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

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Abstract: Spawning periodicity of the green mussel, *P. viridis* (Linn. 1758), from the Moheshkhali channel of the Bay of Bengal, Bangldesh was determined by 'larval abundance' method for a period of one year from November 1990 and October 1991. Higher larval abundance of *P. viridis* was recorded during pre-monsoon (January to April) and post-monsoon (September to December) months. Two significant peaks in spawning were recorded- the major peak in September (post-monsoon period) and a minor peak in April (pre-monsoon season). The abundance of the green mussel larvae was found to be correlated with high abundance of other mollusc larvae. However, a water temperature, salinity and the abundance of zooplankton showed negative correlation with the abundance of *P. viridis* larvae.

Key words: *Perna viridis*; Green mussel; Spawning; Bay of Bengal; Bangladesh

Introduction

The green mussel *Perna viridis* (Linn. 1758) occurs on to the rocky substratum of some coastal islands and poles of the mooring structures in the South-eastern intertidal waters of Bangladesh (Ali, 1975, Ali and Aziz, 1976; Ahmed *et al*., 1978; Ahmed, 1990; Kamal and Khan, 1999). Marine mussels are important bivalve to the ecologist, physiologist, toxicologist, and environmental managers for its unique biological characteristics (Bayne, 1976; Gibson and Gibson, 1981; Kosuge *et al*., 1986; Tanabe *et al*., 1987; Krishnakumar *et al*., 1990; Teo *et al*., 1990; Rivonkar *et al*., 1993a; Cheung, 1993; Miller *et al*., 1993; Ruangwises *et al*., 1994; Chidambaram, 1996). Sea mussels have also got huge attraction to the consumers as human food and ornamental object. It is one of the luxurious and expensive seafood items throughout the South-east Asia, Europe and Australia (Rao, 1974; Boyle, 1981; Pillay, 1993; Rivonkar *et al*., 1993b; Chidambaram, 1996).

Cultivation of sea mussels has got immense importance in many European and South-east-Asian countries due to high consumers demand and price in the international market (Bayne, 1976; Wallace, 1983). The culture of the green mussel has got intensive attention to the researchers and aquaculturist in India and Thailand in recent years as a high-profit

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aqua-business (Rao *et al*., 1976; Qasim *et al*., 1977; Rangarajan and Narasimham, 1980; Chatterji *et al*., 1984; Chaitanawisuti and Menasveta, 1987 Rivonkar *et al*., 1993b), However, the bottle-neck of mussel farming throughout the world is its dependence on supply of wild larvae (Rangarajan and Narasimham, 1980; Rivonkar *et al*., 1993a,b; Chaitanawisuti and Menasveta, 1987). Therefore, for establishing any viable mussel culture programme, a precise knowledge of mussel seed availability in the nearby waters has remained as the key of success (Wallace, 1983). Study for one or more years on spawning behaviour and cycle can provide information on the timing and availability of mussel larvae in area where mussel culture farm is to be established (Bayne, 1976; Wallace, 1983; Rangarajan and Narasimham, 1980).

Three methods have so far been employed for estimating spawning season in bivalve molluscs (Bayne, 1976; Wallace, 1983; Rangarajan and Narasimham, 1980):

- by observing spawning periods in natural or laboratory population,
- by observing the gonad from microscopic preparations throughout the year , and
- by observing the occurrence of larvae in the zooplankton community.

A combination of the above three methods can provide actual figure of the reproductive cycle and behaviour of bivalve molluscs. However, it is a time and labour intensive task in terms of economic point of view (Bayne, 1976), Therefore, mussel culturists throughout the world determine the spawning periodicities by observing abundance of mussel larvae in the zooplankton community from nearby waters (Prasad, 1954; Mason 1971; Nayar and Mahadeven, 1980; Silas, 1980; Alagarswami, 1980; Sitoy *et al.,* 1983; Silvaraj, 1988). Successful evaluation of the abundance of mussel larvae in zooplankton community is considered as a primary criterion in determining the viability of commercial mussel farming (Silvaraj, 1988).

Spawning periodicities and behaviour of various commercially important bivalve molluscs have been reported from many parts of the world (Nelson, 1928; Battle, 1932; Paul, 1942; Chipperfield, 1953; Allen, 1955; Ansel (1961), Durve (1984), Wisley (1964), Wilson and Hodgkin (1967), Wilson and Seed (1975), Seed (1975), Rao *et al.* (1975, 1976), Qasim *et al.* (1977), Alargarswami (1980), Jayabal and Kalyani (1986a) Lee (1988). Further, the need for experimental studies on the availability of bivalve molluscs larvae and seed has been emphasized repeatedly in India as well as other countries (Hrs-Brenko, 1971; Chipperfield, 1953; Dare, 1975; Rao *et al.,* 1976; Qasim *et al.,* 1977; Rangarajan and Narasimaham, 1980; Silas, 1980; Wallace, 1983; and Siraimeetan and Marichany, 1988).

In comparing to the published information on hydro-meteorology of the Bay of Bengal of Bangladesh territory, information on the commercially important bivalve larvae in the zooplankton community is still lacking (Ali *et al.,* 1985a,b; Begum, 1984. Islam, 1982; Mahmood *et al.,* 1976, 1987; Islam and Aziz, 1975a,b, 1979, 1980; Aziz and Islam, 1979; Mahmood and Khan, 1976; Bhuiyan *et al.,* 1982; Kamal *et al*., 1996?).

Therefore, the present study was carried out in order to provide information on the spawning periodicity of *P. viridis* in the Moheshkhali channel by observing the

abundance of its larvae in the zooplankton community. Attempts were also made to determine any relationship of green mussel larval abundance with the abundance of zooplankton, temperature and salinity of the surrounding waters.

Materials and Methods

Spawning periodicities were determined by quantitative analysis of veliger and pediveliger larvae of *P. viridis* present in the zooplankton sample collected at monthly intervals from the Moheshkhali jetty area (between latitudes 21°31'N and longitude 91°85'E) between November, 1990 and October, 1991.

The zooplankton samples were collected through vertical hauling for 15 minutes using a plankton net (bolting silk cloth no 16 gauze; mesh size 74 ③m; ring diameter 30 cm; length 4 m). A Karl Kolb digital flow meter was attached to the mouth of the net to record the quantity of water filtered through the net during sampling. Samples were immediately preserved in 5% neutralized formalin in a plastic container. Zooplankton samples were counted in the Laboratory of Marine Science Institute quickly before discolouration of the larvae by using a Sedgwek rafter counter cell. The result was recorded as individuals per litre. Water temperature and salinity of the surface water was recorded *in situ* by using Celsius thermometer and hand refractometer respectively.

The planktonic larvae of *P. viridis* were identified following Rao *et al.* (1975, 1976), Qasim *et al.* (1977) and Ress (1951). The veliger larvae was identified on the basis of straight hinge, large posterior adductor muscle near straight hinge line, external ciliated velum, labial palps, conspicuous pigmented eye-spot in the centre and yellow colouration on whole body with pale pinkish colour on the umbonal region and greenish brown colour of the digestive gland (Rees, 1951; Rao *et al*., 1975; Qasim *et al*., 1977). The pediveliger larvae were identified on the basis of fairly district umbo at anterior end, ligament at posterior on the hinge line, reduced velum, close-set concentric lines of growth on shell and dark pigmented eye-spot in the centre of the body (Ress, 1951; Rao *et al*., 1975, 1976; Qasim *et al*., 1977).

Results

Monthly occurrence of mussel larvae, molluscs larvae and zooplankton abundance with water temperature and salinity at Moheshkhali jetty area has been shown in Table-1.

The maximum abundance of mussel larvae (1170 indv. l^{-1}) was found to occur in September, 1991 and abundance was nil in May, June and July, 1991. In August, 1991, the larvae were found to appear in small numbers (190 indv. l^{-1}) and in the following month (September) the larvae attained to its peak (1170 indv. l^{-1}). In October, the larval abundance was about half of the previous month (615 indv. l^{-1}) and from October, 1991, the abundance was found to decrease gradually up to January, 1991, (115 indv. l^{-1}). After January, it increased gradually up to April, 1991 (492 indv. l^{-1}) and the larval abundance was found to be nil for the subsequent months of May, June and July, 1991. After July,

1991 the larvae again appeared in small quantity in August, 1991 (190 indv. l^{-1}). Hence seasonal abundance of mussel larvae was found to fluctuate in different months of the year markedly.

Table-1. Monthly abundance of mussel and mollusc larvae, zooplankton (individuals/l), water temperature and salinity from Moheshkhali jetty area between November 1990 and October 1991.

Month	Mussel larvae (indv. l^{-1})	Mollusc larvae (indv. l^{-1})	Zooplankton larvae (indv. l^{-1})	Water temperature (°C)	Salinity (ppt)
Nov. 1990	330	384	15787	25.95	28.6
Dec. 1990	280	302	14882	24.4	29.2
Jan. 1991	115	152	15000	23	29.5
Feb. 1991	305	342	16760	24.5	28.56
Mar. 1991	384	403	14525	26.95	27.15
Apr. 1991	492	522	13250	30.54	29.8
May 1991	00	00	29850	29.75	24.71
Jun. 1991	00	00	28000	29.3	23.06
Jul. 1991	00	00	26600	29.52	22.06
Aug. 1991	190	201	24500	28.06	21
Sep. 1991	1170	1272	18589	29.85	24.1
Oct. 1991	615	671	16557	27.6	26.5
Average	431.22	472.11	19532.58	27.45	26.19

From the Table 1, it is evident that the mussel larvae were found to appear in high concentration during the post-monsoon followed by the pre-monsoon period. During the monsoon period, the larval abundance was found to be nil except one month (August, 1991; 190 indv./L)

Percentage composition: The monthly percentage composition of mussel larvae with molluscs larvae and zooplankton were calculated and represented in Table 2. The maximum percentage composition in relation to molluscs larvae was found in March, 1991 (95.29%) and the minimum in January, 1991 (75.66%). The yearly average percentage composition of mussel larvae was found to be 90.13%. For the larval percentage composition in relation to zooplankton abundance, the maximum value was noticed in September, 1991 (6.29) and the minimum in January, 1991 (0.77%). The yearly average percentage composition was found to be 2.63%.

The ratio of abundance: The monthly and seasonal abundance of mussel larvae in relation to molluscs larvae and zooplankton are represented in Table 3. In case of monthly ration between molluscs and mussel larvae, the maximum ratio was found in January, 1991 (132:1) and the minimum in March, 1991 (1.05:1). The average yearly ratio was found to be 1.11:1. But in case of monthly zooplankton and mussel larvae, the ratio was fluctuated markedly. The maximum value was found in January, 1991 (130.43:1) and the minimum in September, 1991 (15.89:1). The average yearly ratio of zooplankton to mussel larvae was found to be 58.1:1. The higher ratios were found in November, 1990 (47.84:1); December, 1990 (53.15:1); January, 1991 (130.43:1); February, 1991 (54.95:1) and August, 1991 (128.95:1) and the lower ratios were obtained

in September, 1991 (15.89:1). October, 1991 (26.92:1), April, 1991 (26.93:1) and March, 1991 (37.83:1).

Table 2. Monthly percentage composition of mussel larvae with mollusc larvae and zooplankton at Moheshkhali jetty area between Nov. 1990 and Oct. 1991.

Months	Percentage composition of mussel larvae	
	with mollusc Larvae	with zooplankton
Nov. 1990	85.91	2.09
Dec. 1990	92.72	1.88
Jan. 1991	75.66	0.77
Feb. 1991	89.18	1.82
Mar. 1991	95.18	2.64
Apr. 1991	94.25	3.71
May 1991	0	0
Jun. 1991	0	0
Jul. 1991	0	0
Aug. 1991	94.53	0.78
Sep. 1991	91.98	6.29
Oct. 1991	91.65	3.71
Average	90.13	2.63

In case of seasonal ratio of mussel larvae relating to molluscs larvae, the maximum value was noticed in the post-monsoon period (1.1:1) and the minimum in the monsoon period (1.06:1). The average seasonal ratio was found to be 1.08:1. The ratio of mussel larvae in relation to zooplankton abundance, the maximum value was found in the monsoon period (573.42:1) and the minimum in the post monsoon period (27.48:1). The average seasonal ratio between zooplankton and mussel larvae was found to be 215.61:1.

Table 3. Monthly and seasonal abundance ratio of mussel larvae (MUL), mollusc larvae (MOL) and zooplankton (ZP) at Moheshkhali jetty area between Nov. 1990 and Oct. 1991.

Monthly abundance ratio between			Seasonal abundance ration between		
Month	MOL: MUL	ZP: MUL	Seasons	MOL: MUL	ZP: MUL
Nov. 1990	1.16:1	47.84:1	Pre-monsoon	1.09:1	45.94:1
Dec. 1990	1.08:1	53.15:1	(Jan.-Apr.)		
Jan. 1991	1.32:1	130.43:1			
Feb. 1991	1.12:1	54.95:1			
Mar. 1991	1.05:1	37.83:1			
Apr. 1991	1.06:1	26.93:1	Monsoon	106:1	573.42:1
May 1991	0	0	(May-Aug.)		
Jun. 1991	0	0			
Jul. 1991	0	0			
Aug. 1991	1.06:1	128.95:1			
Sep. 1991	1.09:1	15.89:1	Post-monsoon	1.1:1	27.4:1
Oct. 1991	1.09:1	26.92:1	(Sep.-Dec.)		
Average	1.11:1	58:1		1.08:1	215.61:1

The correlation among different variables: The correlation coefficients among water temperature, salinity, abundance of mussel and molluscs larvae and zooplankton were worked out and presented in Table 4. The significant positive correlation was found between molluscs and mussel larvae ($r = 0.99$ at 1% ($p<0.01$) level of significance with 10 d.f.

Table 4. Correlation coefficient (r) among water temperature, salinity, abundance of molluscs and mussel larvae and zooplankton at Moheshkhali jetty area between Nov. 1990 and Oct. 1991 [Figures given in parentheses are the values for 't'].

	WT	S	MOL	MUL	ZP
WT	1.0	-0.58 (2.25)**	0.15 (0.48)	0.17 (0.54)	0.52 (1.93)
S	-	1.0	0.16 (0.51)	0.15 (0.48)	-0.82 (4.53)*
MOL	-		1.0	0.99 (22.19)*	-0.51 (1.87)
MUL	-			1.0	-0.5 (1.88)
ZP	-				1.0

WT= Water Temperature; S= Salinity; MOL= Mollusc larvae; MUL= Mussel larvae; ZP= Zooplankton;
* = Significant at 1% level ($p<0.01$) with 10 d.f.; **= Significant at 5% level ($p<0.05$) with 10 d.f.

The significant negative correlation was found between water temperature and salinity ($r=-0.58$) and between salinity and zooplankton ($r=-0.82$) at 5% ($p<0.05$) and 1% ($p<0.01$) level of significance respectively with 10. d.f. But correlation between mussel larvae and water temperature ($r=0.17$) and salinity ($r=0.15$) was found to be insignificant.

Discussion

The occurrence of mussel larvae in all the seasons except May, June and July, indicates that the spawning seems to take place throughout the year in *P. viridis* excluding the monsoon period. The result of the present investigation indicates two sharp spawning seasons in *P. viridis* around the Moheshkhali jetty area with two peaks- one in September and another in April, 1991. The year-round spawning of *P. viridis* was reported from Indian water with a prolonged spawning season from July to December with peak spawning in September-November followed by a minor peak in February-March (Rao *et al.,* 1975; Alagarswami, 1980 and 1988) which is in close quarter with the present findings.

The higher percentage composition of mussel larvae (75.66-95.29%) with molluscs larvae indicates that *P. viridis* is the dominant species than other mollusc species present around the jetty area. But the ratio of occurrence of mussel larvae in relation to zooplankton was found to fluctuate markedly, which indicates a different spawning pattern of different groups of zooplankton prevailing in the channel.

Several workers stated that water temperature was a major abiotic factor influencing the spawning intensity in all marine organisms in temperate water (Orton, 1920; Allen, 1955; Ansell, 1961; Kinne, 1963, 1964; Seed, 1975). Salinity influenced the spawning in tropical water but high salinity showed some adverse effects on the spawning activity of bivalves (Paul, 1942; Durve, 1984; Jayabal and Kalyani, 1986). But insignificant correlation between larval abundance and water temperature or salinity in the present study could be explained following Bayne (1975a,b, 1976) who worked on two mussel species namely *Mytilus edulis* and *M. galloprovincialis* and stated that some ecological factors alone could not be responsible in spawning of mussel. Bayne (1975a,b, 1976) suggested that spawning in mussel was controlled by a combination of internal and external environmental factors. Further, it is widely suggested that the spawning in lamellibranches is different from one species to others and may occur only over a critical temperature and salinity with geographic variation (Nelson, 1928; Kinne, 1964). Again, it

is evident that the spawning time and intensity is also affected by lunar periodicity in mussel (Battle, 1932), which was beyond the scope of our study.

The present results (insignificant correlation between larval abundance and water temperature and salinity) agrees well with the results of Rao *et al*. (1975) who worked on *Mytilus* (= *Perna*) *viridis* along the central west coast of India. They found the correlation coefficient values at r = 0.16 and r = 0.30 for salinity and water temperature with larval abundance. These results indicate that a higher abundance of *P. viridis* larvae is not solely dependent on high water temperature or higher salinities of the surrounding waters. It could be attributed to other water quality parameters which needs further investigation.

Conclusion

The abundance of *P. viridis* larvae in the zooplankton community in the waters of Moheshkhali jetty area is found to be a good indicator in determining spawning periodicity of the species in the channel. The ratio of *P. viridis* larvae in relation to other mollusc and zooplankton larval community reveals that *P. viridis* inhabiting the Moheshkhali channel spawn during the pre-monsoon (January-April) and post-monsoon (September-December) period with two peaks- the major peak in September and the minor peak in April. Absence of mussel larvae in the zooplankton community during the monsoon reveals that it does not spawn during this period.

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