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GROWTH OF THE GREEN MUSSEL, *PERNA VIRIDIS* (LINN. 1758), FROM MOHESHKHALI CHANNEL OF THE BAY OF BENGAL, BANGLADESH

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ABSTRACT: Growth of *Perna viridis* L. inhabiting Moheshkhali jetty of the channel was studied for one year from November, 1990 to October, 1991. The mussel attained 88.12mm±14.69 in length within 12 months with a mean growth rate of 7.34mm/month. Employing von Bertalanffy's growth equation it was found that *P. viridis* can be 88.43mm, 114.69mm and 121.91mm at the age of 1, 2 and 3 year respectively. The highest growth rate was recorded during November-April, conciding with the maximum abundance of phytoplankton and the greatest salinity. The maximum growth rate (99.38%) was recorded at an early stage and was followed by a sharp decline to 4.47%. The growth pattern of *P. viridis* fitted well with the von Bertalanffy's growth equation: $L_t = 124.65[1-e^{-0.10754\,(t-0.505695)}]$.

KEY WORDS: Growth, *Perna viridis*, Moheshkhali Channel, Bangladesh.

INTRODUCTION

Among the bivalve molluscs in tropical waters, the green mussel, *Perna viridis* L., is an important intertidal filter feeder, found around different coastal islands of Bangladesh. The green mussel has been exploited as a cheap food source by the poor people in many parts of the world. However, now they are considered as a luxury item of food in Europe and North America (Boyle, 1981). Consequently, much effort has been concentrated on its culture by various methods overseas (Chaitanawisuti and Menasveta, 1987). In many countries of Asia and Indo-Pacific region, different species of the green mussel have been cultivated successfully as a cheap source of protein as well as foreign exchange earner (Chatterji *et al.,* 1984).

The very high levels of production, obtained by raft culture in some countries, has aroused the expectation that mussel culture may be a quick means of solving the animal protein needs of the population in the Third World (Pillay, 1993). Mussels are also used as bait, larval feed, fish meal and occasionally in cottage industries (Boyle, 1981). Besides the economic importance, they are being widely used in fundamental ecological, physiological and pollution research (Phillips, 1977).

Information on growth and eco-physiological requirements in a given environment is very important for a successful mussel culture programme (Rivonker *et al.,* 1993). The eco-physiological requirements, survival and growth of *P. viridis* in natural beds and various culture regimes have been studied abroad (Rivonker *et al.,* 1993; Joseph and

Joseph, 1988; Chaitanawisuti and Menasveta, 1987; Chatterji *et al.,* 1984; Parulekar *et al.*, 1982; Cheong and Chen, 1980; Qasim *et al.*, 1977; Rao *et al.,* 1975).

From Bangladesh Ali (1975), Ali and Aziz (1976), Ahmed *et al.* (1978) and Ahmed (1990) reported its occurrence, distribution and systematic from St. Martin's Island, Shahporir dwip and Naaf river while working on other pelecypods. As no information on any eco-physiological aspect of *P. viridis* is available from Bangladesh, the present study aimed to collect data on the growth and environmental requirements of the species inhabiting on the newly built jetty of the Moheshkhali channel.

MATERIALS AND METHODS

Specimens were collected randomly at monthly intervals between Nov., 1990 and Oct., 1991 from the piers of Moheshkhali jetty during low tide. Environmental parameters viz., water temperature, dissolved oxygen, salinity, and phytoplankton abundance of the habitat water have been recorded simultaneously over the study period. Water samples were collected using a Nansen bottle. Water temperature was measured *in situ* with a reversible thermometer attached to the Nansen bottle. Salinity and dissolved oxygen content were measured by standard Mohr-Knudsen (Barnes, 1959) and Winklers methods (APHA, 1976) respectively. To determine phytoplankton abundance, one liter of water at one meter depth was collected by the same Nansen bottle and preserved in a plastic container with 2% neutral formalin. Samples were analyzed in the laboratory of the Institute of Marine Sciences, Chittagong University. The samples were placed in an imhoff cone and allowed to settle for 24hrs. The settled samples were concentrated to 10ml by filtration and decantation (Boyed, 1979). After preparing a homogenous mixture by stirring the concentrated samples, an aliquot of 1ml was removed with a stemple pipette and placed on a Sedwick rafter cell counter under a compound microscope. The enumeration of phytoplankton was carried out carefully and the abundance was expressed as number of phytoplankton cells per liter of water.

The number of green mussels sampled each month ranged from 50 to 91 individuals. In total, 789 specimens were examined. The shell-length (i.e. maximum distance along the long axis of the valves) of each specimen was measured to 0.01mm with Vernier Calipers. As no sexual dimorphism could be discerned externally, no effort was made to study the growth related to sex. The growth was calculated from the mean monthly length of the shell attained by the animal (Ford, 1933; Walford, 1946). The empirical growth curve was fitted to the total length data using the von Bertalanffy's growth equation: $L_t = L_\infty [1-e^{-k(t-t_o)}]$ where, L_t = length at time 't'; L_∞ = length at infinity (asymptotic length); e = base of the natural logarithm; k = growth coefficient; t = time of observation; and t_o = arbitrary origin of growth.

The growth parameter L_∞ was calculated graphically using a Ford-Walford plot (Ford, 1933; Walford, 1946) by plotting L_t+1 against L_t. A line at 45° drawn through the zero point representative of where the length L_t equals the length at L_t+1. The intersection of the two points shows the asymptotic length (L_∞).

The growth coefficient (k) was estimated by the least square method following Bal and Rao (1994) as $b=e^{-k}$ where b is the slope of the equation $l_t+1=a+bl_t$, and 'e' is the base of natural logarithm. t_0 was calculated by the following formula of Ricker (1958):

$t_0=[(\log_e L_\infty + kt_0) - \log_e L_\infty]/k$ where, $\log_e L_\infty + kt_0$ is the value of Y-axis intercept.

Specific growth rate for each month was calculated from the mean monthly length attained by the animal following the formula of Bal and Jones (1960):

$$G = \frac{\log_e L_2 - \log_e L_1}{T_2 - T_1} \times 100$$

Where L_2 and L_1 are the shell length at time T_2 and T_1 respectively and the growth was expressed in percentage per month.

RESULTS

Physico-chemical factors of the habitat water:

The recorded physico-chemical factors are shown in figure 1. The highest water temperature (30.5°C) was recorded in April, 1991 and the lowest (23°C) in January, 1991. The maximum salinity was 29.8ppt in April, 1991 and the minimum was 21ppt in August, 1991. The maximum dissolved oxygen content (7.4mg/L) was found in November, 1990 and the minimum (5.15mg/L) in August, 1991.

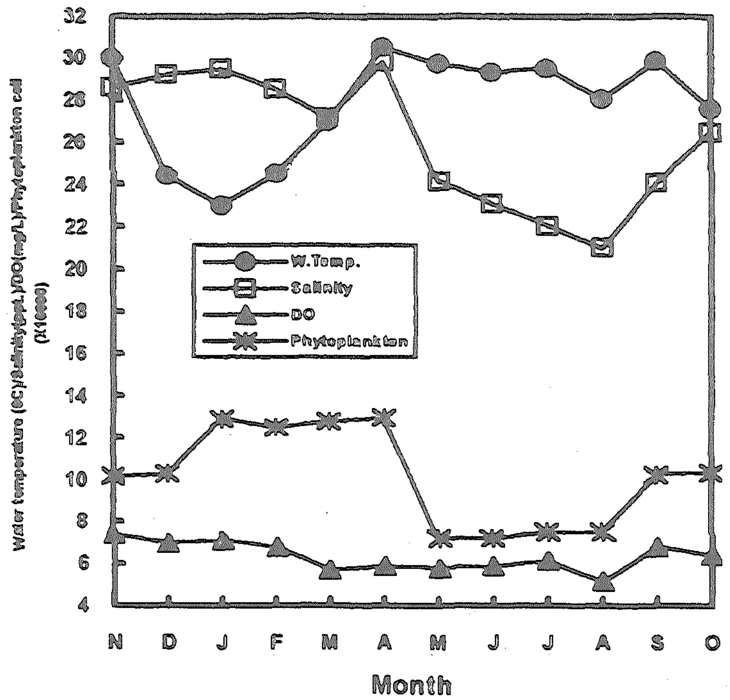

Fig.1. Hydrological factors of Moheshkhali jetty area between November, 1990 and October, 1991.

Phytoplankton abundance was found highest during the pre-monsoon period, from January, 1991 to April, 1991 (129322 to 129777 cells/L respectively), followed by the post-monsoon period from September, 1991 to December, 1990 (102453 to 102833 cells/L). The lowest abundance was recorded during the monsoon from May, 1991 to August, 1991 (72450 to 7522 cells/L) (Fig.1).

Specific growth, growth increment and relative growth:

The maximum and the minimum shell length of the animal were found 97.8mm and 4.78mm respectively. Monthly specific growth rate, relative growth rate and mean monthly length of *P. viridis* are shown in table 1. The maximum specific growth was found in November (99.38%) and the minimum in September (4.47%). Higher relative growth rate was observed at an early stage from November, 1990 to April, 1991 followed by a gradual decline in the increment in the later stages from May, 1991 to October, 1991 (Table 1). Specific growth rate also decreased from 99.38% to 4.47% (Table 1) as the length increased.

Table 1. Average observed length, growth increment, specific growth rate, relative growth rate and the length as determined by the von Bertalanffy's growth equation of *Perna viridis*.

Month	Average observed length (mm) (Mean±S.D.)	Growth increment (mm)	Specific growth rate (%)	Relative growth (%)	Length determined by growth equation $L_t = L_\infty [1-e^{-k(t-t_0)}]$
Nov.'90	6.30±1.15	-	99.38	84.13	6.44
Dec.'90	17.02±3.18	10.72	44.85	62.95	18.44
Jan.'91	27.67±3.81	10.65	29.92	38.49	29.32
Feb.'91	37.32±4.88	9.65	23.76	25.86	39.04
Mar.'91	47.33±5.12	10.01	21.32	21.15	47.77
Apr.'91	58.58±5.19	11.25	10.48	19.21	55.60
May '91	65.05±6.50	6.47	8.41	9.95	62.64
Jun.'91	70.76±7.65	5.71	5.58	8.07	68.97
Jul.'91	74.82±7.48	4.06	6.12	5.43	74.64
Aug.'91	79.54±7.95	4.72	5.78	5.93	79.72
Sep.'91	84.27±9.36	4.73	4.47	5.61	84.32
Oct.'91	88.12±14.69	3.85	-	4.37	88.43

Correlation between growth rate and physico-chemical factors:

The relationship between growth rate and hydrological factors of *P. viridis* is shown in table 2. The maximum growth rate occurred in November-April and the minimum in July-October. This coincided with the abundance of phytoplankton, which was highest during January-April and lowest during May-August, producing a significant positive correlation ($r=0.82$, $p<0.01$). Salinity was also found positively correlated with the growth rate of the mussel (r=0.77, p<0.01). However, water temperature and dissolved oxygen did not show any consistent relationship with the growth rate (Table 2).

Table 2. Correlation coefficients (r) between physico-chemical factors and growth rate of *Perna viridis*.

Parameters	Temperature	Salinity	Dissolved oxygen	Phytoplankton abundance
Growth rate	0.44	0.77*	0.55	0.82*

* significant at 1% (p<0.01) level with 10 d.f.

Fitting the growth equation to the length:

The method developed by Ford (1933) and Walford (1946) of plotting L_t+1 against L_t was followed to fit the growth equation. The asymptotic length (L_∞) attained by the animal was figured out graphically. A line at 45°, drawn through the zero point representative of where the length at L_t equals the length at L_t+1, intersects the curve and the point of intersection suggests the asymptotic length, L_∞ (Fig. 2a).

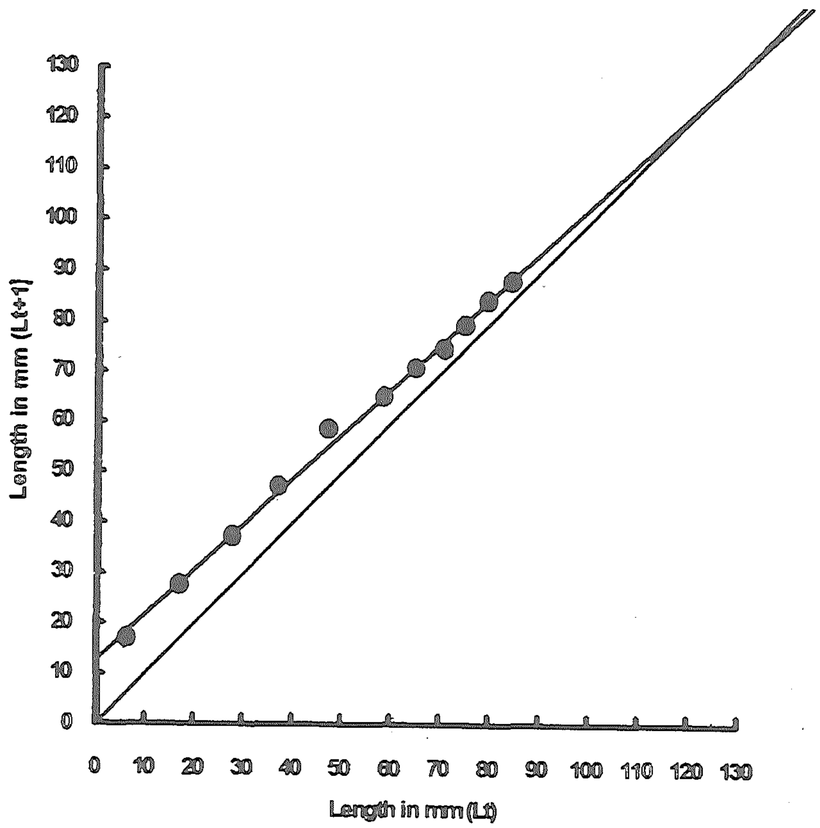

Fig.2a. Ford-Waldford plot of growth of *P. viridis* from Moheshkhali channel.

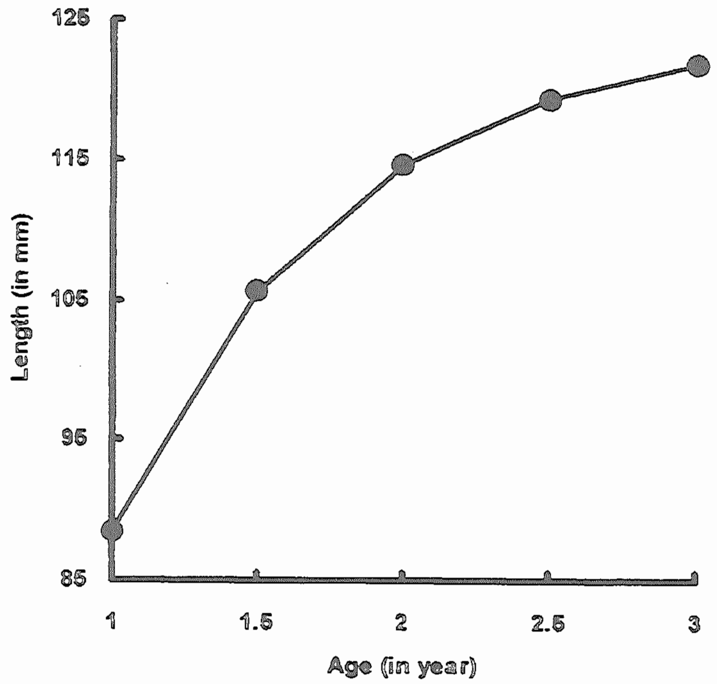

Fig.2b. Theoretical growth curve of *P. viridis.*

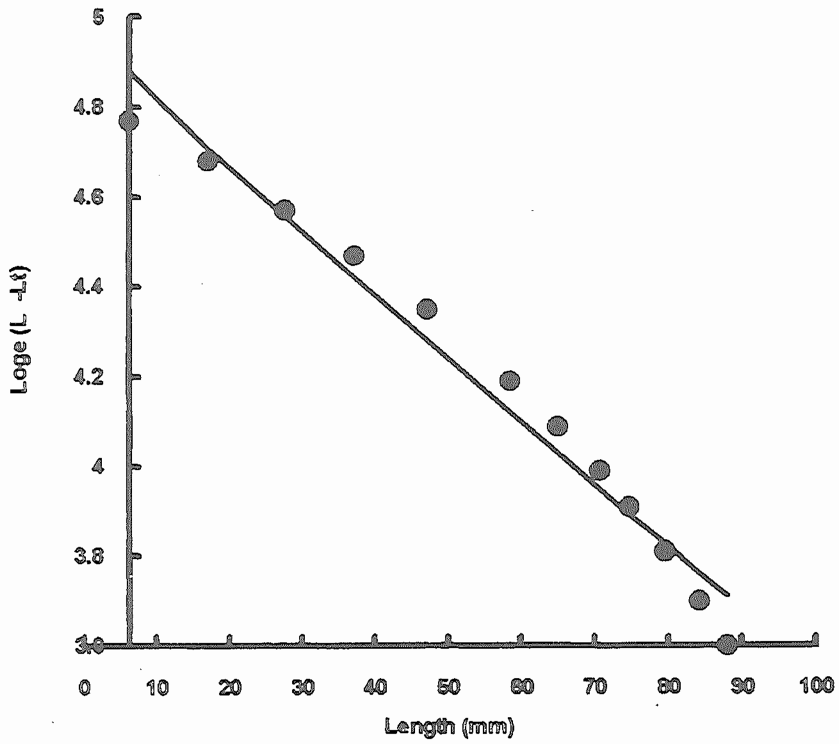

Fig.3. Log_e (L_∞ - L_t) plotted against length for estimation of t_o in *P. viridis.*

Fitting the von Bertalanffy's growth equation:

The values estimated for the parameters of the von Bertalanffy's growth equation are : L_∞ = 124.65mm; k=0.10754; t_0=0.506695. t_0 was calculated by the formula given by Ricker (1958): $t_0=[(\log_e L_\infty + kt_0) - \log_e L_\infty]/k$. For estimating t_0 the value of $\log_e L_\infty + kt_0$ was the Y-axis intercept (4.88) in figure 3, where $\log_e(L_\infty - L_t)$ was plotted against the mean monthly length. Substituting these values in the von Bertalanffy's growth equation, the equation could be expressed as: $L_t = 124.65\ [1-e^{-0.10754\ (t-0.506695)}]$. The theoretical growth curve is presented in figure 2b. From this growth curve, it can be observed that animal attains a length of 88.43mm, 114.69mm and 121.91mm at the age of 1, 2 and 3 years respectively.

DISCUSSION

The length in each month, calculated by the von Bertalanffy's growth equation showed a close agreement with the average observed length attained by *P. viridis* (Table 1). It clearly indicates that the von Bertalanffy's growth equation describes the growth of *P. viridis* adequately, as the mussels were collected from the same environmental habitat throughout the period of study.

The mean monthly length of *P. viridis* suggests that the animal attained a length of 88.12mm in a year or the growth rate was 7.34mm/month. Paul (1942), Rao *et al.* (1975) and Qasim *et al.* (1977) found a monthly growth rate for *P. viridis* of 7mm, 6mm and 5mm respectively by the end of the first year, from Indian natural environments. This comparison reveals that the growth of green mussels inhabiting the Moheshkhali jetty grow faster than those inhabiting Indian waters. The higher growth rate of green mussels in the channel is possibly because of their arrangement in column on the pillars of the jetty, similar to pole culture that renders them with more access to phytoplankton throughout the water column. Besides which, the presence of moderate temperature, salinity and availability of phytoplankton throughout the year may contribute to a higher growth rate. Paulekar *et al.* (1982) showed an increase in total weight of *P. viridis* coinciding with higher temperatures in the summer months at Goa, India. The decrease in the growth rate during the monsoon period is probably due to the low availability of phytoplankton and low salinity. Parulekar *et al.* (1982) and Chatterji *et al.* (1984) also showed that mussel growth was reduced at low phytoplankton density and low salinity.

The interaction of salinity, temperature and availability of food in a particular environment is complex and it is difficult to estimate the exact effect of a particular parameter on the growth rate (Chatterji *et al.*, 1984). However, the growth rate was found related to the salinity and the availability of phytoplankton. Parulekar *et al.* (1982) reported that salinity was the dominant factor along with abundance of phytoplankton. Similar observations were also reported by Qasim *et al.* (1977).

Growth in marine bivalves can be expressed as an increase in body size, weight or volume (Seed, 1976). Assessment of bivalve growth rate by measuring the shell length increment is valid and evidently the growth rate is faster at an early age than in the later stages (Hickman, 1979). The present study supports this statement strongly and shows a decrease in specific growth rate from 99.38% to 4.47% with increase in shell length (Table 1).

The von Bertalanffy's growth parameters are useful indices for comparison between and within species inhabiting different habitats or geographical areas. A comparison of the growth parameters L_∞, k and t_0 for *P. viridis* from different environment are given in table 3. Of the three parameters, values of t_0 are only of theoretical interest. The coefficient k of the von Bertalanffy's equation describes the rate at which an organism approaches its maximum size. k may be used to make comparisons of the rate of growth of the same species growing under different environmental conditions. k can be used as an index of the intrinsic development rate of a species and has importance in intra and inter-specific comparison of growth. k can also be regarded as independent of the level of feeding, but might be expected to vary with environmental factors (Joseph and Joseph, 1988). It is evident from table 4 that the value of k is low in Moheshkhali channel than values reported from Indian waters. Since k denotes the rate at which the growth decreases to reach the asymptotic, higher values of k denote slower rates of growth (Joseph and Joseph, 1988). Thus the rate of growth reported in the present study is faster than that reported for the same species from other countries.

Table 3. A comparison of von Bertalanffy growth parameters in *P. viridis* from different habitats.

Habitat	L_∞	k	t_0	Source
Dona Paula, Goa, India	110	0.1124	-0.0889	Chatterji *et al.* (1984)
Someshwar, Mangalore coast, India	41.93	0.1518	-0.038	Joseph and Joseph (1988)
Moheshkhali channel, Bay of Bengal, Bangladesh	124.65	0.10754	0.506695	Present study

L_∞ suggests the maximum theoretical length an organism can attain under given rate of growth. The low L_∞ values of *P. viridis* from the Mangalore coast and Dona Paula, India (Table 3) might be the result of using data on narrower ranges of growth of the species. The present estimates of L_∞ (124.65mm) is likely to be a more accurate estimate for *P. viridis* because the mean monthly length of the mussels varied from 6.3mm to 88.12mm. This is further supported by the maximum recorded size (L_{max}=97.8mm) of the mussel from Moheshkhali channel which was very near the estimated value of L_∞ (124.65). Though variations in L_∞ are related to feeding efficiency, but L_{max}/L_∞ is constant for a given species (Joseph and Joseph, 1988). Thus the low L_∞ reported from India is not well founded. Most bivalves have sigmoid growth curves and growth initiates at microscopic sizes (Joseph and Joseph, 1988). Even when von Bertalanffy growth equation appears to present observed growth rates adequately, extrapolation of the equation towards smaller size may require an independent investigation.

A comparison of annual growth and monthly growth rate of *P. viridis* from different environments is shown in table 4. The observed monthly growth rate was much higher than those reported from natural habitats overseas. This suggests that the natural environment of the Moheshkhali jetty waters is suitable for the normal growth of the animal.

Table 4. A comparison of the mean annual growth and mean monthly growth rate of *P. viridis* from different environments.

Habitat	Mean annual growth (mm)	Mean monthly growth rate (mm)	Source
Culture Beds:			
Intertidal rope culture Dona Paula Bay, Arabian Sea.	96.0	8.0	Qasim *et al.* (1977)
Subtidal raft culture Goa, India.	92.7	7.73	Parulekar *et al.* (1982)
Laboratory circulating seawater, Goa, India.	89.0	7.42	Chatterji *et al.* (1984)
Natural Beds:			
Intertidal natural bed Velsao Bay, Arabian Sea.	60.0	5.0	Qasim *et al.* (1977)
Natural settlement on floating buoys, Vengurla Bay, Arabian Sea.	72.0	6.0	Rao *et al.* (1975)
Madras Harbour, West coast of India, Arabian Sea.	84.0	7.0	Paul (1942)
Natural settlement on poles of Moheshkhali jetty, Moheshkhali channel, Bay of Bengal.	88.12	7.34	Present study

Qasim *et al.* (1977) reported that mussels grew faster on suspended rope culture than in natural beds at Goa, India. They recorded an average growth of 8mm/month for *Mytilus (=Perna) viridis* on ropes compared with 5mm in natural beds. They also reported that mussels attained marketable size (60-64mm) in 5 months by rope culture. Rao *et al.* (1975) found that mussels reach 60mm in length in 6 months on floating buoys at Vengurla Bay in the Arabian sea (Table 4). In the present investigation, mussels attained 58.58mm within 6 month's (Table 1) that show's the potentiality of the channel as a culture ground.

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