Height-Length Relation of Shells in the Indian Backwater Oyster *Crassostrea madrasensis* (Preston) of the Cochin Harbour*

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Height-length relationship in *Crassostrea madrasensis* (Preston) showed an exponential trend and relation in the form, $H=AL^B$. Deviations of actual values from the mean values consequent to the increase in size were noticed. Height and length approximated in oysters of less than 3.5 cm in height resulting in orbicular shape. In oyster of shell height 3.5 cm to 8 cm, increase in height is faster leading to an oval shape. Above 8 cm in height, the oysters become further elongated. Height-length relation is non-linear with an index (B value) of 1.1156. A linear relationship also holds good as the B value is not very much different from unity ($H = -2.5424 + 2.0036L$).

Shell growth is undoubtedly correlated with the growth of the soft tissues in bivalve molluscs. Studies on shell dimensions of oysters are very important to determine the optimum marketable size of oysters.

Several authors observed variations in shell dimensions owing to differences in habitats, environment, tides, depth, over-crowding etc. NewCombe (1950) ascribed differences in habitats of *Crassostrea virginica* for the considerable variations noticed in shell dimensions. Dame (1972) working on the various allometric relationships in oysters of the same species inhabiting intertidal and sub-tidal regions of North America, noticed variations in shell dimensions. Thomson (1969) working on three species of oysters, namely, *Crassostrea commercialis*, *C. gigas* and *Ostrea angasi* set out in adjacent compartments on wire trays in Pittwater, Tasmania noticed much less variations in shell dimensions and opined that even though shell dimensions in oysters are highly variable it becomes much less when grown in uniform conditions with ample space. Lee & Yoo (1975) analysed morphometric variations in shell dimensions in *Crassostrea gigas* at Gajado oyster farm. From Bombay waters Durve & Shrikande (1976) reported the relation between the area of the oyster shell and its dimensions and pointed out that from the height and length of shell, its area can be determined in *Crassostrea gryphoides*. They employed multiple linear regression technique in their study and arrived at mathematical relations between shell length, shell height and shell area.

Orton (1936) observed considerable variation in length-width ratio in the oyster *Ostrea angulata* growing on soft and hard bottoms and the same phenomena was observed by Gunter (1938) also. The shell height-length relation was observed to decrease with depth in *Venurupis rhomboides* (Holme, 1961). Tanita & Kikuchi (1957) noticed in *Pinctada martensii* a decrease in length-width ratio of shell owing to over-crowding. Joseph (1979) observed only less gain in shell depth in spats.

Dimensional relationship of shells in bivalves more particularly in oysters shows that only very little work has been carried out on this important aspect of bivalve morphometry from Indian waters. Works pertaining to this aspect from Indian waters are those of Paul (1942), Rao & Nayar (1956)

*Formed part of the Ph.D. Thesis of the first author approved by the University of Cochin

Durve & Shrikande (1976) Durve & Dharmaraja (1965) and Nair, 1967. No published data on oysters from Cochin Backwaters are available and hence a detailed study on this aspect to establish the relation between shell dimensions has been carried out.

Materials and Methods

For determining height-length relationship, morphometric data of oysters ranging from 0.2 to 16.9 cm in height were employed. 'Height' is the maximum distance recorded from hinge to the opposite side of the shell, 'length' the greatest dimension of the anterio-posterior axis and 'depth' is the maximum distance between the outer sides of the two shells at a point where the axes of the other two dimension crossed (Galtsoff, 1964). Random samples of wild oysters were collected from the shipping channel, near bar-mouth of the Cochin Backwaters during different months and a total of 1195 oysters of different sizes were used in the morphometric studies.

Results

Height and length were plotted on a graph with length on abscissa and height on ordinate in the form of a scatter graph (Fig. 1). The plot of height against length showed an exponential trend and a relationship of the form $H=AL^B$ was found to be appropriate. On taking logarithm, this gave a linear relationship of the form $Y = a + bX$, where Y is log H, $X = \log L$, $a = \log A$ and $b = B$.

The plot (Fig. 1) showed larger deviations in height for longer oysters. For oysters with height below 3.5 cm, the height and length tended to approximate. However, the ratio changed and larger deviations were observed for oysters above 8 cm in height. Therefore, possibilities for three different relationships between height and length were examined. It was found possible and three different equations were fitted, one for oysters of height 3.5 cm and below, the second for those between 3.5 to 8 cm in height and the third for those above 8.0 cm in height. The three equations in the logarthmic scale with standard error (SE) of regression coefficients and correlation coefficients are presented in Table 1. The corrected sum of squares, cross products and deviation from regression for the three groups are given in Table 2. The residual variances were observed to be heterogeneous. This was further tested by Bartletts' test of homogeneity of variance following Snedecor & Cochran (1968). The computations for the test are furnished in Table 3.

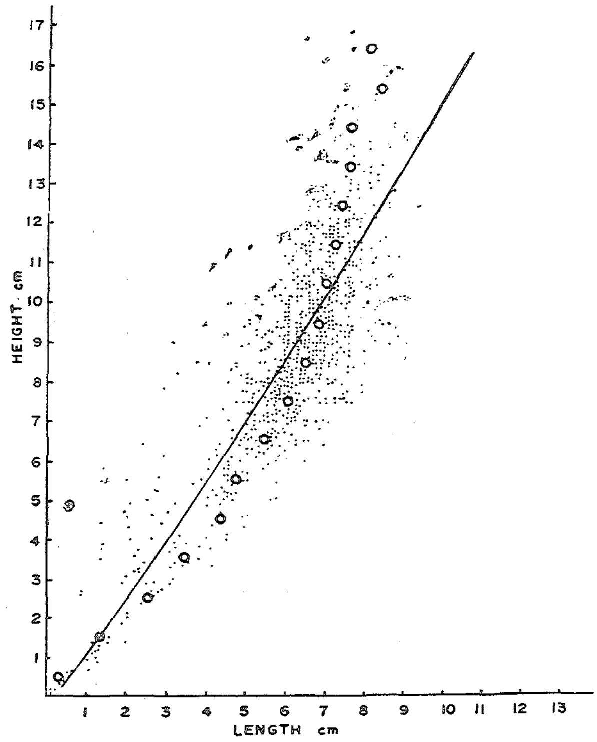

Fig. 1. Height-length relationship of *C. madrasensis*. Circles indicate the mean values of length for the different size groups in height

Discussion

Several workers have noticed pronouned fluctuation in the shape of oyster shells (Yong 1960). The nature of the substrata, density, of population (over-crowding), wave, current depth, salinity and availability of food are all known to influence the growth pattern of bivalve molluscs including oysters. (Korringa, 1952; Swan, 1953; Wilton & Wilton, 1929; Hanso, 1958; Hamai, 1934, 1934a, 1935 and 1935a). Shell growth is correlated with the growth of tissues of the oyster. NewCombe (1950) analysed certain dimensional relationships of the Virginia oyster, *Crassostrea virginica*. Differences in the ratios, namely, length to breadth were observed by him. Rao & Nayar (1956) while studying the rate ot growth in the Indian backwater oyster *Crassostrea madrasensis*

Table 1. *Regression lines of log height on log length*

Group	Regression equation	SE of b	r
Oysters with shell height below 3.5 cm (Group 1)	$Y = 0.01378 + 0.9866 \times$	0.3320	0.9318
Oysters with shell height 3.5 to 8 cm (Group 2)	$Y = 0.4028 + 0.5712 \times$	0.02313	0.6938
Oysters with shell height above 8 cm (Group 3)	$Y = 0.8675 + 0.1669 \times$	0.06220	0.0965

Table 2. *Analysis of covariance of log height on log length*

	dt	Σx^2	Σxy	Σy^2	Regression coefficient	Deviation from regression df	ss	ms
Group 1	135	22.1273	21.8303	24.8054	0.9318	134	3.2681	0.024389
Group 2	291	7.8964	4.5103	3.8009	0.5712	290	1.2250	0.004224
Group 3	766	2.1136	0.3527	6.3153	0.1669	765	6.2564	0.008178

Table 3. *Bartlett's test of homogeneity of variance*

Group	Sum of squares $d^2y.x$ or $(f_1 s_1^2)$	Degree of freedom	Mean squares $S^2y.x$ or (S_1^2)	log si^2	fi log si^2	Reciprocals $\left(\frac{1}{f_i}\right)$
1	3.2681	134	0.024389	-1.6128	-216.1152	0.07463
2	1.2250	290	0.004224	-2.3743	-668.5470	0.003448
3	6.2564	765	0.008178	-2.0873	-1586.8250	0.001307
a=3	10.7495	1198			-2451.4872	-0.004482

$$\bar{s}^{2} = \Sigma f_i s_i^2 / \Sigma f_1 = \frac{10.74951}{1189} = 0.009041$$

$$(\Sigma f_i) \log \bar{s}^2 = (1198)\,(-2.04378) = 2430.0544$$

$$M = 2.3026\,[(\Sigma f_i) \log \bar{s}^2 - \Sigma f_i \log s_i^2]$$

$$= 118.4292$$

$$C = 1 + \frac{1}{3 \mathrm{x} 2} \mathrm{X}\ 0.01158$$

$$\text{Chi-square} = M/C = \frac{118.4292}{1.0019} = 118.2046$$

Highly significant ($p < 0.001$)

$$df = (a-1) = 2$$

from the Adayar Estuary at Madras, observed the relationship of height-width (=height-length) in spat and yearlings. They observed deviations of the actual values from the mean values consequent on the increase in the size of the oysters. Upto 25 mm size groups, height was the same as that of width, resulting in spats of orbicular shape. However, in size groups of 35–55 mm, width was less than height resulting in oysters of oval shape. In the size range 65 mm and above, the animals were distinctly elongate, the width approximating to about three fourth of the height. A similar observation was noticed in this study also, even though the size group in which the deviation of actual values from the mean, resulting in the change of shape was different from that observed by Rao & Nayar (1956). In the present study, for oysters with less than 3.5 cm height approximately, length was found to be more or less the same as that of height. Deviation in length was more pronounced in larger oysters of 8 cm and above in height. It was possible to fit three regression equation for the three groups of oysters as shown in Table 1. It is obvious from a glance of Table 1, that the regression coefficients where significantly different from zero for all the three groups. The small value of the correlation coefficient 'r' for group 3 (0.0965) can be reasonably attributed to larger variations in length for a given height.

The residual variations were observed to be heterogeneous. This was further tested by Bartlett's test of homogeneity of variance (Table 3). The test showed that the residual variances were highly heterogeneous, chi-square being significant with $p < 0.001$. So there was no need to analyse further, the three groups were represented by three different equations. The equations to the three three curves were,

1. $H. = 1.0322\ L^{0.9866}$
2. $H. = 2.5283\ L^{0.5712}$
3. $H. = 7.3704\ L^{0.1669}$

As the standard error of b was found to be larger for group 3, equation 3 could not be used for prediction of average height against a given length. Rao & Nayar (1956) also observed deviation in height for larger oysters. Following them, mean values were calculated for members within size group of 1 cm class interval as given in Table 4.

As is evident from Table 4, upto 3.5 cm. height, height and length were found to be almost equal, showing orbicular shape and this is in agreement to what has been observed by Rao & Nayar (1956). As the increase in height is faster compared to the increase in length (Fig. 1), the oysters are more or less oval in shape in the height range 3.5 to 8 cm. Above 8 cm, they become further elongated in shape.

As the mean values provide a smooth curve to read the approximate height or length an oyster may attain when either of the measurement is known (Rao & Nayar, 1956), a curve was fitted to the mean values given in Table 4. The equation in terms of the logarithm worked out to, $Y = 0.07229 + 1.1156\ X$. The correlation coefficient was 0.9734. The standard error of b was 0.0677 and the 95% confidence interval for b was 0.9710 to 1.2600. The equation to the curve in the original scale worked out to $H = 1.1811\ L^{1.1156}$. This curve with the observed mean lengths (circled points) is shown in Fig. 1. The analysis of height-length relationship shows that the variations in height are not fully explained by variations in length, especially for large oysters. This evidently suggests the probable influence of other factors operating or influencing the shell growth in oysters.

Table 4. *Mean values of length for the various height groups*

Class interval cm	Mid-point	Number	Average length cm
0 – 1	0.5	108	0.34
1.1 – 2	1.5	17	1.32
2.1 – 3	2.5	11	2.59
3.1 – 4	3.5	18	3.41
4.1 – 5	4.5	17	4.25
5.1 – 6	5.5	40	4.67
6.1 – 7	6.5	80	5.44
7.1 – 8	7.5	140	5.95
8.1 – 9	8.5	189	6.37
9.1 – 10	9.5	171	6.69
10.1 – 11	10.5	124	6·89
11.1 – 12	11.5	100	7.06
12.1 – 13	12.5	63	7.34
13.1 – 14	13.5	33	7.51
14.1 – 15	14.5	28	7.58
15.1 – 16	15.5	8	8.26
16.1 – 17	16.5	9	8.03

The height-length relation in *Crassostrea madrasensis* from the Cochin Backwaters shows a non-linear relation with an index (B value) of 1.1156 for the grouped data. As the B value is not very much different from unity, a linear relationship also holds good ($H = -2.5424 + 2.0036\ L$). Several other workers also observed linear relationship between height and length in oysters of different species inhabiting other parts of the world. Thomson (1969) observed the relation $Y = 0.96X - 1.01$, where Y is length and X is height in *Crassostrea gigas* of Tasmania. For *Crassostrea commercialis*, Thomson (1969) found the relation Y=0.65x-0.11 and for *Ostrea angasi* $y=x$. In *Crassostrea gigas,* Bae & Bae (1972) found different height-length relations depending on the death at which they are grown. Pronounced variation in height-length relationship in *C. gigas* even for small variations in depth was noticed by them. Apart from depth, the substrata on which oysters grow are also known to influence the height-width (=height length) relation in *O. angulata* and *C.virginica* (Orton, 1936; NewCombe, 1950; Gunter, 1938) The ratio was found greater in oysters grown in soft bottoms rather than on hard substrata.

We are thankful to the Director, Central Institute of Fisheries Technology, Cochin for the facilities provided for this work. The help rendered by Mr. A.K.Kesavan Nair in the statistical treatment of the data is greatfully acknowledged.

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