Relation Between Weight and Linear Measurements of Shell in *C. madrasensis* (Preston)*

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Relation of weight to height, length and breadth in the Indian backwater oyster *Crassostrea madrasensis* (Preston) is reported. The relative importance of the variables on weight was found to be height, length and breadth in their order of preference. The multiple regression $V = -0.4017 + 0.46743 X + 0.8278 Y + 0.1130 Z$ can be used to estimate the meat weight (logarithm) for given dimensions of length, height and breadth (all in logarithms). An exponential relation between weight and height is also observed.

Several publications on the length-weight relationship in lamellibranchs are available. Newcombe & Kessler (1936) while studying the variations in the growth indices of the clam *Mya arenaria* (L), studied the length-weight relationship. The growth indices of the same clam was studied by Swan (1952). Notable works pertaining to this aspect in other species of clams are those of Hamai (1934) on the relationship of weight, volume and linear dimensions in *Meretrix meretrix*, studies on the morphometry and rate of growth in the clam *Mactra sulacataria* Reev in Tokyo Bay by Hanoka & Shimadzu (1949), and ecological studies in the natural population of the clam *Tapes japonica* with special reference to seasonal variations in the size and structure of the population and to individual growth by Ohba (1959).

From the Indian sub-continent, Nayar (1955) studied the growth of wedge clam *Donax (Latona) cuneatus* (L) which includes studies pertaining to length-weight relation also. He has computed the calculated weights from observed weights by applying the formula $W=AL^{\propto}$ and found that $W= 0.00045\ L^{2.8079}$ or $\text{Log}\ W = —.05165+ 2.8079\ \text{Log}\ L$, where W and L were weight and length respectively. Other studies on length-weight relations in clams are those of Alagarswami (1966), Talikedkar *et al.* (1976) in *Donax cuneatus* and Narasimham (1968) in *Anadara granosa*. On plotting observed and calculated weights against the respective lengths, Talikhedkar *et al.* (1976) found clear agreement between observed and calculated weights. They employed the formula $W = aL^b$ to determine the calculated weights from observed weights for establishing the relationships. By using logarithms, the exponential relation was found to be $\text{Log}\ W=\text{Log}\ a+b\ \text{Log}\ L$, where W and L are weight and length respectively and a and b are constants. They established the relation $W=0.1352\ L^{3.1079}$ or $\text{Log}\ W = -0.9690+3.1079\ \text{Log}\ L$ for length and weight. However, Narasimham (1968) observed two separate regression equations for expressing the length-weight relationship in 3–19mm and 20–63 mm groups. He obtained the relation $Y= -3.7130+3.2096\ X$ for the 3 to 19 mm group and $Y= -2.8732 + 2.6459\ X$ for the 20 to 63 mm group, where Y=log weight and X = log length.

Richards (1928) studied the growth in the green mussel *Mytilus californianus*. Comparative growth in two mussels, namely,

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M. californianus and *M. edulis* at La Jolla, California and Woods Hole, Massachusetts respectively were also carried out by him subsequently (Richards, 1946). Other works pertaining to mussels are those of Fox & Coe (1943), Kuenzler (1961), Seed (1976) and Andreu (1968). Kuenzler (1961) observed in *Modiolus demissus* variation in length-weight slope consequent to sexual maturity. Andreu (1968) observed the relationship between length and gross weight in the Mediterranean mussel *Mytilus galloprovincialis* and expressed it by the equation, $W = 185.10^{-6}\ L^{2.6764}$.

In the Hawaiian pearl oyster *Pinctada* sp. the weight-length relationship was worked out by Galtsoff (1931). Alagaraja (1962) established a linear relation $W = a + bL$ between length and weight in pearl oysters of Krusadai Island, Gulf of Mannar. The linear relationship was statistically tested by him and found to be significantly different for each year age group. The quality of slopes was tested for the same oysters of particular year spats at different ages and found to be not different. The use of length-weight relationship in predicting pearl fishery has also been pointed out by Alagaraja(1962).

Studies on length-weight relationship in edible oysters are also not few. In the British oysters *Ostrea edulis,* Orton (1935) observed a length-weight relation, $W = 0.0404 \times L^{3.631}$. In Spain, Andreu (1968) noticed a length-weight relation $W=487.10^{-6}\ L^{2.7366}$. The growth of oysters in the Galician waters of Spain is very high according to him. At the end of the second year, oysters were observed to reach a weight of 78 g (Andreu, 1969). Lee & Yoo (1975) reported a length-weight relation of $W=0.0689\,H^{2.1963}$ for hardened oysters and $W=0.1379\,H^{2.0603}$ for seed oysters in Korea. Hughes Games (1977) obtained a length-weight relation of $W = 2.75\ L^{2.34}$ for *Crassostrea gigas* and $W=4.34\ L^{2.08}$ for the British oysters.

The foregoing review of literature shows that no study pertaining to the length-weight relation in edible oysters *(Crassostrea madrasensis),* more particularly from those inhabiting the Cochin Backwaters has been carried out. As weight is a power function of length and since length and other morphometric measurements are inter-related it is thought worthwhile to investigate the relation of weight not only to length but also to height and breadth.

Material and Methods

930 wild oysters collected from the shipping channel near bar-mouth in the Cochin Harbour during the different months spread over a period of one year formed the material for the study. The oysters were thoroughly washed with the help of a brush to remove mud and other particulate material found attached to the shell. The fouling animals on the shells were also scrapped off. The height, length and depth were recorded as mentioned in Nair & Nair, 1986. The whole weight of the oyster was taken and after this the oysters were shucked open, the meat taken out from shell, and excess water from meat removed by keeping the meat in between the folds of a filter paper and then weighed. The shells were also weighed separately. All the weighings were made in an Owa Labor German, single pan electrical balance with an accurancy of 0.1 g.

Results

As the weight of the oyster depends on its volume, the appropriate procedure appeared to represent the weight as a function of length, height and breadth. To bring down to linear scale, logarithm of weight, length, height and breadth was taken. Representing logarithms of weight, length, height and breadth by V, X, Y and Z respectively a multiple regression of V on X, Y, Z, namely,

$$\hat{V} = a + b_1 X + b_2 Y + b_3 Z$$

was fitted (Table 1).

When the variables were measured from their respective means, the above relation becomes,

$$\hat{V} = \bar{V} + b_1 x + b_2 y + b_3 z$$

where $x = X\text{-}\bar{X}$, $y = Y\text{-}\bar{Y}$ and $z = Z\text{-}\bar{Z}$

By minimising $(v\text{-}\hat{v})^2$, the values of a, b_1, b_2 and b_3 were obtained (Snedecor & Cochran, 1968) as,

$$\begin{aligned} a &= \bar{V}\text{-}b_1\,\bar{X}\text{-}b_2\,\bar{Y}\text{-}b_3\,\bar{Z} = -0.4017 \\ b_1 &= 0.4674 \\ b_2 &= 0.8278 \text{ and} \\ b_3 &= 0.1330 \end{aligned}$$

Table 1. *The sums, corrected sums of squares and cross products of height, length, breadth and weight*

n	≶V	≶X	≶Y	≶Z
931	803.9502	750.5771	904.3807	589.6504

≶v²	≶x²	≶y²	≶z²
29.75232	5.56049	10.19369	7.84403

≶xy	≶xz	≶xv	≶yz	≶yv
5.04121	3.58044	7.24851	5.80447	11.55687

≶zv
7.52180

Thus the fitted multiple regression became,

$$V = 0.8635 + 0.4674x + 0.8278y + 0.1330y \quad — \quad (1)$$

$$\text{or } V = -0.4017 + 0.46743X + 0.8278Y + 0.1330Z \quad — \quad (2)$$

Looking at the standard partial regression coefficient (Snedecor & Cochran, 1968), $B_1=0.2021$, $B_2=0.4845$ and $B_3=0.06825$, the relative importance of the variables on weight was found in the order: height, length and breadth. The response lines of V on X when Y and Z were held fixed at their mean values, of V on Y when X and Z were held fixed at their mean values; and of V on Z, when X and Y were held fixed at their mean values are shown in Fig. 1. The t-tests for the significance of regression coefficients showed all the three coefficients to be significantly different from zero (Table 2). Thus all the three morphometric parameters, namely, height, length and breadth contributed to the weight of oysters. The relative importance of these three measurements as suggested by the standard partial regression coefficients is also evident from the t-values, the regression coefficients, corresponding to height and length being highly significant.

Table 2. *t-test for the significance of regression coefficients*

$$b_1=0.4674 \quad s(b_1)=0.0759 \quad t_1=\frac{b_1}{s(b_1)}= 6.16^{***} \quad (p< 0.001)$$

$$b_2=0.8278 \quad s(b_2)=0.06193 \quad t_2=\frac{b_2}{s(b_2)}=13.36^{***} \quad (p<0.001)$$

$$b_3=0.1330 \quad s(b_3)=0.06240 \quad t_3=\frac{b_3}{s(b_3)}=2.13^{*}$$

The multiple correlation coeficient (R^2) is 0.4693 which is highly significant from the F-test,

$$F = \frac{R^2}{1-R^2} \times \frac{n-k-I}{k} \text{ with k and n-k-1}$$

d.f. Here, n being 931 and k being 3, F= 273.28 with 3 and 927 d.f. which is highly significant. The prediction equation (2) can be used to estimate the meat weight (logarithm) for given dimensions of length, height and breadth (all in logarithms).

To represent weight W, in terms of height H, an exponential relation of the form,

$$W = AH^B$$

was considered. On taking logarithm, this transformed to,

$$\log W = a + b \log H,$$

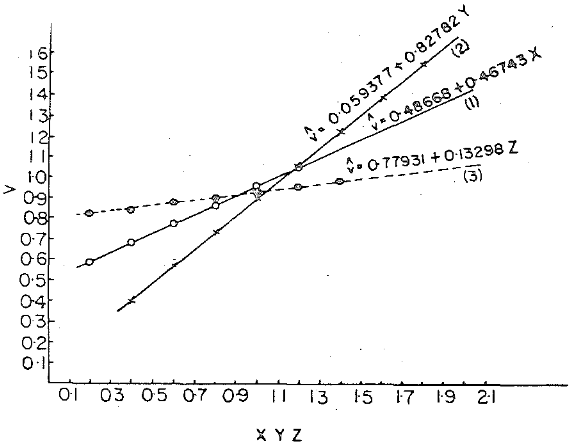

Fig. 1. The response lines of 'V' on 'x' when 'y' and 'Z' are fixed at their meanwhile (1), of 'V' on 'Y' when 'x' and 'Z' are fixed at their mean values (2), and 'V' on 'Z' when 'X' and 'Y' are fixed at their mean values (3)

where a=log A and b=B. By the method of least squares, a and b were estimated at a=-0.1874 and b=1.3033. The correlation coefficient between log H and log W worked out to 0.5635, which is highly significant. Thus the linear relationship between log W and log H and therefore the exponential relationship between W and H is justified. The relationship in terms of logarithms worked out to,

$$\log w = -0.1874 + 1.3036 \log H$$

and in terms of original measurements to,

$$W = 0.6495 \ H^{1.3036}$$

Discussion

Several workers on clams (Kristensen, 1957; Nayar, 1955; Alagarswami, 1966; Talikhedkar *et al.* 1976, Narasimham, 1968), mussels (Richards, 1928, 1946; Seed, 1973, Fox & Coe, 1943), pearl oysters (Alagaraja, 1962; Galtsoff, 1931), edible oysters (Orton, 1935; Andreu, 1968; Lee & Yoo, 1975; Hughes Games, 1977) have established length-weight relations However, as pointed out by Lison (Quoted by Galtsoff, 1964) oyster shell cannot be expressed in precise geometrical terms owing to its variability. The index of shape of oyster shells computed in this study also showed a variation of 1.05 to 5.23 indicating that increase in height and width are not directly proportional to the increase in length (Nair & Nair, 1985). Unlike in clams, oysters, vary a great deal in shape even among members of the same species, the substratum, overcrowding, salinity, velocity of water currents, wave action, depth and exposure all contributing to this phenomenon. The standard partial regression coefficients obtained from the regression analysis of weight on length, height and breadth shows that weight is more influenced by height ($B_2 = 0.4845$), followed by length ($B_1=0.2021$) and breadth ($B_3=0.06825$) in their order of magnitude. This is also evidenced by the slope of the line 2 in Fig. 1, obtained when the length and breadth were held constant in the multiple regression equation (2). The t-test for the significance of regression coefficients substantiated this and also showed that the contribution of length, height and breadth was significant on meat weight. The multiple regression coefficient (R^2) is 0.4693, which is also found to be highly significant by F-test. This indicated that the weight of the oyster meat is related not only to height but to length and breadth also. Krakatistsa & Patlaj (1975) found that in *Ostrea edulis* var. *taurica*, the total weight, shell weight and meat weight are related to height, length and thickness.

The regression equation worked out to study the relation of height (= Length, L in other studies) and weight of oysters in this study showed an exponential relation, $W = 0.6495\ H^{1.3036}$. However, Orton (1935) observed $W = 0.0404\ L^{3.531}$ and Andreu (1968) noticed $W=187.10^{-6}\ L^{2.7365}$ in English oyster *Ostrea edulis* at Britain and Spain respectively. But Hughes Games (1977) observed a relation $W = 2.75\ L^{2.34}$ in *Crassostrea gigas* at a sub-tropical pond in Israel and $W=4.34\ L^{2.08}$ in Great Britain. King (1977) observed the relation $W=0.005\ L^{2.152}$ in *Crassostrea gigas* grown in Australia. Compared to these studies the index B of the height-weight relation in *Crassostrea madrasensis* inhabiting the Cochin Backwaters was found to be less being 1.3036. The smaller index B value obtained in this study shows that changes in length do not introduce appreciably larger changes in meat weight contrary to what was observed in the studies cited above. The different B values obtained by several workers for the length-weight relationship show that these variations can be reasonably ascribed to changes in ecological conditions.

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