

Population Parameters of Green Mussel, *Perna viridis* (Linnaeus, 1758) from Ye Estuary, Mon Coastal Area, Myanmar

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Abstract - Green mussel, *Perna viridis* samples which inhabit in the subtidal bed of Ye Estuary were monthly collected from March 2016 to February 2017 to estimate the population parameters using length-frequency data based analysis of FiSAT II software. Asymptotic length (L_{∞}), growth coefficient (K) and growth performance index (Φ') were calculated as 162.75 mm, 0.87 year⁻¹ and 4.363 respectively. Total mortality (Z), natural mortality (M) and fishing mortality (F) were estimated at 1.86 year⁻¹, 0.81 year⁻¹ and 1.05 year⁻¹. The calculated exploitation level (E) of the population was 0.44 and it (< 0.50) suggests that the stock of *P. viridis* shows the potential for exploitation in Ye Estuary. More exploitation is possible and could be an option for the livelihood of the coastal communities of the area. The recruitment pattern was continuous with one major peak in the months of June-July. The present results could serve as a baseline information for the management of mussel population in Ye Estuary.

Keywords: Exploitation, *Perna viridis*, population parameters, Ye Estuary, Myanmar

I. INTRODUCTION

Green mussel, *Perna viridis*, is one of the popular edible bivalve molluscs inhabited along rocky shore of Sitaw and in the subtidal area of Ye Estuary, Mon coastal area, Myanmar. It is one of the most important bivalves for daily income of local fishermen and it stands second price to the oyster *Crassostrea belcheri*. According to the local mussel fishermen, though the population of *P. viridis* was abundantly observed on the rocky shore of Sitaw last 20 years ago, it is being reduced and the settlement of spats on the rocky substrate cannot support to initiate the mussel farming in the present study area. This may be because of harvesting them before they reached the maturity state. However, rich mussel beds are on the subtidal rocks under about 10 meters below surface water. The mussel fishermen from Zeephuthaung village collect the mussels from the subtidal mussel bed in Ye River Mouth by using diving equipment and chisel. For any given population in an area, the resources available are limited. Hence, a correct understanding of the interactions between the population and its resources is very essential for the sustenance of the population.

P. viridis meat is a valuable source of food for human consumption due to its high quality protein as well as well-balanced nutritional composition such as essential amino acids (Saritha et al., 2015). It is an ideal candidate for aquaculture and commercial cultivation of green mussel is extensively carried out in tropical countries to supply of affordable protein to coastal community (Rajagopal et al.,

2006). A proper management of this stock in Ye Estuary is, therefore, essential for its being commercially important aquaculture organism for human consumption and for the initiation of commercial mussel farming in this area. A thorough knowledge of various growth parameters and sustainable levels of exploitation could go a long way in the scientific management of these valuable bounties. For the management of mollusc resources, knowledge of various population parameters and exploitation level (E) of that population is required. The study of mortality (death rate) and natality (birth rate) are very useful in the estimation of mussel stocks. The estimation of mortality rate is the basic requirement in bivalve stock assessment studies and it can give us an idea about the level of stock available for exploitation.

Although several works have been conducted on fish and prawns in Myanmar, there is still no detailed report regarding the population dynamics and exploitation status of green mussel fishery in Myanmar. The population parameters such as length-frequency distribution, asymptotic length (L_{∞}), growth coefficient (K), growth performance index (Φ'), recruitment pattern, mortality rates (Z , F and M), and exploitation level (E) of *P. viridis* in Ye River Mouth was, therefore, estimated in this study to generate baseline information, which will be essential for future studies and also crucial for sustainable management of the mussel population and to initiate the mussel culture in Ye Estuary.

II. MATERIALS AND METHODS

To study the population parameters of *Perna viridis* which inhabits in the subtidal water of Ye Estuary (Lat. 15° 11' N, Long. 97° 48' E), the samples were randomly collected from the subtidal natural mussel beds during March 2016 - February 2017 (Figure 1). The collected samples were cleaned and directly transferred to the laboratory of Marine Science Department, Mawlamyine University, by using cool box under humid condition. The shell-length (i.e. maximum distance along the long axis of the valves) of each specimen was measured to the nearest 1mm with digital Vernier Calipers. The data were then grouped into total shell length classes by 10 mm intervals. Subsequently the data were analyzed using the FiSAT software as explained in detail by Gayanilo et al., (1996). Asymptotic length (L_{∞}) and growth coefficient (K) of the von Bertalanffy growth function (VBGF) were estimated by means of ELEFAN-1 (Pauly & David, 1981). K -scan routine was conducted to assess a reliable estimate of the K value. The estimates of L_{∞} and K were used to estimate the growth performance index (Φ') of *P. viridis* using the equation: $\Phi' = 2 \log_{10} L_{\infty} + \log_{10} K$ (Pauly and Munro, 1984).

The theoretical age at zero length (t_0) was calculated as: $\text{Log}_{10}(t_0) = 0.392 - 0.275 \text{Log}_{10} L_{\infty} - 1.038 \text{Log}_{10} K$ (Pauly,

1979). Longevity (t_{max}) of the population was estimated according to the equation: $t_{max} = 3/K$ (Pauly, 1984). The inverse von Bertalanffy growth equation (Sparre & Venema, 1992) was used to find the lengths of the *P. viridis* at various ages. Then VBGF was fitted to estimates of length-at age curve using non-linear squares estimation procedures. The VBGF is defined by the equation: $L_t = L_{\infty}[1 - e^{-K(t-t_0)}]$ (Pauly et al., 1992), where L_t is the mean length at age t , L_{∞} the asymptotic length, K the growth coefficient, t the age of the *P. viridis* and t_0 is the hypothetical age at which the length is zero (Newman, 2002).

The total mortality (Z) was estimated by a length converted catch curve method (Pauly, 1984). Natural mortality rate (M) was estimated using the empirical relationship of Pauly (1980): $\log_{10}M = -0.0066 - 0.279 \log_{10}L_{\infty} + 0.6543 \log_{10}K + 0.4634 \log_{10}T$, where M is the natural mortality, L_{∞} the asymptotic length, K refers to the growth coefficient of the VBGF and T is the mean annual habitat temperature ($^{\circ}C$) of the water in which the stocks live. Once Z and M were obtained, then fishing mortality (F) was estimated using the relationship: $F = Z - M$, where Z is the total mortality, F the fishing mortality and M is the natural mortality. The exploitation level (E) was obtained by the relationship of $E = F/Z$ and $Z = F + M$ (Gulland, 1965).

The recruitment pattern which describes how new individuals are added onto the population was determined by the backward projection onto the length axis of the length-frequency data as described in FiSAT. This routine reconstructs the recruitment peak pulses from a time series of length-frequency data to determine the number of peak pulses per year and relative strength of each peak pulse (Al-Barwani et al., 2007). Input parameters are L_{∞} , K , and t_0 , and the normal distribution of the recruitment pattern was determined by NORMSEP in FiSAT (Pauly & Caddy, 1985; Al-Barwani et al., 2007).

III. RESULTS AND DISCUSSION

A. Growth parameters

The present study represents the very first report on the population parameters of *Perna viridis* in the study area as well as in Myanmar. Growth parameters (L_{∞} , K , t_0) are helpful in comparison of growth rates between and within species inhabiting different habitats. The comparison with population parameters of *P. viridis* estimated from VBGF at Ye Estuary differ from those of the same species from other different areas in the world (Table 1). In the present study, a total of 599 *P. viridis* was analyzed for their size-frequency distribution, and the mussel population had a shell length range of 50mm to 163mm. The overall size-frequency distribution (Figure 2) showed a modal shell length of 100-110mm.

Estimated values of growth parameters such as asymptotic length (L_{∞}) of the VBGF and the hypothetical age of birth at zero length (t_0) for *P. viridis* were 162.75 mm and -0.70246. The computed growth curve using these parameters is shown over the restructured length distribution in Figure 3. Asymptotic length (L_{∞}) is the maximum theoretical length an organism can attain under the given rate of growth (Hemachandra et al., 2017). The lowest value of L_{∞} (75.40 mm) is from India (Thejasvi, 2016) and the highest value (194.30 mm) is in Bangladesh (Nural Amin et al., 2005). In

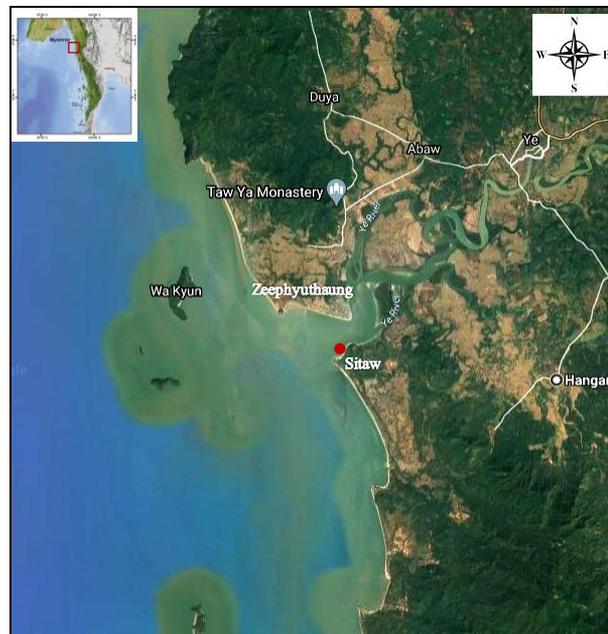


Figure 1. Sampling station of *Perna viridis* in Ye Estuary

the present study, the value of asymptotic length (L_{∞} =162.75 mm) of the mussel from Ye Estuary was relatively smaller than that recorded for *P. viridis* (L_{∞} =184.60mm) from Kakinada Bay, India (Narasimham, 1981) and (L_{∞} =194.30 mm) from intertidal region of Moheskhal Channel, Bangladesh (Nural Amin et al., 2005). This value was higher compared to those in India waters at 75.4 mm, 85 mm, 110 mm 117.50 mm, 136.9 mm (Thejasvi, 2016; Rivonkar et al., 1993; Chatterji et al., 1984; Thejasvi, 2016; Hemachandra et al., 2017), in Bangladesh waters at 124.65 mm, 136.5 mm (Kamal & Khan, 1998; Khan et al., 2010), in Thailand waters at 112 mm Tuaycharoen et al., 1988, in Malaysia waters at 89.4 mm, 102.4 mm, 113.4 mm, 120.75 mm (Choo & Speiser 1979; Al-Barwani et al., 2007; Taib et al., 2016; Kassim et al., 2017) and in Hong Kong waters at 101.9 mmm (Lee, 1985), respectively.

The observed maximum length was 155 mm and the predicted maximum length estimated from the present study was 163.28 mm (Figure 4). The confidence interval was 157.33–169.24 mm (95% probability of occurrence). The best estimated value of growth coefficient (K) was 0.87 year⁻¹ and the growth performance index (Φ') was 4.363 (Figure 5). The coefficient K is the rate at which the animal approaches to the theoretical maximum length and it can be used to compare between the growth of related species or some species in varied habitats. The highest K value (2.14 year⁻¹) was obtained in Malaysia Choo & Speiser 1979 and the lowest value (0.1 year⁻¹) was reported from Zuari estuary, India (Rivonkar et al., 1993). It was observed that the K value (0.87 year⁻¹) of *P. viridis* in the present study was higher than those of *Perna viridis* in India waters (except the result of Thejasvi, 2016), Bangladesh waters (except the result of Khan et al., 2010) and in Hong Kong waters (Lee, 1985) but the value K is more or less closed to those of *P. viridis* reported from Thailand waters (Tuaycharoen et al., 1988). Highest K values (2.14 year⁻¹ and 1.7 year⁻¹) were from Malaysia waters (Choo & Speiser, 1979; Taib et al., 2016) which are higher than the results of present study (Table 1).

The growth performance index (Φ') allows inter-and intra-specific comparison of growth performance in bivalve species of different stock (Abohweyere & Falaye, 2008; Adjei-Boateng & Wilson, 2012). The growth performance index value of *P. viridis* ($\Phi'=4.363$) at Ye Estuary in the present study was the highest value in the results reported from other countries (Table 1). The high Φ' values were reported from Thailand at $\Phi'=4.0984$ (Tuaycharoen et al., 1988) and from Malaysia waters at 4.1965, 4.2331 and 4.3425, respectively (Al-Barwani et al., 2007; Choo & Speiser 1979; Taib et al., 2016).

Growth performance of bivalves could be as a result of influences of environmental factors, and thus, bivalves found at different geographical locations may have different growth performance indices which could be as a result of the prevailing environmental conditions (Krampah et al., 2019). Most of the lower Φ' values were reported from *P. viridis* inhabiting along the intertidal regions of India and Bangladesh waters. The mussels in the intertidal zone are exposed to atmosphere during low tide and hence are under stress continuously when compare to the subtidal natural population of Kakinada Bay, and Ye Estuary (present study) and the subtidal cultured mussels of Thailand and Malaysian waters (Table 1).

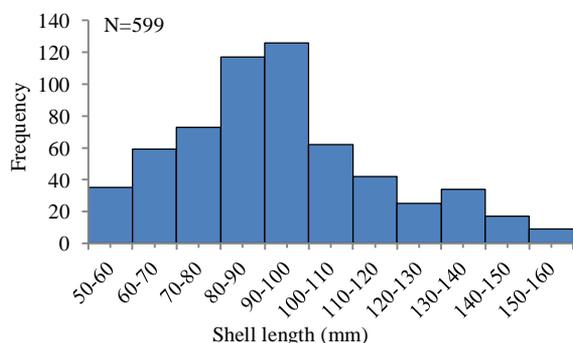


Figure 2. Length frequency distribution of *Perna viridis* from Ye Estuary

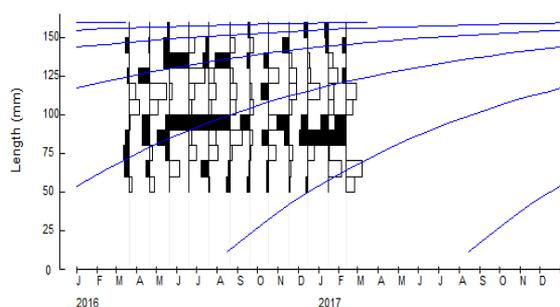


Figure 3. Restructured length–frequency distribution with growth curves superimposed using ELEFAN-1 ($L_{\infty} = 162.75$ mm and $K = 0.87$ year⁻¹)

B. Age and growth

The von Bertalanffy's growth equation substituted with the growth parameters (L_{∞} , K and t_0) estimated from the length frequency data of *Perna viridis* from Ye Estuary could be expressed as $L_t = 162.75 [1 - e^{-0.87(t - (-0.70246))}]$. Therefore, the size attained by *P. viridis* were 86.34, 96.66, 105.58, 113.30,

119.97 and 125.74 mm at the end of 2,4,6,8,10,12 months of age, respectively and 125.74 mm in 1 year, 147.25 mm in 2year, 156.26 mm in 3 year and 160.03 mm in 4 year of age from the theoretical age of fish at birth in its life. The absolute increase has been represented in Figure 6. The calculated average growth rate of *Perna viridis* for the first 6 months was 17.60 mm/month and in the following 6 months was 3.36 mm/month.

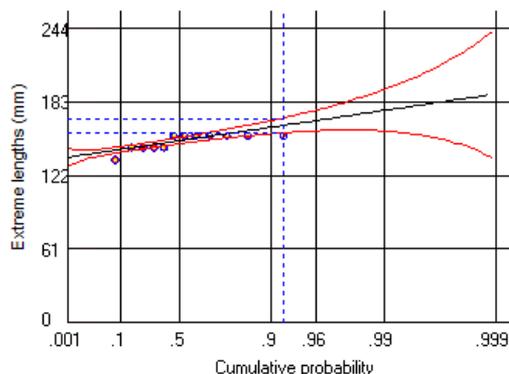


Figure 4. Estimation of maximum length *Perna viridis*

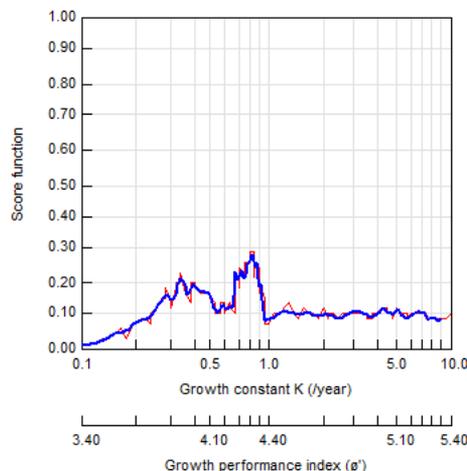


Figure 5. Growth constant (K) and growth performance index (Φ') of *Perna viridis*

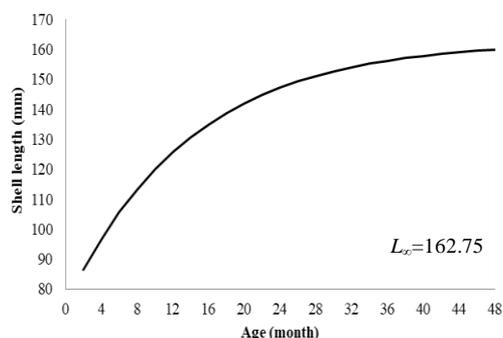


Figure 6. Derived growth curve of *Perna viridis* from Ye Estuary

The longevity (t_{max}) of *P. viridis* was approximately 4 years was estimated for the mussel population in Ye Estuary. From the von Bertalanffy growth equation, the length of *P. viridis* from Ye Estuary at age 1 was 125.74 mm, which suggests that the mussel grows at an average length of

10.48 mm per month. The observed lifespan (4 years) of *P. viridis* from Ye Estuary is higher than approximately 2 years of lifespan reported from the offshore waters of Naf River Coast Bangladesh (Khan et al., 2010) and coastal waters of Malacca, Peninsular Malaysia (Al-Barwani et al., 2007) and also higher than average lifespan of 3 years for *P. viridis* in Hong Kong waters (Lee, 1985). However, Thejasvi (2016) estimated the age of *P. viridis* inhabiting in the subtidal bed of Amdalli was approximately 14 years while mussels inhabiting along the intertidal region of Mukka had a lifespan of 2.25 years in India waters. However the species *Perna perna* from Iture rocky beach, Ghana, India, has a relatively longer lifespan of 6 years with smaller asymptotic length of $L_{\infty}=80.10$ mm (Krampah et al., 2019). The lifespan for the tropical species of the genus *Perna* has been reported to be 4-6 years (Lutz, 1980).

C. Mortality and exploitation

Figure 7 illustrates the length-converted catch curve of *P. viridis* which estimated the total mortality rate (Z) of the populations based on mussels that were fully exploited. The annual mean surface temperature during the sampling period was 30.0°C. In the present study, the total mortality (Z) of *P. viridis* based on the length converted catch curve was 1.86 year⁻¹. The estimated natural mortality (M) was 1.05 year⁻¹ and fishing mortality (F) was 0.81 year⁻¹. Mortality is an important aspect in the population dynamics of mussels (Fabens, 1965) and it could vary enormously depending on environmental conditions. Higher natural mortality versus fishing mortality observed for *P. viridis* in this study indicates an imbalance in the stock. The observation of higher natural mortality in the present study is similar to the findings of the workers from Bangladesh and Malaysia (Nural Amin et al., 2005; Al-Barwani et al., 2007; Khan et al., 2010) and it suggests that mortality based on natural causes was higher than that of exploitation of the mussel in those areas. On the other hand, higher fishing mortality was observed than natural mortality for *P. viridis* in India (Thejasvi, 2016; Hemachandra et al., 2017), indicating that mortality based on exploitation was relatively higher than that based on natural cause. It is undoubtful that predation is the most significant unique source of natural mortality (Karayücel & Karayücel, 1999). Nevertheless, cause for mortality is also attributable to the rampant amount of metabolic stress in relation with spawning (Emmet et al., 1987; Tremblay et al., 1998).

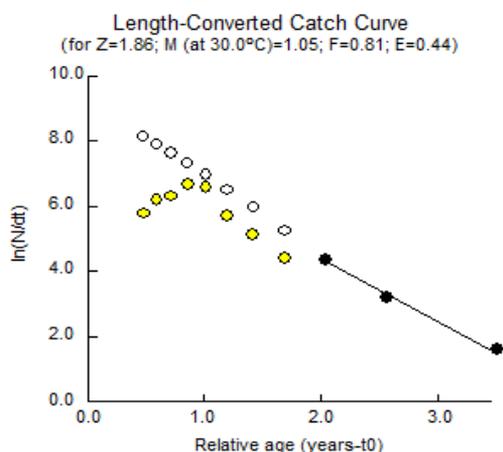


Figure 7. Length converted catch curve of *Perna viridis* from Ye Estuary

The estimated exploitation level (E) of *P. viridis* in Ye Estuary was 0.44. According to Gulland (1965), the yield is optimized when fishing mortality (F) is equal to natural mortality (M); therefore, when the exploitation rate (E) is more than 0.5, the stock is over-fished. Theoretically when $E=0.50$, then the stock of any aquatic species is at the optimum level. The lower value of exploitation level ($E=0.44$) in the present study indicates the 'under-fishing' condition of *P. viridis* in the study area. The lower E values were also estimated from the population of *P. viridis* at $E=0.04$ in Moheskhal channel of Bangladesh water Nural Amin et al., 2005 and at $E=0.32$ from the coastal region of Malaysia water (Al-Barwani et al., 2007). However the high exploitation rates of *P. viridis* reported at $E=0.67$ from intertidal region at Mukka Thejasvi, 2016, at $E=0.77$ from subtidal bed at Amdalli (Thejasvi, 2016) and at $E=0.64$ from intertidal region of St. Mary's group (Hemachandra et al., 2017) in India waters indicating that 'over-fishing' of this species at those areas.

D. Recruitment pattern

The recruitment pattern of *P. viridis* from FiSAT II software for the population at Ye Estuary is shown in Figure 8. The recruitment pattern of *P. viridis* in the present study was continuous throughout the year with the only major peak which observed during June-July. The peak pulse produced 15.51% of the observed recruitment during the study period. The Recruitment has been described as a continuous phenomenon for tropical species because of the relatively stable and elevated water temperatures allowing year-round breeding (Adjei-Boateng & Wilson, 2012; Qasim, 1973; Weber, 1976). The observation of one seasonal pulse of recruitment pattern in the present study is similar to the findings by Al-Barwani et al., (2007) who also observed one seasonal peak (July-August) in the recruitment pattern of *P. viridis* in the coastal waters of Malacca, Peninsular Malaysia and also by Thejasvi (2016) who observed one seasonal peak (April-June) in the recruitment pattern of the same species in the intertidal region at Mukka and in the subtidal bed at Amdalli, India. Two seasonal pulses, however, were observed from Moheskhal channel (March-May & August-October) and Naf river coast (March-June & July-September) in Bangladesh waters (Nural Amin et al., 2005; Khan et al., 2010) and also from Maruda Bay (July & February), Malaysia (Taib et al., 2016).

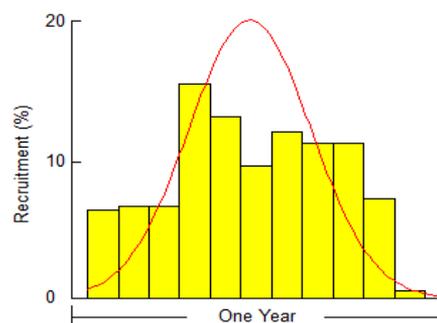


Figure 8. Recruitment pattern of *Perna viridis* from Ye Estuary

Table 1. Comparison on growth parameters of *Perna viridis* reported from different countries

Location	Habitat	L_{∞} (mm)	K (yr^{-1})	Φ'	Temp.	Source
India	subtidal bed, Kakinada Bay	184.6	0.25	3.9304		Narasimham, 1981
	Raft culture, Dona Paula, Goa	110	0.11	3.1336		Chatterji et al., 1984
	Raft culture, Zuari estuary, Goa,	85	0.1	2.8648		Rivonkar et al., 1993
	Intertidal region at Mukka	75.4	1.51	3.5758		Thejasvi, 2016
	Subtidal bed, Amdalli	117.50	0.28	3.5872		Thejasvi, 2016
	Intertidal region at Coconut Island of St. Mary's group of Islands off Malpe	136.9	0.42	3.8960		Hemachandra et al., 2017
Bangladesh	Piers of Moheshkhali jetty, Bay of Bengal	124.65	0.1	3.1938		Kamal & Khan, 1998
	Intertidal region at Cox's Bazaar, Moheshkhali Channel	194.3	0.56	2.32	28	Nural Amin et al., 2005
	Naf river coast	136.5	1.3	2.38	30.2	Khan et al., 2010
Thailand	Pole culture, Upper Gulf	112	1.00	4.0984		Tuaycharoen et al., 1988
Malaysia	Suspended plastic cage, Penang	89.4	2.14	4.2331		Choo & Speiser 1979
	Coastal region, Malacca	102.4	1.5	4.1965	29.44	(Al-Barwani et al., 2007)
	hanging rope method, Maruda Bay	113.4	1.7	4.3425		Taib et al., 2016
	hanging rope method, Kesang coastal water	120.75	0.66	3.9810		Kassim et al., 2017
Hong Kong	Victoria Harbor	101.9	0.30	3.5411	24 - 29	Lee, 1985
Myanmar	subtidal bed, Ye Estuary	162.75	0.87	4.363	30	present study

IV. CONCLUSIONS

The high asymptotic length (L_{∞} =162.75 mm) and growth constant value (K =0.87 year⁻¹) estimated from the present study indicates that the growth of *Perna viridis* from Ye Estuary is higher than those of other countries. The stock of *P. viridis* in the study area is underexploited since natural mortality is higher than fishing mortality. It could be concluded that the stock of the green mussel shows the potential for exploitation in Ye Estuary. More exploitation is possible and could be an option for the livelihood of the coastal communities of the area. However, the exploitation rate (E =0.44) is closed to the optimal level (E =0.5). Therefore, the population of *P. viridis* in Ye Estuary would require the initial action to manage this valuable fishery and ecological resource and to initiate the culture of this species.

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