5. LENGTH - WEIGHT RELATIONSHIP

5.1. INTRODUCTION

Length - weight relationship has been bio statistically evidenced to have a constant relationship between total length and weight of an individual. Length weight relationship is of considerable importance in fishery biology for the calculation of average weight at a certain length and the conversion of an equation of growth in terms of weight at a certain length and conversion of growth equation in terms of length and weight (Cinco, 1982; Pauly and Munro, 1983; Entsna – Mensah et al., 1995; Vazzalor, 1996; King, 1996; Bernandes et al., 2000; Muto et al., 2000). A statistical analysis of morphometric characters gives a better assumption of relationship within the species, at the same time to compare with the same species in different geographical locations (Kuber, 1987). Length and weight are two important components in the biology of species at the individual and population stages. Knowledge on length weight relationship (LWR) is essential for proper appraisal and administration of these fisheries (Park and Oh, 2002). The length weight relationship is an essential tool to convert length to weight vice versa. In few cases it is easier to take morphometrics of weight rather than length, for example, the weight of a cephalopod (Bello, 1991). The growth rates of various parts are not uniform in molluscan fauna (Le Cren, 1951).

The length - weight relationship has a number of functions in stock assessment. Among the functions, the assessment of standing stock biomass, analyzing condition index and comparing the ontogeny of population from different regions are important (Pauly and Munro, 1983).
The length weight relationship formula besides providing a means for calculating weight from length, a direct way of converting logarithmic growth rates evaluated on length into growth rates.

The length of a fish increases with weight, representing that weight of a fish is a function of length. As length is a linear measure and the weight a degree of volume, the relationship between length and weight can be elaborated by the hypothetical cubic law

\[ W = CL^3 \]

Where, \( W \) = weight, \( L \) = length and \( C \) = constant

But Le Cren (1951) suggested that it is advisable to fit parabolic equation of the form \( W = aL^b \) This formula conveys the relation between weight and length better than the cubic formula. If the form and specific gravity remains constant, the formula could be used to calculate the weight of known length and vice versa.

The length - weight relationship can be asserted graphically by plotting the observed length and weight as a scattered diagram.

In the present study the length weight relationship and other allometric relationship of \( Trochus radiatus \) were attempted.

5.2. MATERIALS AND METHODS

5.2.1. Length – weight relationship

Monthly samples of gastropod \( Trochus radiatus \) were randomly collected from the study area. A total of 648 trochids comprising 324 males and 324 females, representing all the size groups observed during the study period were used to study the length - weight relationship and other allometric relationships. The relationship between length and weight of an organism in a given population can be calculated
either by measuring the length and weight of the same animal repeatedly throughout its life span, or by measuring the weight and length of a sample of the animal taken at a particular time. The relationship between length (L) and weight (W) typically takes the form:

\[ W = a L^{b} \]

or in the linear form

\[ \log W = \log a + b \log L \]

(i.e.) \( Y = a + b x \)

Where, \( a = \) intercept; \( Y = \log W \)

\( x = \log L \) and \( b = \) slope

The linear equation was fitted and the estimates of parameters “a” and “b” were obtained by the least squares method.

5.2.2. Allometric relations in *Trochus radiatus*

To study the other morphometric relationships in *T. radiatus*, various measurements were taken following Hermosilia (2007).

i) Length

The distance between the anterior and posterior extremities of the shell in a direction parallel to the ventral margin is measured to the nearest 0.1mm using vernier calipers.

ii) Width (Diameter)

The width (or breadth, or diameter) is the maximum measurement of the shell at right angles to the central axis.
iii) **Total weight**

Total weight of the trochid is accurately weighed (0.001g accuracy) using an electronic mono pan balance.

**iv) Shell weight**

Shells were removed, dried and weighed accurately. Percentage of shell weight to the total weight was calculated for each animal.

**v) Flesh weight**

Shell is carefully removed using a small metal rod and hammer. The moisture in the flesh was removed by a blotting paper and weighed accurately.

The relationship between the length and other shell parameters like width and weight was studied by fitting the regression equation

\[
Y = a + bx
\]
Wherever required, the logarithmic transformation was applied. Here Y is the independent variable, ‘a’ and ‘b’ coefficients of allometry, the constants, which were estimated by the least square regression analysis. Length was used as an independent variable in all the parameters studied.

5.3. RESULTS

5.3.1. Length – weight relationship

The regression line derived from data for males and females of *T. radiatus* showed a linear relationship between the two variables ie, length and weight.

**a) Males**

To understand the length weight relationship of males the data for the monthly samples collected were pooled and the regression equation obtained was as follows.

\[
\log W = -3.4135 + 3.2416 \log L
\]

\(r = 0.98\quad n = 324\)

**Figure 5.2. Length-weight relationship for males of *Trochus radiatus***
b) Females

To understand the length - weight relationship of females, the data for the monthly samples collected were pooled and the regression obtained was

\[
\text{Log } W = -3.6247 + 3.2635 \text{ Log } L
\]

\( (r = 0.98 \quad n = 324)\)

**Figure 5.3. Length - weight relationship for females of *Trochus radiatus***

Analysis of covariance for the regression of log weight on log length in males and females showed insignificant values. Hence, a common equation was derived.

\[
\text{Log } W = -3.6415 + 3.2439 \text{ Log } L
\]

\( (r = 0.98 \quad n = 648)\)
Figure 5.4. Length - weight relationship for males and females of *Trochus radiatus*

![Graph showing length-weight relationship](image)

Table 5.1. Linear regression equation in the form of $\log W = \log a = \log L$ for male, female combined *T. radiatus*

<table>
<thead>
<tr>
<th>Category</th>
<th>Regression equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>$\log W = -3.4135 + 3.2416 \log L$</td>
</tr>
<tr>
<td></td>
<td>$(r = 0.98 \quad n = 324)$</td>
</tr>
<tr>
<td>Females</td>
<td>$\log W = -3.6247 + 3.2635 \log L$</td>
</tr>
<tr>
<td></td>
<td>$(r = 0.98 \quad n = 324)$</td>
</tr>
<tr>
<td>Combined</td>
<td>$\log W = -3.6415 + 3.2439 \log L$</td>
</tr>
<tr>
<td></td>
<td>$(r = 0.98 \quad n = 648)$</td>
</tr>
</tbody>
</table>

The regression parameters of the length and weight relationships of *T. radiatus* and the details of sums of the squares and products of length and weight data of males and females are presented in Tables.
### Table 5.2. Regression parameters for length – weight relationship of *T.*radiatus

<table>
<thead>
<tr>
<th>Category</th>
<th>n</th>
<th>a</th>
<th>b</th>
<th>r</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>324</td>
<td>-3.4135</td>
<td>3.2416</td>
<td>0.98</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Females</td>
<td>324</td>
<td>-3.6247</td>
<td>3.2635</td>
<td>0.98</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

### Table 5.3. Statistics on the length - weight relationships of males and females of *T.*radiatus

<table>
<thead>
<tr>
<th>Category</th>
<th>n</th>
<th>Σx</th>
<th>Σy</th>
<th>Σx²</th>
<th>Σy²</th>
<th>Σxy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>324</td>
<td>406.2349</td>
<td>221.4126</td>
<td>632.9044</td>
<td>178.7204</td>
<td>326.5596</td>
</tr>
<tr>
<td>Females</td>
<td>324</td>
<td>402.5627</td>
<td>208.9674</td>
<td>623.6960</td>
<td>162.6939</td>
<td>304.4607</td>
</tr>
</tbody>
</table>

Where,

- \( n \) = number of gastropods examined
- \( x \) and \( y \) = sum of \( x \) and \( y \) and
- \( x^2, y^2, xy \) = sum of squares and products

### Table 5.4. Regression data for the length - weight relationship for males and females of *T.*radiatus

<table>
<thead>
<tr>
<th>Category</th>
<th>df</th>
<th>Sum of squares and products</th>
<th>b</th>
<th>Errors of estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>( x^2 )</td>
<td>( xy )</td>
<td>( y^2 )</td>
</tr>
<tr>
<td>Males</td>
<td>324</td>
<td>2.0124</td>
<td>6.2346</td>
<td>23.1436</td>
</tr>
<tr>
<td>Females</td>
<td>324</td>
<td>2.3589</td>
<td>8.6123</td>
<td>32.8642</td>
</tr>
<tr>
<td>Total</td>
<td>648</td>
<td>4.3713</td>
<td>14.8469</td>
<td>56.0078</td>
</tr>
</tbody>
</table>
Where, \( df \) = degree of freedom
\( b \) = regression coefficient
\( ss \) = sum of squares and
\( x^2, xy, y^2 \) = corrected sum of square and products

Table 5.5. Analysis of covariance for males and females of \( T.radiatus \)

<table>
<thead>
<tr>
<th>Sources of variation</th>
<th>df</th>
<th>Sums of squares</th>
<th>Mean squares</th>
<th>Observed ‘f’</th>
<th>5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deviation from individual regression</td>
<td>648</td>
<td>1.6739</td>
<td>0.001824</td>
<td>0.2642</td>
<td>-</td>
</tr>
<tr>
<td>Difference between regression</td>
<td>1</td>
<td>0.0074</td>
<td>0.0074</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

The difference is not significant

5.3.2. Other allometric relationships

The other allometric relationships in the gastropod \( Trochus radiatus \) were studied for both the sexes. The regression derived and other values are presented in Tables (5.6 - 5.7).

Table 5.6. The regression values derived for various characters on shell length for male \( T.radiatus \)

<table>
<thead>
<tr>
<th>Relationship</th>
<th>n</th>
<th>a</th>
<th>b</th>
<th>r</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length x width</td>
<td>324</td>
<td>3.9865</td>
<td>0.4872</td>
<td>0.97</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Length x shell weight</td>
<td>324</td>
<td>-3.4286</td>
<td>3.1056</td>
<td>0.96</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Length x flesh weight</td>
<td>324</td>
<td>-4.4548</td>
<td>2.9458</td>
<td>0.94</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
Table 5.7. The regression values derived for various characters on shell length for female *T. radiatus*

<table>
<thead>
<tr>
<th>Relationship</th>
<th>n</th>
<th>a</th>
<th>b</th>
<th>r</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length x width</td>
<td>324</td>
<td>3.4227</td>
<td>0.6412</td>
<td>0.97</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Length x shell weight</td>
<td>324</td>
<td>-3.4286</td>
<td>3.0214</td>
<td>0.96</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Length x flesh weight</td>
<td>324</td>
<td>-5.1725</td>
<td>3.2147</td>
<td>0.94</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Figure 5.5. Relationship between length and flesh weight in females of *Trochus radiatus*

Figure 5.6. Relationship between length and shell weight in females of *Trochus radiatus*
Figure 5.7. Relationship between length and width in females of *Trochus radiatus*

Figure 5.8. Relationship between length and shell width in males of *Trochus radiatus*

Figure 5.9. Relationship between length and flesh weight in males of *T. radiatus*
5.4. DISCUSSION

The change in the shape of growing animals at a point of time is due to the concurrent increase in size and weight respectively. Analysis of the length-weight relationship has become a standard practice in fishery studies (Ricker, 1975). Knowledge of the length - weight relationship has a vital importance in fishery as it not only helps in establishing the yield, but in converting one variable to another. Of the two, length is easier to measure and can be converted into weight in which the catch is invariably expressed (Bal and Rao, 1984). The standard comparison is used for bivalves being total length against total weight.

Intra and inter specific comparison of growth can be made using the slope or exponent of the length - weight equation, which typically lies between 2.5 and 4.0 for most animals. When comparing two exponents, the animal with the higher slope value is increasing in weight per unit of increase in length at a faster rate than the animal where the slope value is lower.
When the slope of the length-weight relationship is equal to 3.0, weight is considered to be increasing as the cube of the length and indicative of isometric body growth (Ricker, 1958). When the slope is not equal to 3, growth is said to be allometric.

In the present study, length-weight data for *T. radiatus* was analyzed separately for males and females. The ‘b’ values for both sexes varied between 3.2416 and 3.2635 for males and females respectively. The ‘b’ values obtained falls in the range mentioned for the molluscan species available from Indian waters (Nayar, 1955; Shunula, 1989).

John (1980) has established that the changes in constant allometry of length-weight relationship are associated with increase in size and sexual maturity in *Anadara rhombae* and in *Katelysia opima* (Kalyanasundaram, 1982).

The results obtained in the present study on *Trochus radiatus* indicated that the allometric relationships of various parameters such as length × width; length × flesh weight; length × shell weight etc., are linear for length based parameters and follow cube law in the case of weight based parameters. The results showed that they followed a similar pattern observed in other species of molluscs by various authors (Mohan and Damodaran, 1981; Mohan *et al.*, 1986; Jayabal and Kalyani, 1986). Jayabal and Kalyani (1986) concluded that the correlation coefficient values for various body and shell characters taken for study are significant (P< 0.001). Nayar (1955), Durve and Dharmaraja (1965), Talikedkar *et al.* (1978), Mohan (1981) and Mohan and Damodharan (1981) studied and explained the importance of the study of allometric relationship and its applications with respect to commercial exploitation of molluscan species in India. Durve and Dharmaraja (1965) have established that the
slope of the fitted regression line is the same for entire size range of animals examined.

However, there are several limitations to shell length as a measure of animal size. First, as gastropod shells age, the spires begin to erode. Spight et al. (1974) consistently observed negative “growth” (change in shell length) over the winter in *Thais lamellosa* at Shady Cove which he recognized as being due to spire erosion. Second, as animals increase in size there is a progressively smaller change in length for a given change in body weight so given the limit on resolution of length change imposed by the repeatability of caliper measurements (0.1 - 0.2 mm), changes in weight will be more readily detected than changes in length. Third, in mature gastropods, where shell growth is almost negligible, body weight may still vary seasonally in association with spawning, reduced activity over the winter or increases or decreases in the food supply. These body weight changes would pass undetected if only shell length is recorded. Finally if populations differ from each other in shell shape or if there is shape variation among individuals within a single population. Then a given length change in animals of the same initial length will be associated with different changes in body weight (Richard, 1982).

The present study shows the ‘r’ values obtained for the various parameters in respect of *T. radiatus* are $L \times SW = 0.96$ and $L \times W = 0.97$ indicating high correlation coefficient. This is comparable to that of the results obtained by Jayabal and Kalyani (1986), who have indicated that the allometric relationship in all combinations showed that the factors are significantly related to each other. Similar results have also been obtained by John (1980) and Kalyanasundaram and Kasinathan (1983). There is a significant difference found between length weight relationship of males and females of *Littorina scabra* from Port Novo waters reported by Maruthamuthu.
and Kasinathan (1985). According to Jones (1970) Length weight relationship LWR may change seasonally, so the data on LWR should be taken annually. Benny (1992) has reported for length weight relationship in *Chicoreus ramosus* was having allometric growth. *Pinctada radiata* growth rate was higher for young ones than the large animals (Mohamed *et al.*, 2009).