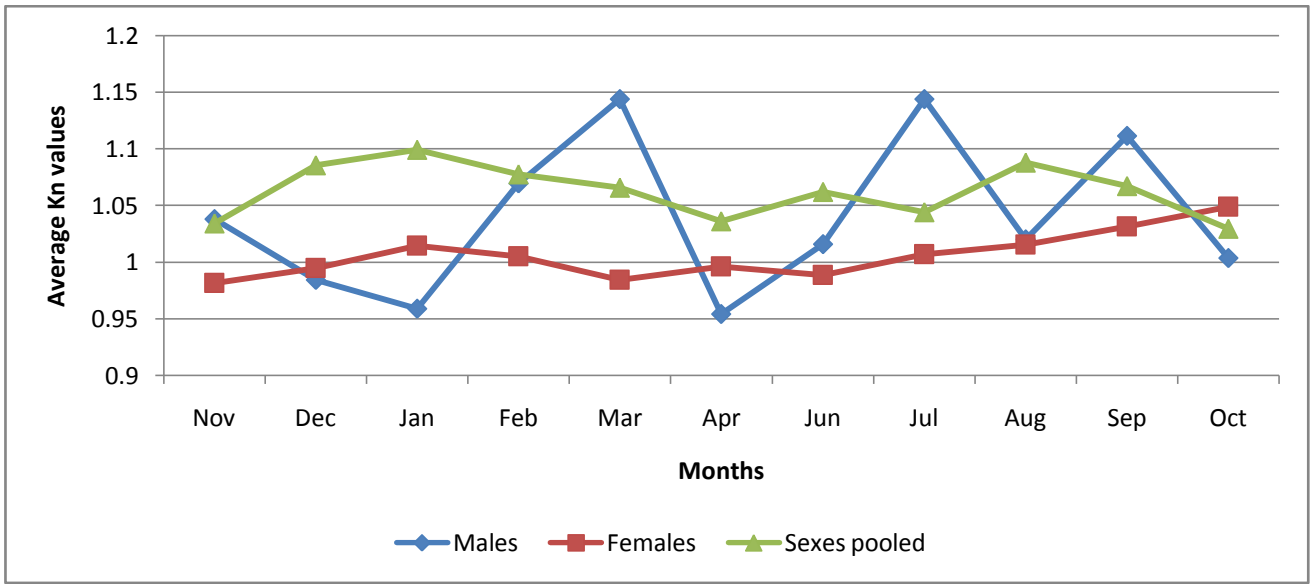

Fig. 4 Month -wise condition factor of *S. melantho* in males, females and sexes combined.

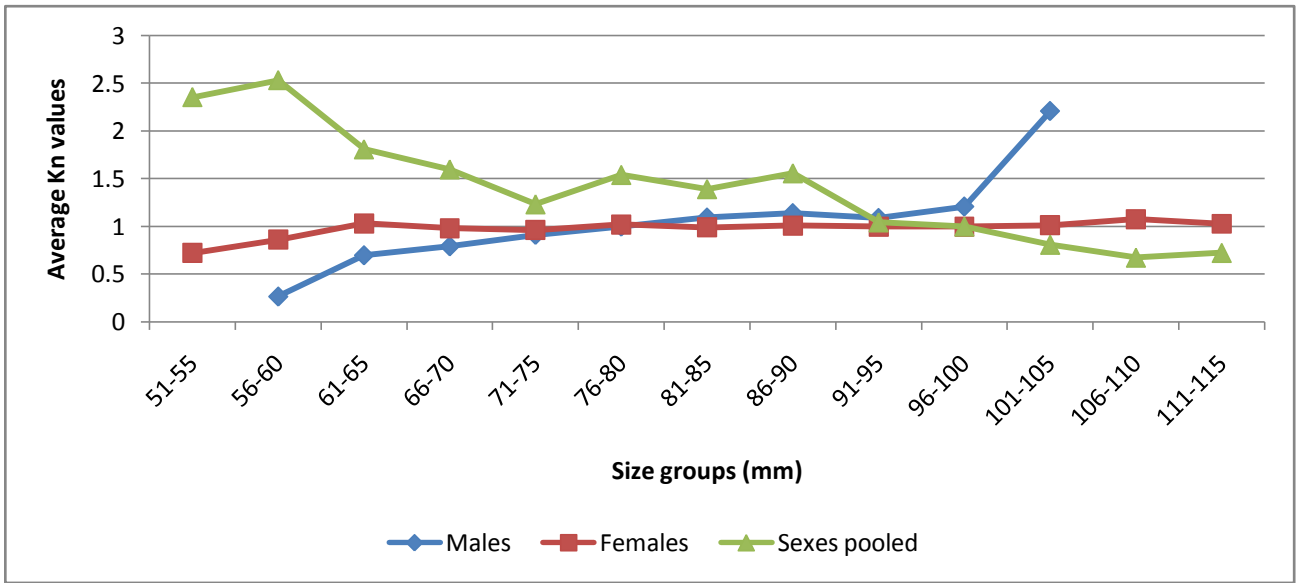

Fig. 5 Length-wise condition factor of *S. melantho* in males, females and sexes combined.

Discussion

In fisheries, studies on morphometric relationships like length–weight, carapace length–total length, abdomen length–total length of the species is useful for the stock assessment and population dynamics of the species. It is also an index of the condition factor, which is a vital parameter for the evaluation of the specific condition of the species, particularly growth and reproductive state. The value of the exponent 'b' is between 2.5 to 3.5 or usually close to 3.0 (Carlander, 1969). If 'b' is 3 the growth is isometric. If it is allometric, it may be positive (> 3.0) or negative (< 3.0). According to Hile (1936) and Martin (1949) the exponent is usually lies between 2.5 to 4.0. But Allen (1951) has reported that 3 is the ideal value. Hall (1962) has studied the relationship of carapace length and weight of twenty four penaeid shrimps and observed the longest specimens are lesser heavy and the same condition has been found among the species of the same genus and variation in different genera. The exponent value is found to be nearer to 3 in females and less than three in males of *S. crassicornis* (Sukumaran, 1978). Ramamurthy (1994) has observed the 'b' values in *M. affinis* (males- 3.2306; females- 3.3892), *M. monoceros* (males-2.6288,

females-3.4502), *P. stylifera* (males - 2.5978; females - 3.1688) and *S. crassicornis* (males - 2.0495; females - 1.1455) and the length-weight the relationship is significant at 1% level for the three shrimps where as in *P. stylifera* it is insignificant. According to Murthy and Ramaseshiah (1996) the relationship between total length and tail weight is not significantly different in males and females of *M. dobsoni* and between total length and carapace length is significantly different in both males and females.

Ramaseshaiah and Murthy (1997) have observed a significant difference in the relationship between length – weight and total length–carapace length for males and females in *M. barbata* and the exponent 'b' value is 3.2731 in males and 3.3762 in females. According to them males are heavier than females up to a total length of 73mm and females are heavier than males from 77mm onwards with both sexes weighing equally. An allometric relationship between body weight and carapace length has been observed in males and females of *S. melantho* by Ohtomi and Irieda (1997) in Kagoshima Bay. A significant growth variation between sexes with the exponent 'b' value of 2.92 in males and 3.29 in females has been reported by Dinesh Babu (2006) in *M. monoceros*, off Saurashtra coast. Dinesh Babu and Manissery (2007) have observed significant differences between slopes and elevations of total length-total weight, with the 'b' value in males is 3.18531 and in females it is 2.76114 in *S. choprai*. In case of the relationship between carapace length and total length a significant variation has been observed between males and females with the exponent values of 2.71882 in males and 2.6055 in females. Sarada (2010) has observed significant relationship between males and females with the 'b' values as 3.01 in males and 2.98 in females in *Penaeus semisulcatus*.

In the present study, a linear relationship has been observed between the length and weight in *S. melantho* and the regression values of both the sexes are found to be statistically significant. The 'b' value for males is 2.7377 suggesting that the males show negative allometry. The 'b' value of female is 2.9569 indicating the isometric growth with the values to close "3". The exponential values for males and females were nearer to '3' indicating that the weight increases correspondingly to the length. The 'b' value for combined sexes is 3.1962 suggesting positive allometry. The calculated length-weight curve fitted to the sets of data showed a close relationship between the observed and calculated values. ANCOVA has confirmed a significant difference between males and females in the regression coefficients of *S. melantho* with respect to total length and carapace length. A linear relationship has been observed between the total length and abdominal length and the regression coefficients are found to be statistically significant in males and females.

The mean condition factor or 'ponderal index' or mean Kn value represents the general well being of the animal and is the ratio between observed and smoothed or calculated mean weight ($W/\bar{w}$) for each size group and for all length groups combined during different months of the year. The modes of Kn values can be taken an index of gonadal maturity and spawning season or better feeding conditions (Le Cren, 1951). Rajyalakshmi (1961) has observed that the relative condition factor is high in smallest size groups and a decline afterwards where as in case of monthly fluctuations the index is lowest in winter months (November to March) and highest in summer (March to July) and monsoon (July to November) months in *Metapenaeus brevicornis*. Sukumaran (1978) has reported fluctuation Kn factor in a rhythmic manner against different size groups in males and females of *S. crassicornis*. The coefficient of condition 'k' has been constant in *Fennoropenaeus indicus* and *M. dobsoni* under different feeding levels although the growth rate has varied considerably, indicating that there is no change with the increase in size of the shrimps in laboratory conditions (Nair *et al*, 1982).

Devi *et al* (1983) have observed the condition factor to be very high in *F. indicus* and *M. dobsoni* due to adequate food and suitable environment and it is relatively constant with respect to size in *M. dobsoni* in Cochin back waters. According to Patel *et al* (1984) peak values of the relative condition factor have been observed in the size groups of 71-80 mm and 161-170 mm in September indicating the size and month of maturity and spawning and low Kn values in 81-90 mm and 151-160 mm in November. Patel *et al* (1986) have also observed the same pattern in *P. penicillatus*. Joseph and Soni (1986) have found the change of Kn value in different months in case of *M. kutchensis*, reaching the peak stage and trough in December at a size group of 96 – 105mm whereas for female at 196 – 205mm. Lower values for male has been observed at 136 – 145mm and 146 – 155mm and in female it is at 106 – 115mm length group. Lawal –Are and Akinjogunla (2012) have observed that that there were differences in the condition factors for males and females of *P. notialis*.

In the present study on *S. melantho* the relative condition factor in different months showed peak values were observed in March and July for males and October for females and for the sexes combined data showed highest in January and August indicating either the high feeding intensity or the maturing stages or both. The Kn value in males and females was highest in the size groups of 101-105 mm and 106-110 mm respectively. The data of sexes combined showed peak value at 56-60mm.

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