Chiang Mai J. Sci. 2010; 37(2) : 344-354
www.science.cmu.ac.th/journal-science/josci.html
Contributed Paper

Population Dynamics of the Green-Lipped Mussel, *Perna viridis* from the Offshore Waters of Naf River Coast, Bangladesh

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Received: 16 April 2009
Accepted:18 December 2009

ABSTRACT

The population parameters like asymptotic length, growth co-efficient, mortalities, recruitment rate and length-weight relationship of green-lipped mussel, *Perna viridis* in the offshore waters of the Naf River were studied between February 2007 and January 2008. Monthly length frequency data of *P. viridis* were analyzed using FiSAT software for estimating population parameters including asymptotic length (L_∞), growth co-efficient (K) and recruitment pattern to assess the status of the stock. Asymptotic length (L_∞), growth co-efficient (K) and the growth performance index (φ) were calculated as 13.65 cm, 1.30 year $^{-1}$ and 2.38 respectively. Total mortality (Z), natural mortality (M) and fishing mortality (F) were estimated at 1.90 year $^{-1}$, 1.09 year $^{-1}$, and 0.81 year $^{-1}$ respectively. The recruitment pattern was found continuous, displaying a double major peak event per year. The exponent 'b' value estimated for this species under study was below 3 (b<3) indicating that the growth pattern showed negative allometric growth.

Keywords: population dynamics, *Perna viridis*, offshore water, Naf River coast, Bangladesh.

1. INTRODUCTION

Green-lipped mussel, *Perna viridis* is a cheap source of protein and has been cultured with great success using various methods at different places of both hemispheres [1]. *P. viridis* is an ideal species for culture because of its fast growth rate and tolerance to a wide salinity range [2] and contributes to sustenance fisheries in India and other South-East Asian countries [3]. Green-lipped mussel culture can be a vital force and potential means for increasing production of protein at low cost to meet the needs of fast growing populations; as a means of producing high-priced commodities for export and earning foreign exchange; as creating employment opportunities; and as a way of using large coastal areas which are still unproductive and/or unexploited [4].

Intertidal invertebrates depend on the successful settlement and recruitment of dispersing larvae to maintain population. Successful recruitment to the adult population

may be highly variable in space and time, reflecting the demographic diversity of a population [5,6]. Numerous studies have focused on the physical and biological processes that influence settlement patterns of planktonic larvae on morphologically and chemically distinct substrates [7]. However, many marine invertebrates, such as green-lipped mussels, may re-settle several times on different substrates during their post-larval and juvenile stages [8]. The population themselves also may be regulated by biological and physical factors that affect adult green-lipped mussels, such as competition, predation, hydrographic forces, temperature and salinity. The sum total of these biological and physical factors is likely to be reflected in the growth and mortality rates of green-lipped mussels within various populations [9]. Therefore, comparison among mussel population must be taken into a combination of interacting factors that affect green-lipped mussels at various life-history stages.

Bangladesh has an extensive shelf area of about 69,900 km^2 of which about 37,000 km^2 is within 50 m depth zone and has potential fishery resources. The coastal water of Bangladesh is one of the most productive zones in the world and rich in fish and shell-fishes including molluscs [10]. Along the coastal area, varieties of marine habitats such as sandy, muddy and rocky grounds, mangrove areas and coral reefs are inhabited by the bivalves, and thus are potentially viable for the development of shellfish fishery. Several surveys identified mollusc species and their abundance, distribution with some notes on ecology along the coast of Bangladesh [11,12]. The high tidal amplitude, sufficient tidal current, absence of pollutants and high phytoplankton abundance offer an ideal environment for the development of molluscs culture around coastal waters of Bangladesh [13].

The green-lipped mussel, *P. viridis* was reported for the first time in Bangladesh by Ahmed [13] from Shahpury dwip (island) of Teknaf along the Naf River coast. It plays a major role in the ecosystem of shallow coastal waters of Bangladesh. The tribal community of this coastal region exploits molluscs from the natural beds, especially the green-lipped mussel (*P. viridis*), oyster (*Crassostrea sp.*) and clam (*Meretrix meretrix*), primarily for their own consumption and local sale [14]. The marine green-lipped mussels are popular food items in many other countries around the globe. There has been a few reports on population dynamics and status of exploitation of *P. viridis* in Bangladesh prior to this study. Hence, the estimation of population parameters of this species of molluscs from the coast of Bangladesh is very important.

Knowledge of various population parameters such as asymptotic length (L_∞) and growth co-efficient (K), mortalities (natural and fishing) rate and length-weight relationship are necessary for planning and management of mollusc resources. There are many tools for assessing the stock status. Of these, FiSAT (FAO-ICLARM Stock Assessment Tools) has been most frequently used for estimating population parameters of fin fish and shellfish [15-18], primarily because it requires only length-frequency data. The aim of the present study was to estimate the population parameters such as asymptotic length, growth co-efficient, mortality (natural and fishing) rate, recruitment and length-weight relationship of *P. viridis* in order to assess the stock status of the species from the offshore waters of Naf River and to provide data that could be useful for planning and management of fishery resources.

2. MATERIALS AND METHODS

2.1 Study Site

The study was carried out in the Naf River

situated in the south-eastern coast of Bangladesh (Figure 1). The Naf River is located on the apex of the Bay of Bengal, approximately between latitude 20°47′ N and longitude 92°28′ E. The river is exposed to a strong hydrodynamic regime. Oceanographic conditions are mediated by the predominantly southerly winds and swells, and the confluence of the northbound currents. The bed of the river is sandy-muddy from the upper region towards the lower region where tidal water has free flow. The study site was chosen in a way to include hotspots of mass production of green-lipped mussels around the coast.

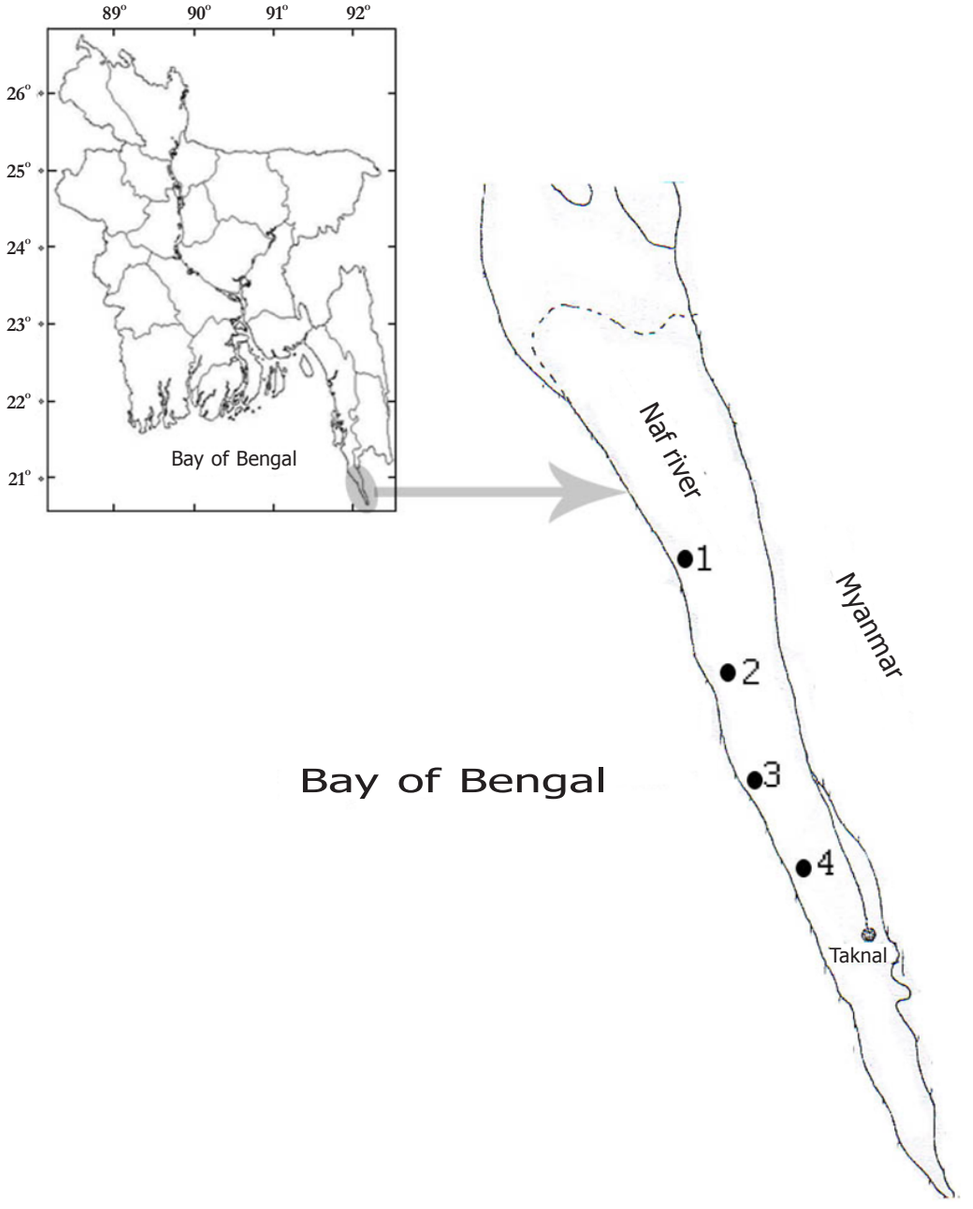

Figure 1. Sampling locations in the coast of Naf River, Bangladesh.

2.2 Sample Collection

P. viridis were collected at random monthly between February 2007 and January 2008 at four landing sites in the Naf River. Specimens of *P. viridis* were attached with the stone in inter-tidal zone of the coast. An iron rod was used during sampling for separating the specimens from the stone. Green-lipped mussels from the study sites were collected at comparable depths to avoid confounding effects of depth [19] and with comparable densities. Samples were immediately preserved in 10% formalin at the field level and brought to the laboratory for analysis.

2.3 Sample Preparation and Analysis

Mussels samples were kept at room temperature and dissected using hexane pre-rinsed stainless steel instruments. Shell length (maximum anterior – posterior dimension) of each green-lipped mussel was measured with a pair of vernier calipers to 0.1 mm and total weight was taken by an electronic balance of 0.001g accuracy. In total 2,142 specimens were measured and weighed. The data from the four stations were then pooled month-wise and subsequently grouped into length classes at 2 cm interval. Then the data were analyzed using FiSAT software by length-frequency data analysis [20].

2.4 Data Analysis

To establish the length-weight relationship, $W = aL^b$ was applied [21,22], where W is the weight (g), L is the total length (cm), 'a' is the intercept (condition factor) and 'b' is the slope (relative growth rate). The parameters a and b were estimated by least square linear regression on log-log transformed data:

$$\text{Log}_{10}\, W = \text{Log}_{10}\, a + b\, \text{Log}_{10}\, L$$

The co-efficient of determination (r^2) was used as an indicator of the quality of the linear regression [23]. Additionally, the 95% confidence limits of parameter b and the statistical significance level for r^2 were estimated.

An estimate of maximum length (L_{max}) was obtained using the data and the extreme value theory [24], as implemented in the FiSAT software. Asymptotic length (L_∞) and growth co-efficient (K) of the Von Bertalanffy Growth Formula (VBGF) were estimated by means of ELEFAN-1 [25]. Estimated L_∞ and K were used to calculate the growth performance index (φ) [26] using the equation:

$$\varphi = \text{Log}_{10}\, K + 2\, \text{Log}_{10}\, L_\infty$$

Recruitment rates were obtained by backward projection on the length axis of a set of length-frequency data as described in the FiSAT routine. To estimate length at recruitment (L_r) the mid point of the smallest length group in the collected data was taken as length at recruitment [27].

Fishing mortality (F) was obtained by subtracting natural mortality (M) from total mortality (Z) and exploitation rate (E) was obtained from F/Z [28]:

$$[E = F/Z = F/ (F+M)]$$

3. RESULTS

3.1 Length-Weight Relationship

Length and weight of individuals for determining the length-weight relationship ranged from 2.3 to 13.4 cm and 3.38 to 14.95g, respectively. The length-weight relationship is presented in Figure 2 and was calculated as Log W = - 0.46471 + 2.529 Log L; in exponential form the equation is $W = 0.343\, L^{2.529}$ ($r^2 = 0.97$; $P < 0.01$). Figure 2 showed that the length-weight relationship of *P. viridis* in the Naf River was continuous and the continuous line is the linear regression on log-log expression of the length-weight values. The

computed relative growth rate (*b*) was 2.529 (± 0.101) and condition factor (*a*) was 0.343. The *b* values ranged from 2.313 to 2.719 with 95% confidence limit. The exponent '*b*' value estimated for this species under study was below 3 in this study area indicating the allometric pattern of growth. The value of '*r*' for this species recorded in the present study was 0.99 indicating highly significant relationship between length and weight.

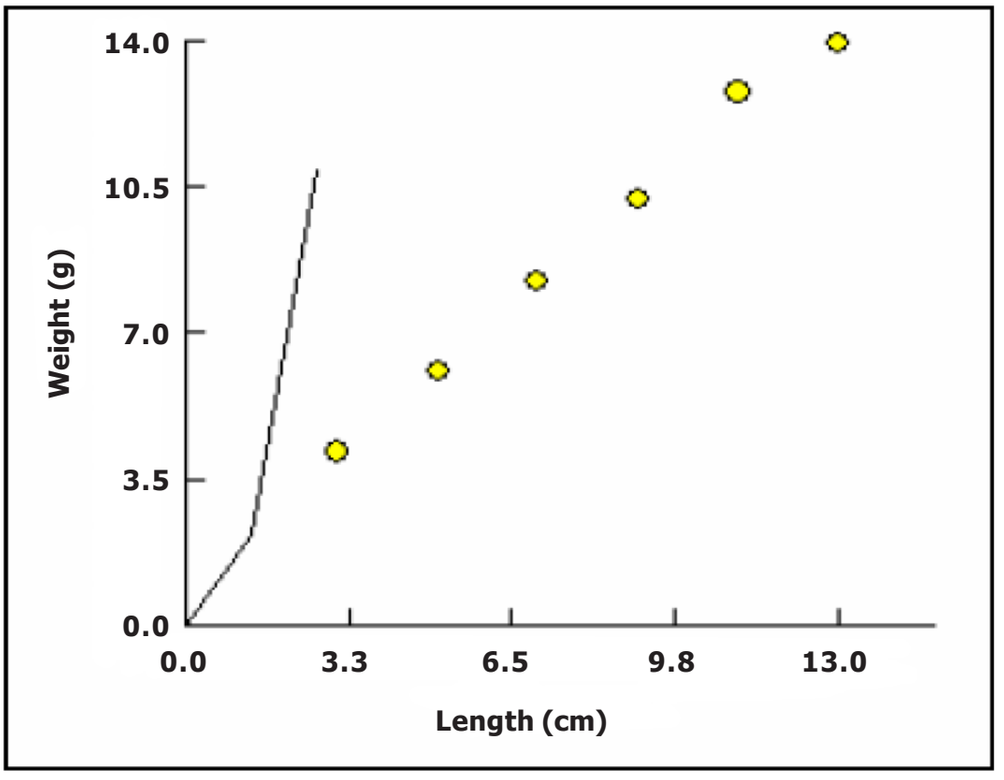

Figure 2. Length-weight relationship of *P. viridis* in the Naf River coast, Bangladesh [Dots are in the mid values of length (class interval 3 cm) and weight (class interval 3.5 gm), the continuous line is the linear regression on log-log expression].

3.2 Growth parameters

The observed extreme length and the predicted extreme length (L_{max}) were 13.4 cm and 15.8 cm respectively. The range of 95% confidence interval for extreme length was 12.31 – 18.29 cm. The ELEFAN-1 (Electronic Length Frequency Analysis) program estimated asymptotic length ($L\infty$) and growth co-efficient (K) of the Von Bertalanffy Growth Formula (VBGF) for *P. viridis* were 13.65 cm and 1.30 year^{-1} respectively (Table 1). The computed growth curve with these parameters is superimposed over the restructured length distribution in Figure 3. The calculated growth performance index (φ) of *P. viridis* was 2.38 and the growth of this species was found to be positive pattern in the coast of Naf River, Bangladesh (Figure 4).

Table 1. Population parameters of *P. viridis* in the Naf River coast, Bangladesh.

Population parameters	*P.viridis*
Asymptotic length ($L\infty$) in cm	13.65
Growth co-efficient (K) year^{-1}	1.30
Growth performance index (φ)	2.38
Amplitude of oscillation (c)	0.00-0.94
Natural mortality (M) year^{-1}	1.09
Fishing mortality (F) year^{-1}	0.81
Total mortality (Z)	1.90
Length range (cm)	2.3 – 13.4
Sample size (n)	2142

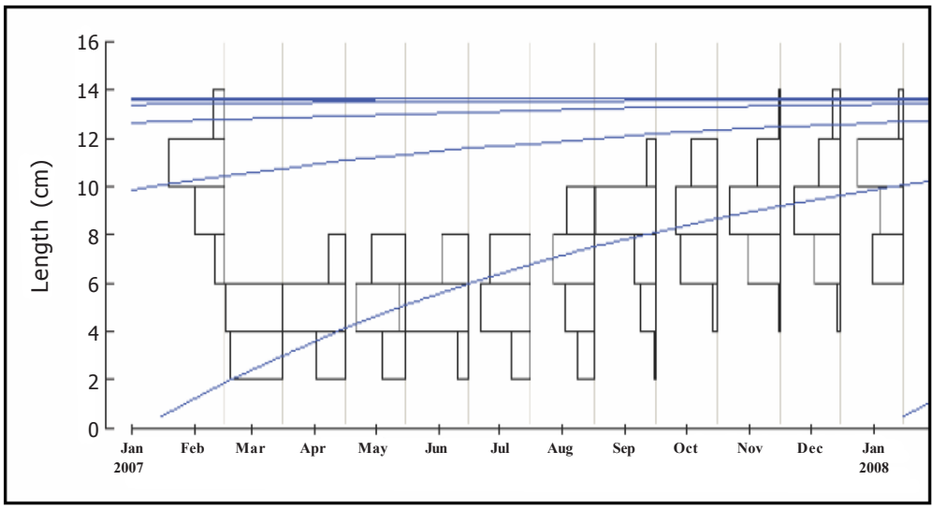

Figure 3. Von Bertalanffy growth curves ($L\infty$ = 13.65 cm and K = 1.30 year^{-1}) for *P. viridis* superimposed on restructured length-frequency histograms. Black and white bars = positive and negative deviation from 'weighed' moving average of two length classes representing pseudo cohorts.

3.3 Mortalities

Total mortality co-efficient (Z) was estimated as 1.90 year^{-1} using the length converted catch curve. Natural mortality (M) and fishing mortality (F) were calculated as 1.09 year^{-1} and 0.81 year^{-1} respectively (Table 1). Analysis of empty shells in the adult green-lipped mussel beds suggest that green-lipped mussels died of natural causes rather than through predation. The ranges in abundance for dead shells for the one year were 1-70 and 1-20 individuals/m^2 respectively. The seasonal variability among large (< 2.5 cm) empty shells indicated that a greater number of empty shells were present June to August in the coast of Naf River (Figure 5), and subsequently their number declined towards December.

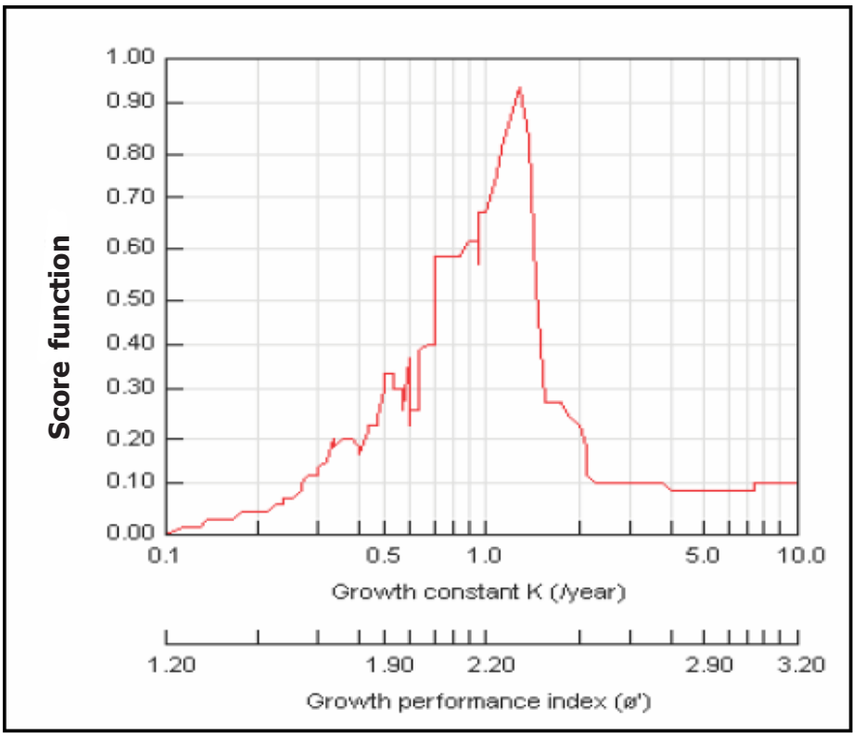

Figure 4. Von Bertalanffy growth constant curve of *P. viridis* in the Naf River coast, Bangladesh.

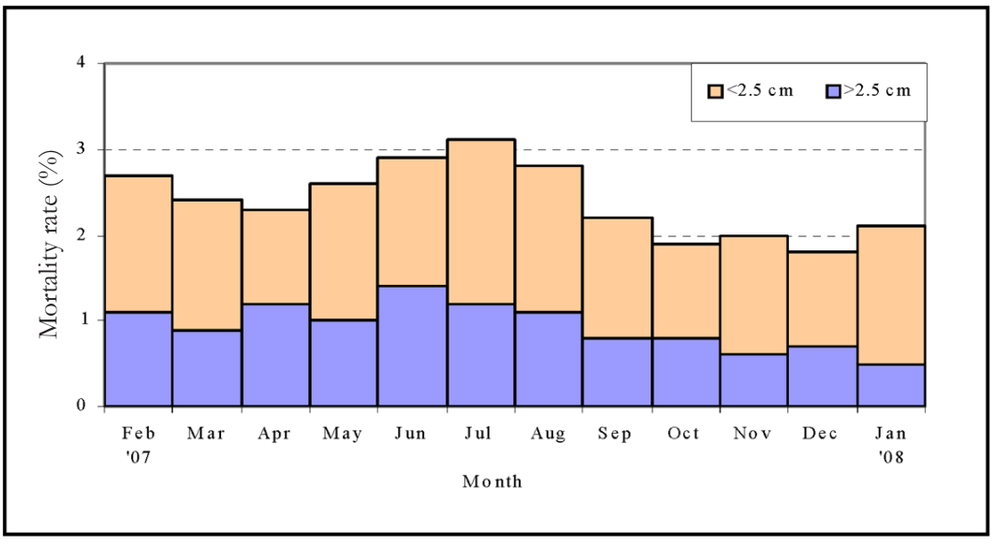

Figure 5. Mortality rate of *P. viridis* in the Naf River coast, Bangladesh during the study period.

3.4 Recruitment Pattern

The recruitment pattern of *P. viridis* was continuous throughout the year with two major peaks. Seasonal changes in recruitment rates were similar in all the sizes. In the Naf River coast, highest percent in recruitment was observed in August, followed by a gradual decline up to December in one year (Figure 6). For *P. viridis*, recruitment was found to occur twice annually. Two peaks were found, one in May another one in August. The first recruitment occurred between March to June and the second one between July to September. The length at first capture (L_c) estimated for *P. viridis* ranged from 0.5 cm to 2.4 cm where as the recruitment sizes (L_r) ranged between 0.3 and 1.6 cm during the study period.

4. DISCUSSION

The findings reported in this study represent the first report on the length-weight relationship of *P. viridis* in the study area. The relative growth rate *b* generally lies between 2.5 and 3.5 [29] and the relation is said to be isometric when it is equal to 3 as reported for most fish [22]. In the present study, estimated *b* (2.529) lies between the values mentioned by Carlander [29] and Ecoutin *et al.* [30], and is significantly smaller than isometric value (3) at 5% level. This indicates the negative allometric growth for *P. viridis* in the Naf River coast, Bangladesh.

The estimated asymptotic length ($L\infty$) is 13.65 cm and growth co-efficient (*K*) is 1.30 year^{-1} for *P. viridis* in this study. The comparison with growth parameters from other studies (Table 2) show that differences exist for *P. viridis* from other areas of the world. The highest value of $L\infty$ (13.65 cm) was obtained from the study of Naf River, Bangladesh coastal waters and the lowest value (10.19 cm) was in Hong Kong waters [31]. The highest *K* value (1.50 year^{-1}) was obtained from Malaysia [18] and the lowest value (0.25 year^{-1}) was reported from India [32]. It was observed that the $L\infty$ of *P. viridis* from Naf River, Bangladesh coastal waters is higher than other countries (Table 2) but *K* is more or less very close to *P.viridis* of Thailand waters [33].

The highest natural mortality (1.09 year^{-1}) versus fishing mortality (0.81 year^{-1}) observed for *P. viridis* in this study indicates an imbalance in the stock. The yield is optimized when fishing mortality (*F*) = natural mortality (*M*) [28].

The recruitment pattern suggests that annual recruitment consists of two seasonal pulses (Figure 6), i.e. two cohorts are produced per year; the highest peak occurs in March-June followed by a second peak occurring in July-September. However, studies on larval abundance and spat collection in the St. Martin coast of Bangladesh [34] showed that green-lipped mussel larvae settle throughout the year but the highest peak was found in October and the second highest in March. The recruitment peaks detected in this study period should correspond to the first and second larval settlement.

ACKNOWLEDGEMENTS

The authors would like to extend their appreciation to the Universiti Malaysia Sarawak, Malaysia for providing fellowship for this study, and to the authority of Institute of Marine Sciences and Fisheries, University of Chittagong, Bangladesh for providing laboratory facilities to conduct the study.

Table 2. Population parameters of genus *Perna* and other bivalves as reported in other countries.

Location	Species	L_∞ (cm)	K year^{-1}	φ	T (^{o}C)	Reference
Bangladesh	*P. viridis*	13.65	1.30	2.38	30.2	Present study
Malaysia	*P. viridis*	10.23	1.50	4.19	29.44	[18]
Hong Kong	*P. viridis*	10.19	0.30	-	-	[31]
India	*P. viridis*	11.46	0.25	-	-	[32]
Thailand	*P. viridis*	11.20	1.00	-	-	[33]
Germany	*Donax sp.*	8.20	0.27	-	-	[35]
Korea	*C. gigas*	10.37	2.35	4.40	16.0	[36]
Venezuela	*Crassostrea*	7.60	3.96	4.34	-	[37]

L_∞ - Asymptotic length, K - Growth co-efficient, φ - Growth performance index, T - Temperature.

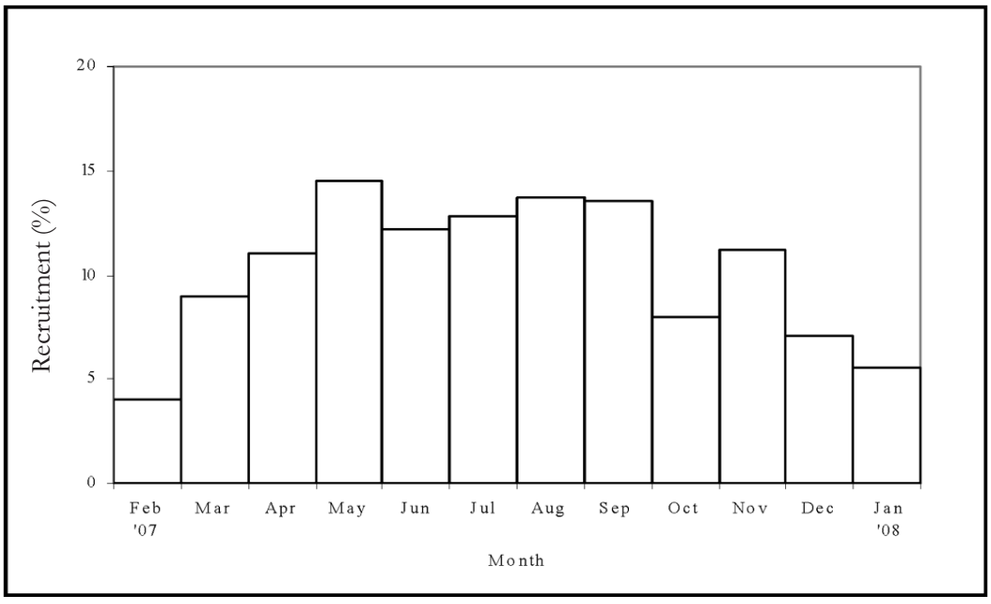

Figure 6. Recruitment pattern of *P. viridis* in the Naf River coast, Bangladesh during the study period.

REFERENCES

[1] Parulekar A.H., Dalal S.G., Ansari Z.A. and Harkantra S.N., Environmental physiology of raft-grown mussels in Goa, India, *Aquaculture,* 1982; **29:** 83-93.

[2] Mallia J.V., Muthiah P. and Thomas P.C., Growth of triploid oyster, *Crassostrea madrasensis* (Preston), *Aqua. Res.,* 2006; **37:** 718-724.

[3] Chatterji A., Ansari Z.A., Ingole B.S. and Parulekar A.H., Growth of the green mussel, *Perna viridis* (L.) in a sea water circulating system, *Aquaculture,* 1984; **40:** 47-55.

[4] Srinibhadh A., Role of aquaculture in economic development within South-East Asia, *J. Fish. Res. Board Can.,* 1976; **33(4):** 899-901.

[5] Hunt H.L. and Scheibling R.E., Role of early post-settlement mortality in recruitment of benthic marine invertebrates, *Mar. Ecol. Prog. Ser.,* 2002; **155:** 269-301.

[6] Enderlein P. and Wahl M., Dominanace of blue mussels versus consumer-mediated enhancement of benthic diversity, *J. Sea Res.,* 2004; **51:** 145-155.

[7] Jeffs A., Holland R., Hooker, S. and Hayden B., Overview and bibliography of research on the green shell mussel, *Perna canaliculus*, from New Zealand waters, *J. Shell fish Res.,* 2002; **18:** 1-14.

[8] Buchanan S. and Babcock R., Primary and secondary settlement by the green shell mussel *Perna canaliculus*, *J. Shell fish Res.,* 1997; **16:** 71-76.

[9] Zeldis J., Robinson K., Ross A. and Hayden B., First observation of predation by New Zealand green shell mussels (*Perna canaliculus*) on zooplankton, *J. Exp. Mar. Biol. Ecol.,* 2004; **311:** 287-299.

[10] Ahmed A.T.A., Islam R. and Sanaullah M., A preliminary report on the molluscan fauna of the Bay of Bengal with notes on their ecology, *J. Asia. Soc. Bangladesh (Sc.),* 1978; **3(2):** 59-82.

[11] Ali S., Notes on a collection of shells from the St. Martin's Island, *Bangladesh J. Zool.,* 1975; **3:** 153-154.

[12] Ali S. and Aziz K.M.S., A systematic account of molluscan fauna of the St. Martin's Island, *Bangladesh J. Zool.,* 1976; **4:** 23-33.

[13] Ahmed A.T.A., Identity and abundance of molluscan fauna of the Bay of Bengal, Bangladesh Agricultural Research Council, Dhaka, 1990.

[14] Wahab M.A. and Amin S.M.N., Assessment of abundance, distribution and standing crops of green mussel (*Perna viridis*), clam (*Meretrix meretrix*) and oyster (*Crassostrea sp.*) and their harvest as a potential alternative livelihood option for poor individual and groups within coastal communities, Support for University Fisheries Education and Research (SUFER) Project, DFID, University Grants Commission, Dhaka, Bangladesh, 2004; 37pp.

[15] Mancera E. and Mendo J., Population dynamics of the oyster *Crassostrea rhizophorae* from the Cienaga Grande de Santa Marta, Colombia, *Fish. Res.,* 1996; **26:** 139-148.

[16] Blaber S.J.M., Staunton-Smith J., Milton D.A., Fry G., Velde T.V., Pang J., Wong P. and Boon-Teck O., The biology and life-history strategies of Ilisha (Teleostei: Pristigasteridae) in the coastal waters and estuaries of Sarawak, *Estuar. Coast. Shelf Sci.,* 1998; **47:** 499-511.

[17] Amin S.M.N., Rahman M.A., Haldar G.C., Mazid M.A. and Milton D., Population dynamics and stock assessment of Hilsa shad, *Tenualosa ilisha* in Bangladesh, *Asia. Fish. Sci.,* 2002; **15:** 123-128.

[18] Al-Barwani S.M., Arshad A., Amin S.M.N., Japar S.B., Siraj S.S. and Yap C.K., Population dynamics of the green mussel *Perna viridis* from the high spat-fall coastal water of Malacca, Peninsular Malaysia, *Fish. Res.,* 2007; **84:** 147-152.

[19] Wacker A. and Elert E.V., Food quality controls reproduction of the zebra mussel (*Dreissena polymorpha*), *Oecologia,* 2003; **135:** 332-338.

[20] Gayanilo F.C., Sparre P. and Pauly D., The FAO-ICLARM Stock Assessment Tools (FiSAT) users guide, FAO computerized information series, fisheries, FAO, Rome, 1996; 126 pp.

[21] Ricker W.E., Computation and interpretation of biological statistics of fish populations, *Bull. Fish. Res. Board, Canada,* 1975; **191:** 382 pp.

[22] Quinn T. and Deriso R.B., *Quantitative fish dynamics,* Oxford University Press, New York: 1999; 542 pp.

[23] Scherrer B., *Biostatistique,* Morin, Montreal, Paris. SPSS Inc. 1999. Systat version 9. SPSS Inc., USA, 1984.

[24] Formacion S.P., Rongo J.M. and Sambilay V.C., Extreme value theory applied to the statistical distribution of the largest lengths of fish, *Asia. Fish. Sci.,* 1991; **4:** 123-135.

[25] Pauly D. and David N., ELEFAN-1 BASIC program for the objective extraction of growth parameters from length frequency data, *Meeresforschung,* 1981; **28:** 205-211.

[26] Pauly D. and Munro J.L., Once more on the comparison of growth in fish and invertebrate, *Fishbyte,* 1984; **2:** 21.

[27] Murty V., Srinath M., Livingston P., Appannasastry Y. and Srinivasarengan S., Stock assessment of silverbelies of India with particular reference to Andra Pradesh and Tamil Nadu, *Indian J. Fish.,* 1992; **39(1):** 42-64.

[28] Gulland J.A., *The fish resources of the oceans,* West by fleet survey. Fishing News (Books) Ltd., FAO: 255, 1971.

[29] Carlander K., *Handbook of freshwater fishery biology*, Vol. 1. The Iowa State University Press, Ames, 1977; **1A:** pp.431.

[30] Ecoutin J.M., Albaret J.J. and Trape S., Length-weight relationships for fish populations of a relatively undisturbed tropical estuary: the Gambia, *Fish. Res.,* 2005; **72:** 347-351.

[31] Lee S.Y., The population dynamics of the green mussel, *Perna viridis* (L) in Victoria Harbour, *Asia. Mar. Biol.,* 1985; **2:** 107-118.

[32] Narasimham K.A., Dimensional relationships and growth of green mussel *Perna viridis* in Kakinada Bay, *Indian J. Fish.,* 1981; **28:** 240-248.

[33] Tuaycharoen S., Vakily J.M., Saelow A. and McCoy E.W., *Growth and maturation of the green mussel (Perna viridis) in Thailand,* In McCoy E.W. and Chongpeepien T., ed. Bivalve mollusc culture research in Thailand, Department of Fisheries, Bangkok, Thailand. International Center for Living Aquatic Resources Management, Manila, Philippines, *ICLARM Technical Reports,* 1988; **19:** 88-101.

[34] Hossain M.S., Shamsuddoha M. and Akhteruzzaman M., Mollusc aquaculture for sustainable coastal livelihood, Support for University Fisheries Education and Research (SUFER) Project, DFID, University Grants Commission, Dhaka, Bangladesh, 2004.

[35] Laudien J., Brey T. and Arntz W.E., Population structure, growth and production of the surf clam *Donax serra* (Bivalvia, Donacidae) on two Namibian sandy beaches, *Estuar. Coast. Shelf Sci.,* 2003; **58:** 105-115.

[36] Vakily J.M., Determination and comparison of bivalve growth, with emphasis on Thailand and other tropical areas, International Center for Living Aquatic Resources Management, Manila, Philippines, ICLARM Technical Report 36, 1992; 125 pp.

[37] Angell C.L., The biology and culture of tropical oysters, International Center for Living Aquatic Resources Management, Manila, Philippines. ICLARM Study Review, 1986; **12:** 42.