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POPULATION STRUCTURE AND ALLOMETRIC GROWTH OF *PERNA VIRIDIS* FROM KARACHI COAST

Meher Fatima[1], Sohail Barkati[2] and Solaha Rahman[3]

[1]*Institute of Marine Science, University of Karachi, Karachi-75270, Pakistan*
[2]*Department of Zoology, University of Karachi, Karachi-75270, Pakistan, e-mail: sohailbarkati@yahoo.com*
[3]*M.A.H. Qadri, Biological Research Centre, University of Karachi, Karachi-75270, Pakistan*

ABSTRACT

The population of the green mussel *Perna viridis* at Paradise Point remained stable most of the year with recruitment in July and November. Allometric studies demonstrated that relationship between length and width of shell changed with the season; in some months length increased isometrically with the width and in others the shell length increased faster than width. Increase in shell length was faster than shell weight in all seasons. Shell length increased faster than shell height. A clear seasonal trend in length to dry tissue weight was observed. Dry tissue weight increased isometrically with length in one half of the year but showed negative allometry in the other part.

Key words: Population, green mussel, allometric studies, Karachi coast, *Perna*.

INTRODUCTION

The green mussel (*Perna viridis* L.), a ubiquitous bivalve of tropical Indo-Pacific region is widely distributed on rocky intertidal beaches of Karachi and Balochistan. Lack of knowledge about size frequency distribution and growth restrict the biologists from drawing reliable conclusion about other important aspects of biology. Most studies on population structure and growth of mussels address *Mytilus edulis*; recently Buschbaum and Saier (2001) studied growth of *M. edulis* in Wadden Sea. Changes in length frequency distribution from Lindaspollene, Norway was investigated by Barkati (1989). Hosomi (1980) published a preliminary report on four populations of *M. edulis* from Japan. Population dynamics of *P. viridis* occurring in a polluted harbour of Hong Kong was studied by Lee (1986).

The most reliable and widely used method of studying changes of growth pattern in bivalve mollusks is based on allometry. Allometric relationships for various soft and hard parts of a number of bivalve species have been investigated. Studies related to the members of family Mytilidae are extensively reviewed by Seed (1968, 1973) and Seed and Suchanek (1992). Some of the notable contributions on the subject are those of Brown *et al.* (1976), Shafee (1978), Hickman (1979, 1992), Narasimham (1980), Hosomi (1985), Vakily *et al*. (1988) and Alunno-Bruscia *et al.* (2001).

Information on growth characteristics of mytilid species from Pakistan coast is very limited. In fact, only one paper (Barkati and Choudhry, 1988) contains some data about the allometric relationships of the mussel with special reference to the effect of tidal height. Studies of similar kind on other molluscan species are those of Barkati and Khan (1987) on three species of oysters, Barkati and Tirmizi (1986) on a mangrove gastropod (*Telescopium telescopium*) and of Fatima and Temuri (1991) on a gastropod (*Cellana radiata*) from rocky beach of Karachi coast. The present investigation was planned to obtain information about the growth pattern of *P. viridis* inhabiting the intertidal rocky ledge at Paradise Point of the Karachi coast. This sort of knowledge is of prime importance for the optimum exploitation of the edible mussel on commercial basis.

MATERIALS AND METHODS

Perna viridis were collected from the rocky ledge of Paradise Point at regular monthly intervals during low tides from January to December 1989. The mussels were usually collected with the help of chisel, hammer and iron rod with care; they were placed in polythene bags and brought back to the laboratory. The mussels so collected in about one and a half hour standard time were considered as randomly collected. In the laboratory, mussels were first cleaned, counted and their shell lengths (longest distance between anterior and posterior end of the shell), height (maximum dorso-ventral distance) and width (maximum distance between the lateral axis) were taken with a vernier caliper up to the nearest 0.01 mm.

The entire sample was divided into size classes of 10 mm each. The percentage composition of each size class was calculated and plotted as histogram for each monthly sample. The mussels were dissected open, their soft tissues were separated from the shells, placed on an absorbent paper for 30 seconds and then weighed to obtain the wet tissue weight. The empty shells and soft tissues were dried in a vacuum oven at 70^{o}C for at least 48 hours to get the dry weights of shell and tissues.

Allometric growth

Allometry may be defined as the relationship between growth rate of one part of an organism and that of another or between one part and the whole organism and is generally expressed by a power function of the following from:

$$Y = \mathbf{a}\, X^{\mathbf{b}}$$

Where X and Y are two variables whereas **a** and **b** are two constants denoting **y** intercept and regression coefficient (slope), respectively, of the best fit regression line. These constants were calculated by least square regression. When expressed in logarithmic form the above equation becomes: $\text{Log } y = \log \mathbf{a} + \mathbf{b} \log x$

Variability in growth rates of different shell and tissue parameters during the study period was studied as outlined in Brown *et al.* (1976). Coefficients of variation were calculated from the standard deviation expressed as percentages of the means. In order to get an insight of the growth rate of the mussels submerged in water, 50 mussels of about 1.0 cm shell length were collected from the natural bed of Paradise Point. The mussels were placed in fine net baskets made up of nylon and hung along the sides of suspended wooden raft in the sea near P.N.S. Himalaya at a distance of about 20-km from Paradise Point, on April 25th, 1989. These mussels remained submerged under water all the time irrespective of the low or high tides. After a period of one month net bags were taken out of water and the shell lengths were measured. Similarly, in October small mussels of 1.0 to 2.0 cm shell lengths were tide to the ropes with a cotton cloth and left there submerged under water for about one month.

The data related to various aspects of growth were tabulated and processed using various statistical packages. Shell dimensions with growth, allomertric equations were developed and employed to study the changes in different parts of the mussel. All measurements were first recorded against shell length and from these data average values for unit length were computed. Tests for significance to compare coefficients of slope and correlation were performed using covariance analysis.

RESULTS

Population Structure

During first quarter of the year, January to March, mussels of small shell length were in small number whereas these were totally absent during April-May period (Fig. **1**). In the months of June and July, mussels with shell length less than 2.0 cm were observed in considerably larger number (3.0 and 32 %, respectively). The population structure of June sample may be categorized as bimodal. Samples of August to October period were unimodal as the year classes of these samples overlapped and hard to be distinguished in age groups. The mussels collected in November displayed bimodal frequency distribution. Mussels contributing the first modal group consisted of less than 3.0 cm shell length and a second one comprising of 4.0 to 6.0 cm shell length group. The histogram of December sample showed two modal groups of 1.0 to 2.0 and 5.0 to 6.0 cm shell length as prominent group.

Since the rings present on the shells does not indicate many regular stoppage of growth, these rings cannot be used to age the shells. Moreover, separation of sample into year classes on the basis of size distribution was not proved possible in the present study.

Shell Length – Shell Width Relationship

A test for the slopes of the length – width regression analyses shows that these two variables are related isometrically (Fig. **2**) during seven months. In four months (March, June and October to December) a negative allometric relationship was recorded (Table 1) indicating a faster increase in shell length compared to shell width.

Shell Length – Shell Height Relationship

Although the allometric relationship between shell height and shell length was negative during the study period (Fig. **2**), the rate of increase in shell height varied considerably. Increase in shell height was at its lowest in April, and a drop in ‘b’ values was evident in October (Table 1). It may be observed that rate of increase in height remained high during monsoon period (May to September) and in November.

Shell Width – Shell Height Relationship

The shell width of the mussel increased faster than shell height throughout the year. The values of the slope are significantly lower than the theoretical slope (1.0) at $P>0.001$ (Table 1). A comparison of the ‘b’ values of different monthly samples shows that these values remained high between January and March before dropping down to the lowest value of the year in April (0.523). A second fall in the 'b' values was observed in September and October. The low 'b' values in December indicate a decrease in growth rate of shell width. In December shells were relatively wider in shape compared to the other months, whereas in March the mussels were comparatively very narrow.

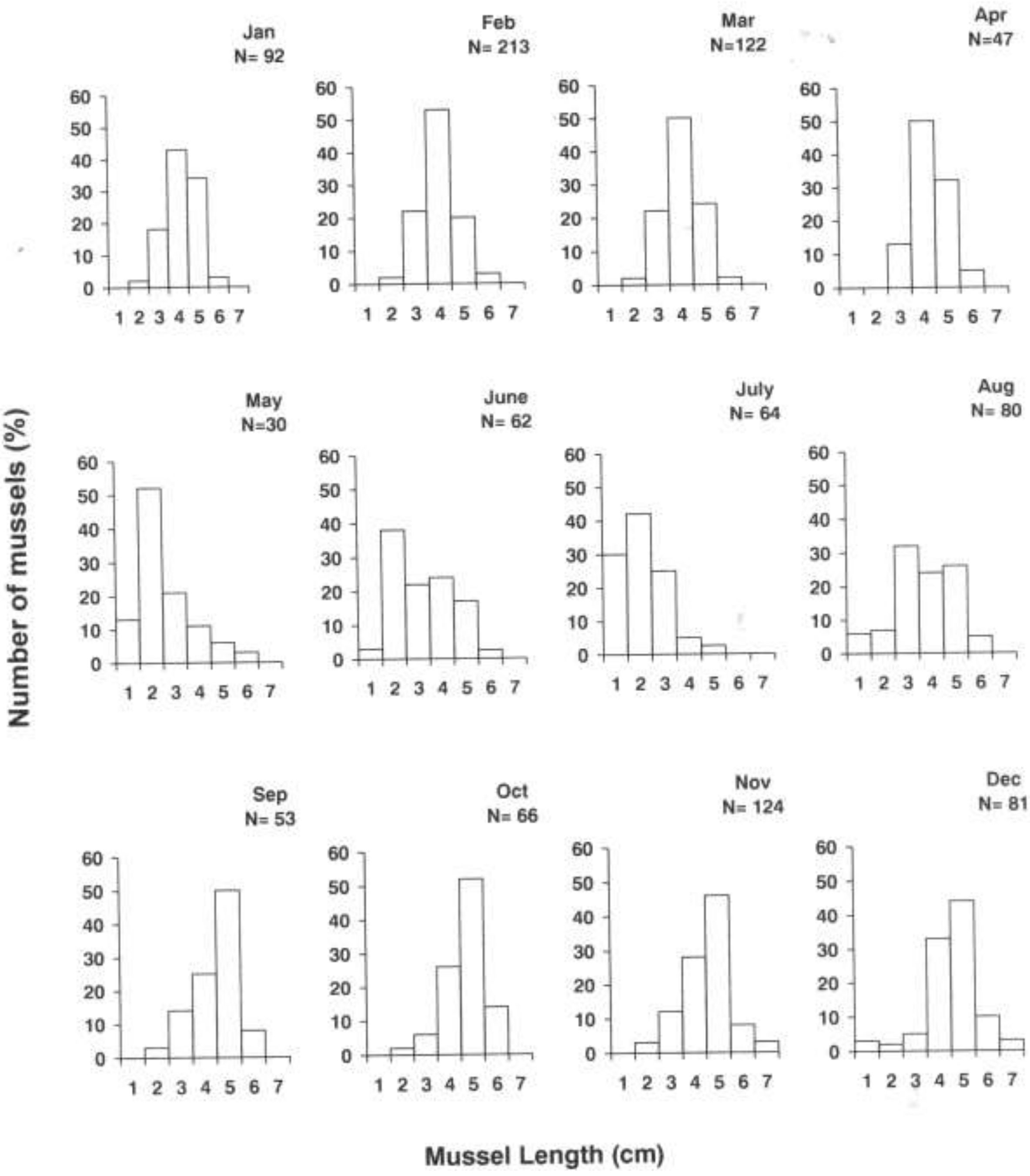


Fig. 1. Histograms showing shell length frequency distribution (%) of *Perna viridis* from January to December 1989.

Shell Length – Shell Weight Relationship

The relationship between shell length and shell weight is of characteristic exponential form (Fig. **3**). Shell length increased faster than shell weight in all monthly samples (Table 2). The values of slope 'b' are significantly lower than the theoretical slope of 3.0 at p>0.001 ('b' value of September and November samples are significantly different at p>0.005).

Shell Length – Dry Tissue Weight Relationship

There exists a significant deviation from the theoretical slope of 3.0 in five months (February, March, June, September and December; Table 2) in which shell length increased faster than dry tissue weight (negative allometry). In the remaining seven samples shell length and dry tissue weight showed identical rate of growth (isometry; Fig. **3**). Positive allometry was not observed in any sample of the year. Seasonal changes in 'b' values indicate that growth rate of dry tissue weight dropped down twice in a year, first in February and then in September.

Shell Weight – Dry Tissue Weight Relationship

Relationship between growth of shell weight and dry tissue weight was negatively allometric during February, August and September which means that growth of shell weight was faster than tissue weight (Table 1). The lowest 'b' values was recorded in September (0.675) indicating the slowest rate of growth in tissue compared to shell weight. Conversely, in January, April, July and December the dry tissue weight increased faster in tissue than shell weight showing a positive allometry (b>1). The dry tissue and shell weight had similar rates of growth during March, May, June, October and November. A t-test analysis showed that in these samples 'b' values were not significantly different from the theoretical slope.

Shell Height – Shell Weight Relationship

It may be seen from Table 2 that the shell height to shell weight relationship is isometric in six monthly samples. The values or regression slopes of these six samples are not significantly different from the theoretical slope of 3.0, indicating that growth rate of shell height and shell weight is similar. In the remaining six months of the year the relationship was anisometric. The 'b' values of five of these samples are significantly lower than the theoretical value of 3.0 indicating that shell height increased faster than shell weight as is evident from the 'b' values (3.327) which differed significantly at p>0.001 from the isometric value of 3.0. Although the 'b' values of August to October samples seem to indicate faster growth in shell weight, these 'b' values are statistically similar to the isometric relationship.

Shell Width – Shell Weight Relationship

The shell width of *P. viridis* increased faster than shell weight in all the samples indicating that the relationship between the two variables is negatively allometric at P>0.001 in eleven monthly samples except in November in which the 'b' value differed from the theoretical slope at P> 0.01 (Table 2).

Growth Characteristics of Standard Size (6.0 cm shell length) mussel

Shell Width: The rate of increase in shell width of a standard size mussel varied between 2.1 and 2.4 cm. However, with the exception of June (2.39) and December (2.46) when the growth rates were at the maximum, the shell width increased at the same rate.

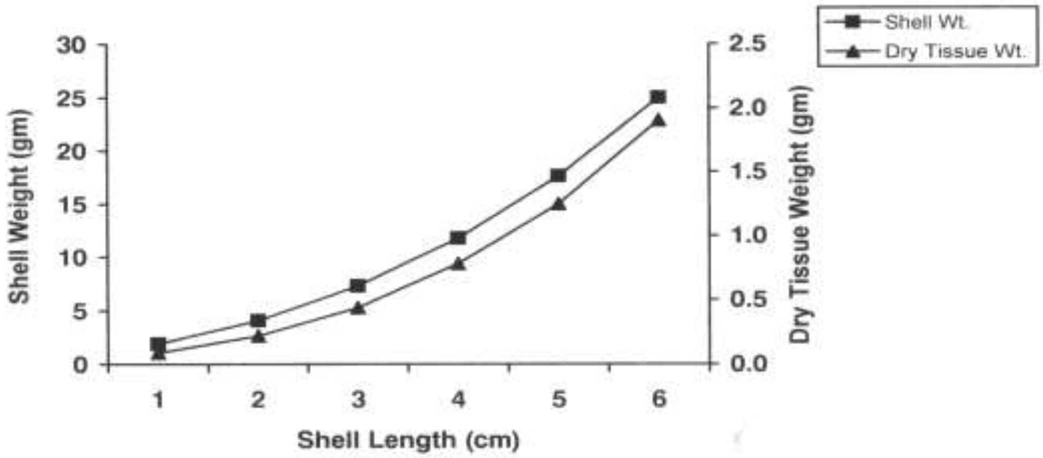
Shell Height: Very small seasonal difference in values of shell height was noted. In June the shell height of a standard size mussel was relatively grater than in other months. It varied from 2.18 to 2.46 cm during the study period.

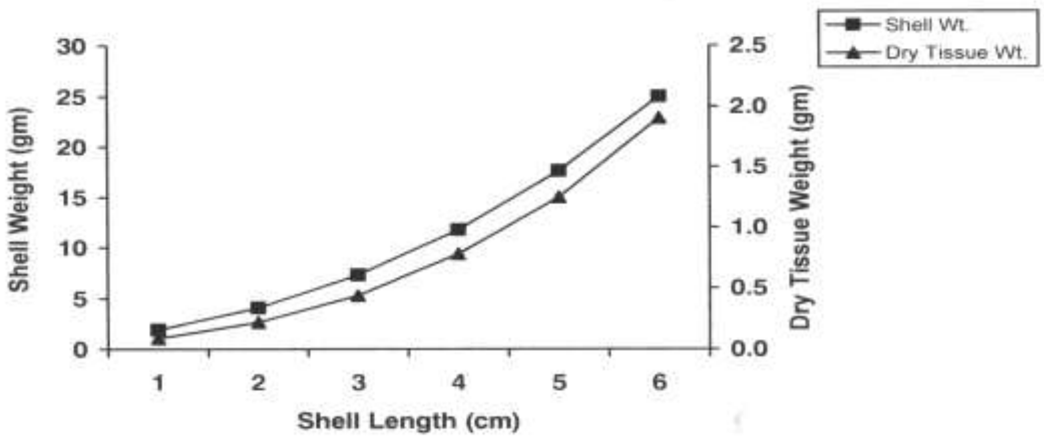
Shell Weight: Shell weight of a 6.0 cm shell length mussel showed pronounced changes during the year. The shell weight ranged between 10.62 (April) and 13.48 (August). The shell weight was comparatively high during July and September and low during January to April. The shell weight declined gradually from August to October before rising in November.

Dry Tissue Weight: Dry tissue ranged between 0.6 g and 1.32 g. The values were at minimum during February - March and rose gradually to the maximum in July. After a sharp drop in August a gradual increase in dry tissue weight was noticed.

Percent Growth

Percent increase in various linear and weight variables of the green mussel are shown in Tables 3 and 4. Percent increase in all linear and weight variables were maximal in the small size mussels. The percent increment was very high in weight variables (shell and dry tissue weight) compared to linear dimensions (shell height and width) for each size class. Moreover, the rate of relative growth was exceptionally high in mussels of less than. 1.0 cm shell length which decreased with increase in shell length. The samples of June 1989 is best example to see the difference in rate of relative growth between small and large size mussels. For 0.5 to 1.0 cm shell length, relative increase in shell weight and dry tissue weight was 443.6 and 463.0%, respectively. These values reduced to 21.44 (shell weight) and 22.08 percent (dry tissue weight) for 6.0-6.5 cm shell length group of mussels (Table 4).





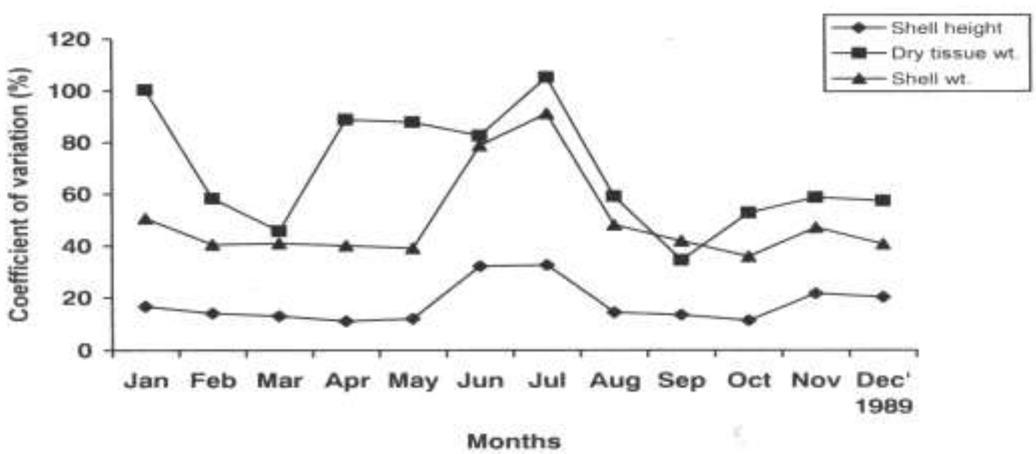


Fig. 2. Relationship between shell length and shell height, and shell length and shell width of *Perna viridis* for January 1989 sample; allometric curves fitted with the regression equations $Y = 0.276\ X^{0.800}$ and $Y = 0.376\ X^{0.983}$, respectively.
Fig. 3. Relationship between shell length and shell weight, and shell length and dry tissue weight of *Perna viridis* for January 1989 sample; allometric curves fitted with the regression equations $Y = 0.108\ X^{2.618}$ and $Y = 0.003\ X^{3.104}$, respectively.
Fig. 4. Seasonal changes in coefficient of variation (%) for shell height, shell weight and dry tissue weight of *Perna viridis*.

Coefficient of Variation

Variability in different shell and tissue variables of the green mussel, *Perna viridis*, was studied for twelve monthly samples. The parameters include shell length, width, height, shell weight and dry tissue weight (Table 5; Fig. **4**). Details of variability are described below separately for each variable.

Shell length: Shell length displayed considerable variability during the year (Fig. **4**). The highest variability in shell length was noticed in June-July (35.22 and 38.50 %, respectively). In most part of the year (in 8 out of 12 months) the variability was considerably low, ranging between 15.67 and 20.39 %. February, May and August were the months of low variability.

Table 1. Parameters of regression analyses for various relationships of mussels (*Perna viridis*) from Karachi.
Theortical value of 'b' for these relationships is 1.0. SL, Shell length; SH, Shell height; SW, Shell width; SWt, Shell weight; DTWt, Dry tissue weight.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.1989
Sample Size	92	213	122	47	29	62	84	80	53	66	124	81
Log a (y intercept)												
SL - SW	-0.98	-0.88	-0.75	-0.74	-0.87	-1.20	-0.97	-0.95	-1.06	-0.77	-0.96	-0.70
SL - SH	-0.32	-0.31	-0.15	-0.02	-0.16	-0.44	-0.24	-0.32	-0.23	-0.09	-0.39	-0.32
SW - SH	0.54	0.55	0.53	0.65	0.58	0.49	0.51	0.50	0.63	0.64	0.45	0.39
SWt. - DTWt.	-3.06	-2.26	-2.72	-3.39	-3.21	-2.58	-2.72	-2.57	-1.76	-2.72	-2.19	-2.56
b (Coeff. of allometry)												
SL - SW	0.98	0.93	0.85	0.84	0.93	1.16	0.98	0.97	1.03	0.86	0.98	0.90
SL - SH	0.80	0.80	0.69	0.62	0.70	0.88	0.75	0.80	0.74	0.66	0.84	0.79
SW - SH	0.68	0.66	0.70	0.52	0.60	0.70	0.67	0.70	0.57	0.57	0.82	0.79
SWt. - DTWt.	1.14	0.74	0.93	1.34	1.22	1.00	1.20	0.81	0.68	1.08	1.02	1.12
r^2 (Coeff. of determination)												
SL - SW	0.81	0.78	0.75	0.67	0.77	0.89	0.78	0.78	0.78	0.71	0.96	0.85
SL - SH	0.77	0.75	0.75	0.82	0.80	0.96	0.78	0.87	0.86	0.83	0.96	0.87
SW - SH	0.66	0.57	0.74	0.61	0.67	0.91	0.77	0.81	0.67	0.63	0.91	0.81
SWt. - DTWt.	0.75	0.55	0.70	0.68	0.79	0.92	0.96	0.68	0.71	0.50	0.97	0.91
t- test												
SL - SW	-0.35	-2.00	-3.41	-1.85	-0.77	3.02	-0.29	-0.45	0.33	-2.12	-0.94	-2.54
SL - SH	-4.35	-6.43	-8.50	-9.02	-4.70	-4.72	-5.85	-7.44	-6.12	-9.00	-9.88	-6.09
SW - SH	-6.15	-8.49	-7.82	-7.65	-4.92	-10.41	-8.38	-8.11	-7.77	-8.04	-8.23	-5.07
SWt. - DTWt.	2.01	-5.41	-1.31	2.44	1.82	0.03	-7.81	-7.68	5.42	0.61	0.94	3.13
Probability												
SL - SW	N.S	N.S	0.001	N.S	N.S	0.002	N.S	N.S	N.S	0.001	0.001	0.050
SL - SH	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
SW - SH	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
SWt. - DTWt.	0.050	0.001	N.S	0.010	N.S	N.S	0.001	0.001	0.001	N.S	N.S	0.005

Shell width: Changes in the variability of shell width followed the pattern of shell length. The shell width was least variable in February, May and October and most variable in June and July (Table 5). The period between January and May and from August to October may be recognized as period of low variability for shell widths.

Shell height: Variability in shell height (Fig. **4**) was almost same as observed for shell length and width. Maximum variability in shell height was recorded in June, July, November and December. The highest variability of the year was seen in July (32.67 %). Variability decreased gradually from January to reach the lowest in April (11.15 %).

Shell weight: A clear seasonal trend may be seen. The values of coefficient of variation started decreasing from January (50.67 %) to reach one of the most lowest values of the year in May (39.14 %). The highest variability was observed in June-July as was observed in the case of shell length, height and width. Mussels of August to December samples were least variable in shell weight.

Table 2. Parameters of regression analyses for various relationships of mussels (*Perna viridis*) from Karachi. Theortical value of 'b' for these relationships is 3.0. SL, Shell length; SH, Shell height; SW, Shell width; SWt, Shell weight; DTWt, Dry tissue weight.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.1989
Sample Size	92	213	122	47	29	62	84	80	53	66	124	81
Log a (y intercept)												
SL - SWt.	-2.22	-1.77	-1.30	-1.05	-1.62	-1.79	-2.01	-2.49	-2.43	-1.92	-2.63	-1.84
SL - DTWt.	-5.77	-3.97	-4.20	-4.83	-4.98	-4.43	-5.09	-5.18	-3.42	-5.37	-4.91	-4.76
SH - SWt.	-0.62	-0.474	-0.455	-0.716	-0.771	-0.532	-0.821	-1.16	-1.16	-1.17	-1.186	-0.497
SW - SWt.	0.55	0.65	0.65	0.89	0.68	0.78	0.56	0.39	0.69	0.65	0.22	0.20
b (Coeff. of allometry)												
SL - SWt.	2.62	2.34	2.05	1.91	2.29	2.44	2.52	2.84	2.76	2.44	2.89	2.37
SL - DTWt.	3.10	1.99	2.08	2.57	2.66	2.49	2.99	2.75	1.88	2.99	2.97	2.73
SH - SWt.	2.653	2.504	2.515	2.781	2.924	2.72	2.83	3.30	3.28	3.26	3.33	2.66
SW - SWt.	2.34	2.10	2.17	1.79	2.20	1.94	2.18	2.59	2.21	2.25	2.87	2.45
r^2 (Coeff. of determination)												
SL - SWt.	0.91	0.60	0.72	0.63	0.85	0.95	0.94	0.89	0.95	0.87	0.48	0.89
SL - DTWt.	0.74	0.45	0.60	0.44	0.62	0.91	0.88	0.87	0.68	0.56	0.97	0.86
SH - SWt.	0.79	0.58	0.69	0.63	0.84	0.95	0.84	0.72	0.86	0.82	0.96	0.81
SW - SWt.	0.86	0.54	0.77	0.59	0.88	0.90	0.86	0.90	0.82	0.76	0.97	0.97
t- test												
SL - SWt.	-0.49	-5.08	-8.12	-5.08	-3.90	-7.57	-9.54	-3.88	-2.80	-4.68	-2.74	-6.87
SL - DTWt.	0.54	-6.59	-5.96	-0.99	-0.83	-4.98	-0.03	-1.81	-6.32	-0.03	-0.69	-2.16
SH - SWt.	-2.38	-3.42	-3.19	-0.69	-0.31	-3.51	-1.25	-1.58	-1.50	-1.35	5.11	-2.36
SW - SWt.	-6.80	-6.74	-7.72	-5.43	-5.15	-12.50	-8.49	-6.90	-5.44	-4.79	-2.84	-5.96
Probability												
SL - SWt.	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.005	0.001	0.005	0.001
SL - DTWt.	N.S	0.001	0.001	N.S	N.S	0.001	N.S	N.S	0.001	N.S	N.S	0.020
SH - SWt.	0.020	0.001	0.001	N.S	N.S	0.001	N.S	N.S	N.S	N.S	0.001	0.050
SW - SWt.	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.010	0.001

Table 3. Seasonal variation in values of coefficient of variation (%) for the mussel *Perna viridis* from Paradise Point.

Months 1989	Shell length	Shell width	Shell height	Dry tissue wt.	Shell weight
January	18.58	20.39	16.74	100.38	50.67
February	15.66	17.00	14.14	58.33	40.58
March	16.10	16.33	13.08	45.80	41.05
April	16.50	17.72	11.15	88.84	40.20
May	15.55	17.70	12.01	87.81	39.14
June	35.22	41.84	32.27	82.65	78.76
July	38.50	45.47	32.67	105.17	91.18
August	16.44	18.00	14.53	59.16	48.16
September	16.80	19.10	13.51	34.58	41.92
October	15.33	15.67	11.38	52.82	35.96
November	24.22	24.88	21.65	58.73	47.12
December	23.50	22.17	20.28	57.41	40.77

Dry tissue weight: Variability was high in January (100.38 %), which decreased to 45.8 in March before rising gradually to the maximum in July (105.17 %). The variability reduced thereafter to attain the minimum of the year in September (34.58 %). Variability in dry tissue weight differed from all other variables in the month of second fall in variability, which was October in all other cases and September in case of dry tissue weight.

Dry tissue weight was the most variable parameter. Moreover, weight parameters (shell weight, dry tissue weight) were twice as variable as the linear variables (length, height and width of the shell).

DISCUSSION

Complete absence of small size mussels during first quarter of the year and dominance of medium size (4.0 to 5.0 cm shell length) mussels indicated little recruitment during this period. Although the length frequency distribution remained unimodal during most part of the year, the population may be consisting of more than one year classes which overlap in size due to different rates of growth assuming the characteristic form of mixed population. Growth of bivalve mollusks almost stops when they become old. The younger merges into older class, this bimodal type of distribution, as observed in June, becomes unimodal due to the faster growth of young mussels. Such cases for other bivalve species have been reported by Orton (1920), Hughes (1970) and Seed and Brown (1975). Similar conclusion was drawn by Hosomi (1980) for one of the four populations of mussel (*M. galloprovinicialis*) of fish farm in Japan. He related the appearance of juveniles in large number during July-August due to dense settlement converting the unimodal structure into bimodal form. Recruitment and fast growth was related to rich nutrient supply and less number of predators. A fall in number of small mussels was associated either to increase in predator or the fast growth of juveniles to reach the 4.0 to 5.0 cm shell length (Hosomi, 1980).

Seed (1969) faced another problem; he failed to recognize the individual year classes in *M. edulis* due to the presence of a large number of small mussels in the population at any one time. Moreover, extended spawning and settlement periods were also considered as important contributory factors for this type of population structure. Similarly, Wallace (1980) mentioned that differential growth of individuals of a year class, size distribution in the population may not correspond to the particular year class.

Working on population of a *M. edulis,* Barkati (1989) reported polymodal distribution as reported for many other bivalve populations (Seed, 1969). Although Barkati (1989) has reported the continued appearance of miniature mussels in the samples throughout the year, results of his reproductive study did not suggest the same recruitment pattern of juvenile mussels as was actually observed in the field. Seed (1976) and Barkati (1989) are of the opinion that recruitment of juveniles to the mussel population may also be investigated through a study of seasonal changes in the population structure of mussels.

Growth of an organism is usually studied either in terms of absolute value or by comparing the rate of increase of one part of organism with that of another or with whole organism, that is normally termed as allometry. Results of allometic relationships between various shell and tissue variable of the mussel *P. viridis* indicated pronounced seasonal pattern of variation.

Shell length either increased faster or at identical rate of shell width in the green mussel, *P. virids* from Karachi throughout the year, with the exception of just one month (June) in which shell width increased faster than length. It means that shell becomes wider with increase in mussel length. The most probable reason for fast growth in shell width in June and September is the availability of relatively more space allowing the mussels to increase in shell width. A relatively faster growth in shell width in late summer and autumn in two gastropod species (*Telescopium telescopium* and *Cellana radiata)* from the same coast was reported (Barkati and Tirmizi, 1986; Fatima and Temuri, 1991).

Shell length of *P. viridis* increased faster than shell height all the year round resulting in mussels of low heights in large size mussels. The results of Seed (1973), Brown *et al*. (1976), Hickman (1979) and Hosomi (1985) on *M. galloprovinicialis* are in agreement with the present results showing faster increase in length.

Dry tissue weight increased at a rate equal to or lesser than length. Increase in dry tissue weight normally slowed down during spawning and post spawning months. The seasonal variation in dry tissue weight indicates two peaks of spawning, one in February and the other in September. The increase in dry tissue weight slowed in February and September as shown by the values of ‘b’ (less than 2.0). Increase in dry tissue weight was isometric with shell length in January and November. High peaks of primary productivity in northern Arabian Sea were recorded in November (Kabanova, 1964; Banse, 1984). Minimum growth rate of tissue in February was also the result of, in addition to spawning, the presence of large number of competitors on the mussel bed making it difficult for the mussels to get enough food. The present observations are in close agreement with those of Hosomi (1987) who stated that growth slows down as population density increased. Lee (1986) on the other hand has related the no-growth period in *P. viridis* during January to April in Hong Kong to the drop in temperature i.e. below 18^{o}C.

Shell weight of *Perna viridis* increased slower than shell length throughout the year, resulting in lighter shells in older and large size shells. The shell weight of blue mussel, *M. edulis* increased exponentially with shell length. In *M. galloprovincialis* shell weight was isometrically related to shell length (Hosomi, 1985).

Isometric relationship between shell and dry tissue was noticed for five months of the year. In four (January, April, July and December) of the remaining seven months, increased faster than shell weight but a reverse trend was displayed during February, August and September. These were the months during which gametes were released reducing the dry tissue weight of mussels. Shell weight was also found to be isometrically related to dry tissue weight in *M. edulis* at Ireland (Brown *et al.*, 1976).

Growth of mussels was shown to vary considerably with the time of submergence (Mossop, 1922; Baird and Drinnan, 1957; Baird, 1966; Fox and Coe, 1943; Seed, 1968, 1973) who demonstrated that the shell weight increased as the time of emergence increased. Recently Barkati and Khan (1987) showed that species of oysters occurring higher in the intertidal area possessed heavier shells compared to those living low in the tidal zone. However, some publications appeared supporting the view contrary to that just mentioned (Wilbur and Jordey, 1952; Rao, 1953; Dame, 1972), they found heavier shells in sublittoral mussels compared to intertidal ones.

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