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VARIATION IN SHELL SHAPE OF *PERNA VIRIDIS* (LINNAEUS, 1758) COLLECTED FROM TWO ROCKY SITES OF MAKRAN COAST, PAKISTAN

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ABSTRACT

Seasonal growth pattern in two populations of Asian green mussel, *Perna viridis* (Linnaeus, 1758), was studied along the Makran coast, Balochistan. Field trips were made along coastal areas of Gwadar East Bay and Sur Bundar on seasonal basis for a period of one year during 2001. Negative allometry was noticed in shell length and shell width relationship and shell width – shell height relationship in all the samples of bivalve molluscs from the two study sites. However, isometric relationship in shell length and shell height was noticed in all samples except in one sample (October) of Gwadar East Bay site. From both study sites, results showed that the relative growth (percent increment) of the shell height and width decreased with increasing shell size. The percent increment was highest in mussels of smaller size.

Key words: Makran coast, growth, green mussels, *Perna viridis.*

INTRODUCTION

Bivalves' molluscs are an important component of marine food web. They are one of the most commercially important source of food for coastal people as well as for other animals, such as shorebirds, fishes, crustaceans (Van der Veer *et al*., 1998; Hiddink *et al*., 2002; Beukema and Dekker 2005; Fox, 2003).

Perna viridis (Linnaeus, 1758) commonly known as Asian green mussel are abundantly recorded from Indo-China and harvested in the region due to its rapid growth as a source of food for human. It is a native marine bivalve molluscs. They can tolerate and survive in wide range of temperatures i.e. 11-32 °C and salinity i.e. 18-33 ppt (NIPMIS, 2020). Mussel growth is exclusively fast in high salinity waters with high concentrations of phytoplankton. They are recorded from wide variety of habitat from shallow littoral zone to a depth of 15 m showing wide tolerance for turbidity concentrations and pollution. These are of large size, with shells naturally growing up to 80-100 mm in length and rarely exceeding greater than 160 mm (Rajagopal *et al*., 2005). Their life span is around three years (Power *et al*., 2004).

Asian green mussel is ubiquitous and commercially important marine molluscs. It has been reported in the coastal waters of Indo-Pacific region due to shipping and aquaculture activities (Yoshiyasu *et al*., 2004; McDonald, 2012). These have been cultured in various Pacific regions (Eldredge, 1994; Vereivalu, 1990), the Caribbean (Agard *et al*., 1993; Hicks *et al*., 2001) and Atlantic coasts of America (Power *et al*., 2004; Benson *et al*., 2001; Rylander *et al*., 1996).

The most consistent and commonly used method of studying changes of growth pattern in bivalve molluscs is based on allometry. Allometric relationships for various soft and hard parts of a number of bivalve species have been investigated for managing resources and estimating environmental impact on it (Palmer 1990; Boulding and Hay 1993). Some of the notable contributions on the subject are those of Hickman (1979), Ravera and Sprocati (1997), Rueda and Urban (1998) and Deval (2001). Allometric studies are adequate method of estimating total flesh weight and biomass of an organism (Hibbert 1977; Rodhouse *et al*., 1984; Ross and Lima, 1994).

Information regarding growth characteristics of bivalve molluscs is available from Sindh coast, Pakistan. Changes in growth of different bivalve species of Karachi coast was documented by Asif (1979). Ahmed (1988) studied population density and size weight relationship of Razor clam *Solen truncatus*, from the sandflats of Bundal Island, Korangi Creek, Karachi. Barkati and Khan (1987) documented growth variation in oysters' species of Sind. Allometric variation in shell shape of four species of Pakistani oysters was studied by Siddiqui and Ahmed (2001). Barkati *et al*., (2006) observed population structure and allometric growth of a mangrove clam, *Marcia cor* (Sowerby). Two publications on the population structure and growth of *Perna viridis* are also available along various shores of Karachi. Variation in growth patterns of green mussel from different tidal heights was studied by Barkati and Choudhry (1988). Fatima *et al*., (2006) studied population structure and allometric growth of *Perna viridis* from Karachi coast.

Pakistan bordering Northern Arabian Sea has a long coast line of 990 km, out of which Baluchistan has 670 km extending from Hub River in the east to Jiwani in the west. Northern Arabian Sea particularly coastal waters of Baluchistan along Makran are highly productive due to unique phenomenon of reversal of monsoons. In spite of being productive coastal area the biodiversity of marine organisms along Makran has not been studied in detail except sea weeds (Shameel and Tanaka, 1992; Shameel *et al*., 1996; Shameel *et al*., 2000) and plankton (Saifullah, 1979; Baig *et al*., 2006).

The development of deep sea port at Gwadar along Makran will have great bearing on the marine and coastal environment of the region including biodiversity of the area. Gwadar tombolo divides the coastal waters into two bays East Bay and West Bay. According to UNESCAP (1996) average sea water temperature at Gwadar ranges from 19.5 ºC to 28.3 ºC and from 23.5 ºC to 29.3 ºC off Makran coast and the average salinity off Makran coast ranges from 36.05 $^{0}/_{00}$ to 36.74 $^{0}/_{00}$. However the average salinity during 2006 in East Bay Gwadar has been observed as high as 40 $^{0}/_{00}$ (Anon., 2007). The tidal range at Gwadar port is 1.8 m (Pakistan tide Table, 2005). During Southwest monsoon the strong and persistent winds generate waves of about 1.0 m (Anon., 2007). Due to arid climate Makran coast is dominated by sandy beaches. Along Gwadar and Pasni, the sandy beaches are almost flat and are subjected to erosion due to high energy waves during south west monsoon.

Although molluscs form the major component of invertebrate population on the rocky shores of Makran (Ahmed *et al*., 1982; Siddiqui and Ahmed, 2002; Afsar *et al.*, 2012; Jahangir *et al*., 2012), no studies had been undertaken dealing with their spawning and growth patterns. However, couple of publications are available on sex ratio, reproductive pattern and parasites of bivalve molluscs (Afsar *et al.*, 2014; Jahangir *et al.*, 2014).

The present investigation was planned to obtain information about the growth pattern of *Perna viridis* inhabiting various sites of Gwadar East Bay, Sur Bundar and Pasni along Makran coast bordering Northern Arabian Sea. This sort of knowledge is of prime importance for the optimum exploitation of the edible mussel on commercial basis from Baluchistan.

MATERIAL AND METHODS

Field trips were made to different locations along coastal areas of Makran (Balochistan) which are various sites of Gwadar East Bay (25° 9′ 8.99″ N; 62° 19′ 54.82″ E), Near Jetty (25° 07′ 46″ N; 62° 19′ 40.0″ E), Near Coast Guard (25° 13′ 39.41″ N; 62° 19′ 54.82″ E), Sur Bandar (25° 13′ 39.41″ N; 62° 28′ 2.98″ E) and Pasni (25° 13′ 35.0″ N; 63° 30′ 18.17″ E) at low tides on seasonal basis for a period of one year during 2001 (Fig.**1**). The mussels were randomly collected with the help of chisel, hammer and iron rod with care; they were placed in polythene bags and brought back to the laboratory. 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 the help of vernier caliper.

Zar (1974) was followed for the statistical treatment of data. The allometric growth is expressed by an equation

$$y = a.x^b$$

where x is used as independent and y as dependent variable, respectively, whereas a and b are constants. The constant b, which is equilibrium constant or a coefficient of allometry, indicates the ratio of the growth rates of two variables used.

The regression line or the least-square line can be calculated by the equation

$$\log y = \log a + b \log x$$

where y = independent value
x = dependent value
a = y intercept
b = slope of the line

Coefficient of variation was calculated from the standard deviations expressed as percentages of the means.

OBSERVATIONS

A. Opposite Coast Guard, Gwadar East Bay

Shell Length – Shell Width Relationship

A negative allometric relationship was recorded throughout the study period (Table 1; Fig. **2**) indicating a faster increase in shell length compared to shell width. Increase in shell length was at its highest in January and gradually decreased to lowest in October 2001. The values of the slope are significantly lower than the theoretical slope (1.0) at P > 0.005 in January 2001 and at P > 0.001 in rest of the samples (Table 1).

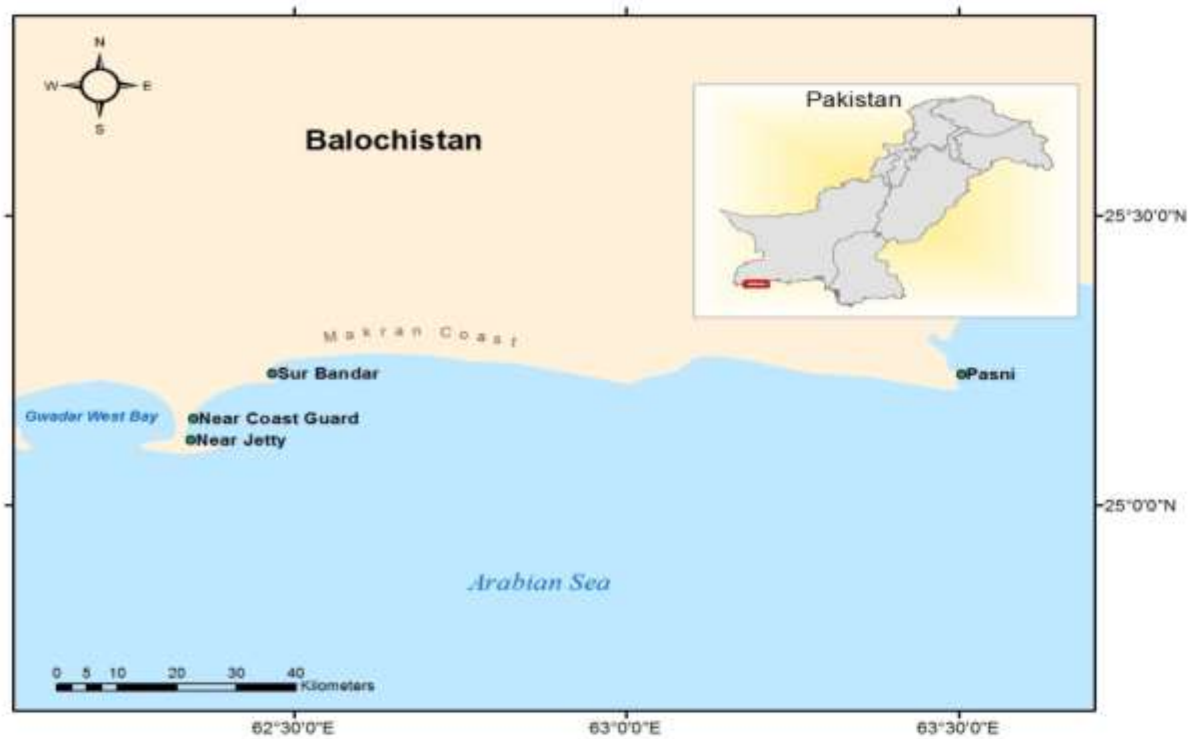

Fig. 1. Map of Gwader East Bay showing sampling sites; Sur Bandar and Opposite Coast Guard rocky shores.

Shell Length – Shell Height Relationship

The allometric relationship between shell length and shell height was almost isometric in January, April and July 2001 (Fig. **3**), the rate of increase in shell length and shell height was identical. However, negative allometry was observed in October 2001 (Table 1). A comparison of the b values of different monthly samples shows that these values remained high between January to July before dropping down to the lowest value of the year in October (0.68).

Shell Width – Shell Height Relationship

The shell width of the mussel increased faster than shell height throughout the year (Fig. 4). The values of the slope are significantly lower than the theoretical slope (1.0) at $P > 0.001$ in April and July (Table 1). The low b values in July and October indicate a decrease in growth rate of shell width (Fig. 5).

Percent Growth

Percent increases in various linear variables of the green mussel, *Perna viridis* are shown in Tables 3. Percent increase in all linear variables were maximal in the small size mussels. Moreover, the rate of relative growth was exceptionally high in mussels of less than 2.0 cm shell length which decreased with increase in shell length. The samples of October 2001 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 height and shell width was 59.6 and 52.3 %, respectively. These values reduced to 3.3 (shell height) and 3.0 percent (shell width) for 10.0-10.50 cm shell length group of mussels (Table 3).

Coefficient of Variation

Variability in different shell variables of the green mussel, *Perna viridis*, was studied for four quarterly samples. The parameters include shell length, width and height (Table 5; Fig. **6**). Details of variability are described below separately for each variable.

Shell length: Shell length displayed considerable variability during the year (Fig. **6**). Lowest variability in shell length was observed in January (21.57) and highest variability was noticed in April (28.93).

Shell width: Changes in the variability of shell width followed the pattern of shell length. The shell width was least variable in January, July and October and most variable in April (Table 5).

Shell height: Variability in shell height (Fig. **6**) was minimum in January and highest in October 2001 (116.17 %). Variability increased gradually from January to reach the highest in October 2001).

Table 1. Parameters of regression analyses for various relationships of mussels (*Perna viridis*) from Opposite Coast Guard, Gwader East Bay, Makran. Theortical value of 'b' for these relationships is 1. SL, Shell length; SH, Shell height; SW, Shell width.

		Jan.	Apr.	July	Oct. 2001
1	**Sample Size**	50	102	115	75
2	**Log a (y intercept)**				
	SL - SW	0.53	0.68	0.69	1.01
	SL - SH	0.71	0.39	0.34	0.70
	SW - SH	0.36	0.62	0.58	0.72
3	**b (Coeff. of allometry)**				
	SL - SW	0.89	0.80	0.79	0.61
	SL - SH	0.98	0.95	1.00	0.68
	SW - SH	0.90	1.18	1.19	1.07
4	**r^2 (Coeff. of determination)**				
	SL - SW	0.93	0.94	0.94	0.64
	SL - SH	0.90	0.90	0.88	0.58
	SW - SH	0.90	0.94	0.83	0.85
5	**t- test**				
	SL - SW	-3.117	-10.076	-11.188	-7.314
	SL - SH	-2.345	-1.486	-0.084	-4.901
	SW - SH	-0.532	5.929	3.631	1.318
6	**Probability**				
	SL - SW	0.005	0.001	0.001	0.001
	SL - SH	0.050	N.S	N.S	0.001
	SW - SH	N.S	0.001	0.001	N.S

B. Sur Bundar.

Shell Length – Shell Width Relationship

A negative allometric relationship was recorded throughout the study period (Table 2) indicating a faster increase in shell length compared to shell width. Increase in shell length was at its highest in January and gradually decreases to lowest in July 2001 (Table 1). The values of the slope are significantly lower than the theoretical slope (1.0) at P > 0.001 in all the samples (Table 2).

Shell Length – Shell Height Relationship

A negative allometric relationship between shell length and shell height was observed throughout the year (Fig. **2**). A comparison of the b values of different monthly samples shows that these values remained high in January and October and low during April and July 2001.

Table 2. Parameters of regression analyses for various relationships of mussels (*Perna viridis*) from Sur Bandar, Gwader East Bay, Makran. Theortical value of 'b' for these relationships is 1.0. SL, Shell length; SH, Shell height; SW, Shell width.

		Jan.	Apr.	July	Oct. 2001
1	**Sample Size**	386	105	212	113
2	**Log a (y intercept)**				
	SL - SW	0.67	0.73	0.83	0.77
	SL - SH	0.39	0.62	0.61	0.52
	SW - SH	0.63	1.17	0.94	0.92
3	**b (Coeff. of allometry)**				
	SL - SW	0.78	0.75	0.71	0.77
	SL - SH	0.84	0.70	0.73	0.84
	SW - SH	1.03	0.63	0.84	0.89
4	**r^2 (Coeff. of determination)**				
	SL - SW	0.85	0.52	0.69	0.81
	SL - SH	0.79	0.55	0.57	0.76
	SW - SH	0.85	0.48	0.55	0.62
5	**t- test**				
	SL - SW	-13.120	-3.471	-8.890	-6.593
	SL - SH	-7.158	-4.775	-6.211	-3.708
	SW - SH	1.525	-5.803	-3.128	-1.736
6	**Probability**				
	SL - SW	0.001	0.001	0.001	0.001
	SL - SH	0.001	0.001	0.001	0.001
	SW - SH	N.S	0.001	0.005	N.S

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 not significantly different in January and October 2001. However, lower than the theoretical slope (1.0) at P > 0.001 & 0.005 in April and July, respectively (Table 2). The low b values in April and July indicate a decrease in growth rate of shell width (Fig. 7).

Percent Growth

The results show that the relative growth (per cent increment) of the shell height and width decreased with increasing shell size (Table 4). The percent increment was highest in mussels of smaller size. The sample of January 2001 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 height and shell width was 79.5 and 71.4 %, respectively. These values reduced to 3.5 (shell height) and 3.2 percent (shell width) for 12.0-12.50 cm shell length group of mussels (Table 4).

Coefficient of Variation

Variability in different shell variables of the green mussel, *Perna viridis*, has been studied for four quarterly samples. The parameters include shell length, width and height (Table 6; Fig. **8**). Details of variability are described below separately for each variable.

Shell length: Shell length displayed considerable variability during the year (Fig. **8**). Highest variability in shell length was observed in January (53.8) and lowest variability was noticed in April (11.13).

Shell width: Changes in the variability of shell width followed the pattern of shell length except in October, when it becomes extremely high (505.24). The shell width was least variable in April and July and most variable in October (Table 6).

Shell height: Variability in shell height (Fig. **8**) was maximum in January and minimum in April 2001 (10.7 %).

Table 3. Relative growth (Per cent) in shell height and width of the green mussel, *Perna viridis* from Opposite Coast Guard, Gwader East Bay, Makran. SH, Shell height; SW, Shell width.

Size class	Jan.		Apr.		July		Oct. 2001	
(cm)	SH	SW	SH	SW	SH	SW	SH	SW
0.51 - 1.00	-	-	-	-	-	-	59.694	52.324
1.01 - 1.50	-	-	-	-	-	-	31.474	27.901
1.51 - 2.00	-	-	31.543	25.965	-	-	21.438	19.087
2.01 -2.50	-	-	23.676	19.608	24.974	19.279	16.247	14.506
2.51 - 3.00	-	-	18.970	15.751	19.936	15.498	13.098	11.708
3.01 - 3.50	14.869	14.713	15.820	13.169	16.622	12.958	10.968	9.810
3.51 - 4.00	12.773	12.622	13.566	11.308	14.236	11.128	9.436	
4.01 - 4.50	11.178	11.059	11.870	9.907	12.462	9.753	8.274	7.414
4.51 - 5.00	9.940	9.833	10.561	8.825	11.081	8.684	7.367	6.608
5.01 - 5.50	8.956	8.858	9.503	7.947	9.970	7.821	6.645	5.956
5.51 - 6.00	8.141	8.055	8.643	7.227	9.066	7.118	6.050	5.424
6.01 - 6.50	7.467	7.385	7.923	6.635	8.307	6.530	5.551	4.981
6.51 - 7.00	6.896	6.820	7.315	6.127	7.670	6.031	5.130	4.602
7.01 - 7.50	6.403	6.334	6.796	5.690	7.119	5.604	4.768	4.278
7.51 - 8.00	5.981	5.916	6.337	5.313	6.646	5.230	4.452	3.994
8.01 - 8.50	5.604	5.544	5.946	4.984	6.232	4.909	4.178	3.748
8.51 - 9.00	5.278	5.222	5.599	4.695	5.866	4.621	3.936	3.532
9.01 - 9.50	4.987	4.931	5.283	4.434	5.538	4.363	3.716	3.336
9.51 - 10.00	4.720	4.674	5.009	4.199	5.247	4.137	3.523	3.165
10.01 - 10.50	4.490	4.438	4.758	3.993	4.986	3.930	3.349	3.007

Table 4. Relative growth (Per cent) in shell height and width of the green mussel, *Perna viridis* from Sur Bandar, Gwader East Bay, Makran. SH, Shell height; SW, Shell width.

Size class	Jan.		Apr.		July		Oct. 2001	
(cm)	SH	SW	SH	SW	SH	SW	SH	SW
0.51 - 1.00	79.506	71.462	-	-	-	-	-	-
1.01 - 1.50	40.749	37.062	-	-	-	-	-	-
1.51 - 2.00	27.467	25.066	-	-	-	-	-	-
2.01 -2.50	20.710	18.954	-	-	-	-	-	-
2.51 - 3.00	16.627	15.226	-	-	-	-	-	-
3.01 - 3.50	13.884	12.734	-	-	-	-	-	-
3.51 - 4.00	11.916	10.944	-	-	10.228	9.932	11.824	10.786
4.01 - 4.50	10.450	9.593	-	-	8.970	8.715	10.352	9.457
4.51 - 5.00	9.289	8.539	-	-	7.987	7.755	9.218	8.418
5.01 - 5.50	8.375	7.691	6.926	7.429	7.194	6.993	8.301	7.583
5.51 - 6.00	7.613	7.002	6.302	6.763	6.552	6.363	7.550	6.904
6.01 - 6.50	6.984	6.420	5.782	6.206	6.012	5.840	6.926	6.330
6.51 - 7.00	6.449	5.931	5.345	5.733	5.550	5.397	6.394	5.851
7.01 - 7.50	5.994	5.513	4.967	5.324	5.160	5.014	5.942	5.434
7.51 - 8.00	5.595	5.147	4.638	4.976	4.820	4.682	5.548	5.077
8.01 - 8.50	5.246	4.826	4.350	4.663	4.520	4.393	5.203	4.760
8.51 - 9.00	4.938	4.547	4.101	4.395	4.256	4.137	4.898	4.481
9.01 - 9.50	4.666	4.295	3.870	4.149	4.020	3.909	4.627	4.236
9.51 - 10.00	4.420	4.068	-	-	3.811	3.703	4.387	4.013
10.01 - 10.50	4.203	3.867	-	-	3.622	3.519	4.164	3.816
10.51 - 11.00	4.002	3.684	-	-	-	-	3.971	3.632
11.01 - 11.50	3.818	3.516	-	-	-	-	3.788	3.468
11.51 - 12.00	3.655	3.365	-	-	-	-	3.625	3.320
12.01 - 12.50	3.504	3.227	-	-	-	-	3.474	3.180

Comparison between the Opposite Coast Guard, Gwadar East Bay & Sur Bundar:

Shell length and shell width relationship showed negative allometry in all the samples of bivalve molluscs from the two study sites i.e. Opposite Coast Guard, Gwader East Bay and Sur Bundar. Isometric or positive allometry was not observed from any site throughout the observation period.

Three samples (January, April and July 2001) showed isometric relationship in shell length and shell height and only one sample (October 2001) showed negative allometry from opposite Coast Guard, Gwadar East Bay. However, all samples showed negative allometry from Sur Bandar.

Negative allometry was noticed in shell width – shell height relationship in all the samples of bivalve molluscs from the two study sites. Isometric or positive allometry was not observed from any site throughout the observation period.

From both study sites, results showed that the relative growth (per cent increment) of the shell height and width decreased with increasing shell size. The percent increment was highest in mussels of smaller size.

Table 5. Seasonal variation in values of coefficient of variation (%) for the mussel *Perna viridis* from opposite Coast Guard, Gwader East Bay, Makran.

Months 2001	Shell length	Shell width	Shell height
January	21.577	20.663	19.972
April	28.931	24.233	27.743
July	26.421	21.945	28.123
October	24.832	20.631	116.175

Table 6. Seasonal variation in values of coefficient of variation (%) for the mussel *Perna viridis* from Sur Bander, Gwader East Bay, Makran.

Months 2001	Shell length	Shell width	Shell height
January	53.891	46.077	51.562
April	11.134	11.073	10.761
July	15.567	14.003	15.735
October	20.449	505.245	19.446

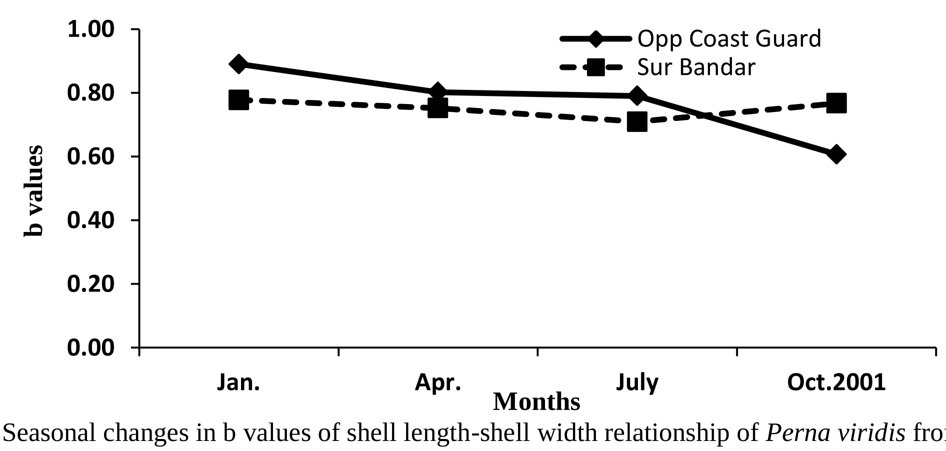

Fig. 2. Seasonal changes in b values of shell length-shell width relationship of *Perna viridis* from the two study sites: Sur Bandar and Opposite Coast Guard.

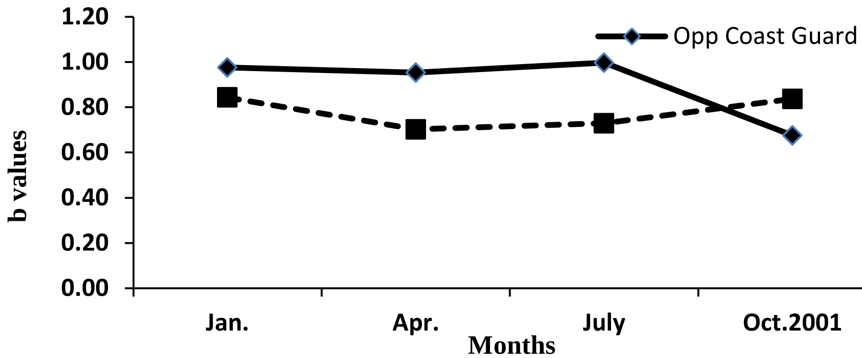

Fig. 3. Seasonal changes in b values of shell length-shell height relationship of *Perna viridis* from the two study sites: Sur Bandar and Opposite Coast Guard.

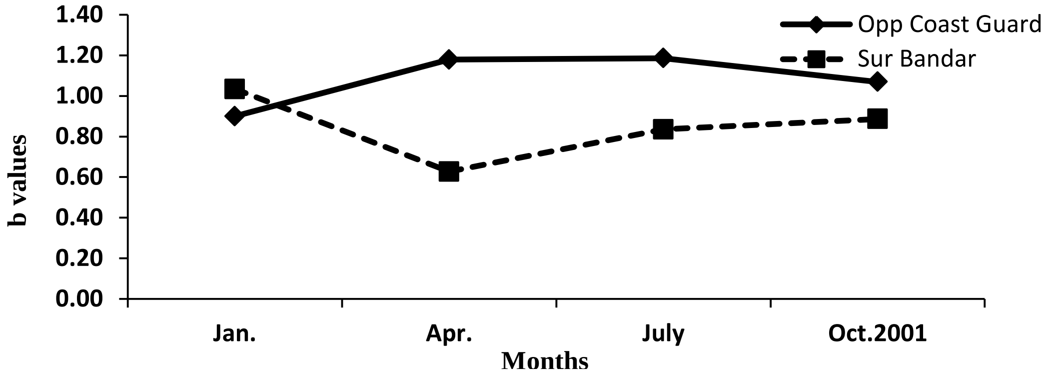

Fig. 4. Seasonal changes in b values of shell width- shell height relationship of *Perna viridis* from the two study sites: Sur Bandar and Opposite Coast Guard.

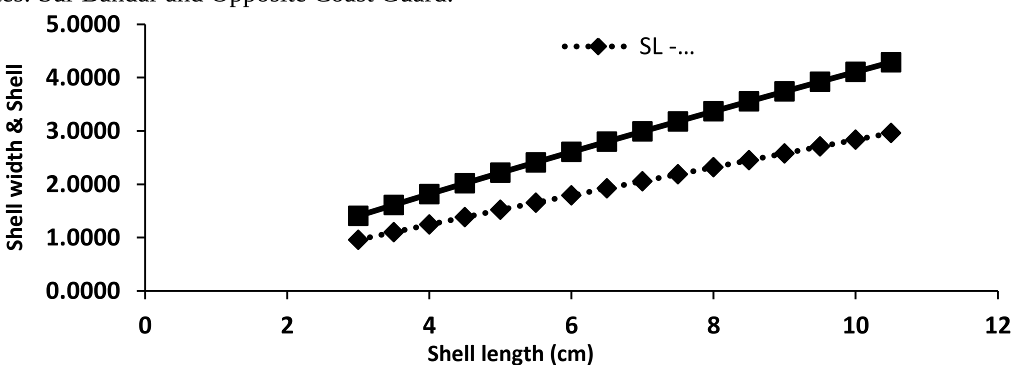

Fig. 5. Relationship between various linear parameters as function of shell length of *Perna viridis* for January 2001 sample from Opposite Coast Guard. SW, Shell Width; SH, Shell Height; SL, Shell Length.

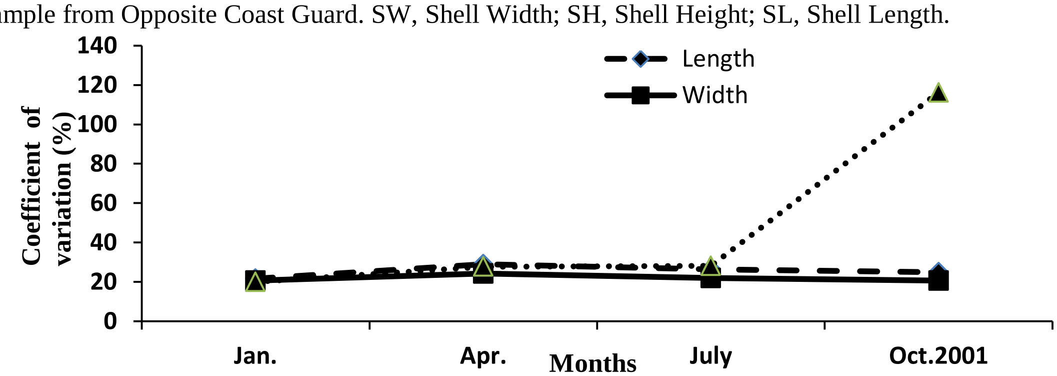

Fig. 6. Seasonal changes in coefficient of variation (%) for shell length, shell width and shell height of *Perna viridis* from Opposite Coast Guard, Gwadar.

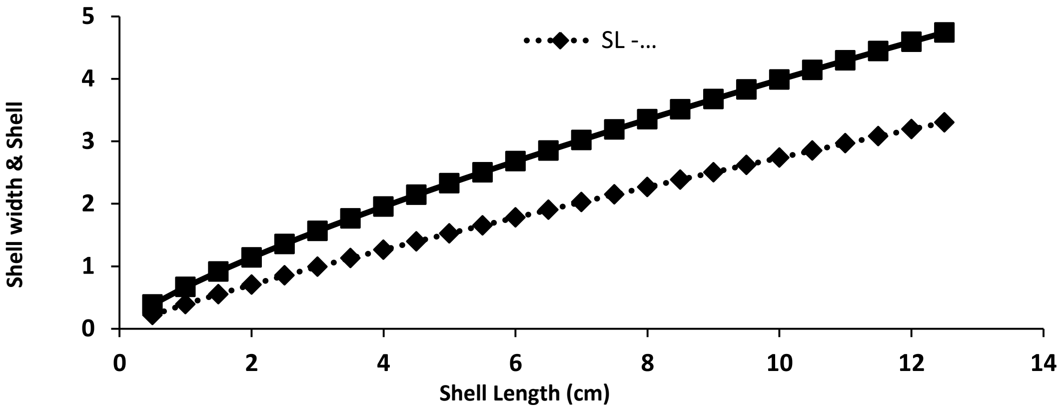

Fig. 7. Relationship between various linear parameters as function of shell length of *Perna viridis* for January 2001 sample from Sur Bandar. SW, Shell Width; SH, Shell Height; SL, Shell Length.

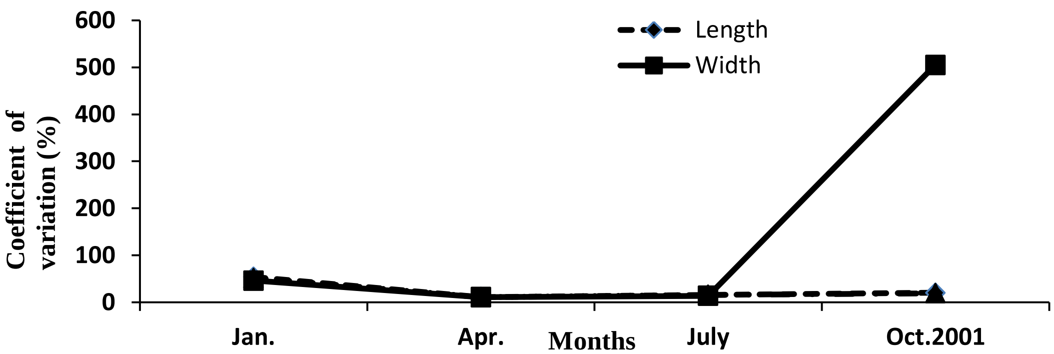

Fig. 8. Seasonal changes in coefficient of variation (%) for shell length, shell width and shell height of *Perna viridis* from Sur Bandar, Gwadar.

Coefficient of Variation

Shell length: Shell length displayed considerable variability during the year from both study sites. Moreover, highest variability in shell length was observed in January and lowest variability was noticed in April from both sites.

Shell width: Changes in the variability of shell width followed the pattern of shell length from both study sites. The shell width was least variable in January, July and October and most variable in April from Opposite Coast Guard, Gwader East Bay. However, the shell width was least variable in April and July and most variable in October from Sur Bundar, Gwadar East Bay.

Shell height: Variability in shell height (Fig. **6**) was minimum in January and highest in October 2001 from Opposite Coast Guard. However, variability in shell height was maximum in January and minimum in April 2001 from Sur Bundar.

The inference of the present investigation showed that the relative growth of the shell width decreased with increasing shell size. Length, width and height displayed linear relationships. The larger clams tend to be wider in shape because of relatively faster growth in width compared to length and height. Percent growth in linear variables decreased as length increased.

DISCUSSION

The information about the age and growth of individual organisms within the population is necessary for estimating population dynamics of bivalve molluscs. 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.

Publications with emphasis on allometric relationship of bivalves have been carried out. Some authors have studied the length and weight relationship of different species. For instance, Franz (1993) determined absolute and allometric growth rates of *Geukensia demissa* from two shore-level at a site within the Jamaica Bay National Wildlife Refuge (NY). Shell length, height, width and volume were calculated for studying growth of bivalve in northern Australia by Gimin *et al*. (2004). *Mytilus galloprovincialis* growth was investigated after the Prestige oil spill off northwestern Spain by Peteiro *et al*. (2006). Babaei *et al*. (2010) analyzed the allometric relationship of clam from the eastern coasts of Persian Gulf. Vitaliano and Bejda (2011) studied variation in growth of ribbed-mussels from salt marshes of New York.

However, some authors analyse shell length, height and width relationship of different bivalve species. Selin (2000) analyzed fluctuation in allometric growth and shape of bivalve shell from numerous parts along the Sea of Japan. Alunno-Bruscia *et al*. (2001) examined the effect of diet and population density on the shape and size and biomass relationship of blue mussel.

Several environmental factors commonly affect the morphology of the bivalve molluscs, population density seems to have one of the most significant effect on blue mussel (Seed, 1968; 1973; Brown *et al*., 1976). Mussels' shells found in the thick population area usually become elongated (Richardson and Seed 1990; Alunno-Bruscia *et al*., 2001) and Bertness and Grosholz (1985) also noted extreme deformation in few individuals. Same inference was also observed in other marine species of the world, such as, in oysters (Tanita and Kikuchi, 1957; Chinzei *et al*., 1982), clams (Ohba, 1956; Cigarria and Fernandez, 1998) and tunicates (Paine and Suchanek, 1983). Mussels shape probably depends upon the availability of food, physical factors or their interaction in the high population area (Seed, 1968).

Mussels' growth, longevity and reproduction are also affected by variation in environmental variables like temperature, salinity, food and currents. However, other environmental factors also affect the physiological functions in bivalves at a local scale as well. Growth and reproduction also depends upon the submergence, sediments and quality and quantity of food, and seems to have major role in a particular area (Beukema *et al*., 2002; Carmichael *et al*., 2004). Franz (1993), De Montaudouin and Bachelet (1996) and Honkoop and Beukema (1997) recorded high growth, condition index and reproductive activity due to the longer submersion time and thus more chance of food intake at lower intertidal areas. Furthermore, relationship between other molluscan species and other benthic fauna within a community also effect the growth of bivalve molluscs (Hummel, 1985; Kamermans *et al*., 1992; Kamermans, 1993). Denisenko (2014) correlates the growth of bivalve molluscs with North Atlantic and Arctic oscillations, water temperature variations and level of precipitation.

Present study showed that allometric studies of length and width of the green mussel *Perna viridis* at Opposite Coast Guard, Gwadar East Bay and Sur Bundar, Makran coast varied according to the season; shell length increased faster than width in some seasons, whereas, shell length increased faster than shell height throughout the year.

Shell length increased faster than the shell width in the green mussel, *Perna viridis* from Opposite Coast Guard, Gwader East Bay and Sur Bundar, Makran coast throughout the year. Shell length of *Perna 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.

Fatima *et al*., (2006) conducted allometric studies of the green mussel *Perna viridis* at Paradise Point, Karachi coast. The 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. Shell length increased faster than shell height. 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 *Perna viridis* increased faster than shell height all the year round resulting in mussels of low heights in large size mussels from Opposite Coast Guard, Gwadar East Bay and Sur Bunder, Makran Coast and are in accordance with the Fatima *et al.* (2006) from the Karachi coast.

High peaks of primary productivity in northern Arabian Sea were recorded in November (Kabanova, 1964; Banse, 1984). Fatima *et al.* (2006) observed minimum growth rate of tissue in *perna viridis* during February. It is due to spawning as well as due to 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 *Perna viridis* during January to April in Hong Kong to the drop in temperature i.e. below 18^{o}C.

Barkati and Choudhry (1988) estimated analysis of covariance and indicated that mussels *Perna viridis* occurring at low tidal height or remaining submerged for a long period under water, possessed shells of low weights.

Shell length increased faster than height in all populations, but shell width increased faster than length in Buoys mussels reflecting that it is probably the space on the natural beds hindering the growth in shell width of mussels. Relative growth decreased with increasing shell length in all populations. Barkati *et al*. (2006) analysed population structure and allometric growth of a mangrove clam, *Marcia cor*. Regression analyses provided information on changes in growth characteristics with increase in size and change in season. Shell length and shell weight were found to exhibit an exponential relationship whereas length, width and height displayed linear relationships. The larger clams tend to be wider in shape because of relatively faster growth in width compared to length and height. Percent growth is linear and weight variables decreased as length increased. Similar conclusion was drawn in the present results for *Perna viridis* along the Balochistan coast.

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The author declares no conflict of interest.

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