GROWTH OF *PERNA VIRIDIS* (LINNAEUS, 1758) FROM EXPERIMENTAL RACK CULTURE IN SITAW, YE ESTUARY, SOUTHERN MON COASTAL AREA

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Abstract

The study on the experimental rack culture of *Perna viridis* (Linnaeus, 1758) was conducted in Sitaw, Ye estuary (Lat. 15º 11' N, Long. 97º 48' E), Southern Mon coastal area. The mussel seeds (8.64 ± 0.73) were collected from the rocky shore of Sitaw and planted in "Plastic baskets" to evaluate their growth and survival rate between May 2016 and April 2017. The result showed that the seeded mussels attained 90.03±11.46 mm in length within 1 year with a mean growth rate of 7.28 mm/month. The length frequency data of 60 individuals of green mussels were analyzed using the latest version of the FAO-ICLARM Fish Stock Assessment Tools (FiSAT II). The estimated asymptotic lengths (L_∞) and growth coefficient (k) of the cultivated Asian green mussel in Ye estuary were relatively high at 120.23 mm and 1.3 year^{-1}. The environmental parameters of Ye estuary seem to favor for the growth and high survival rate (>90%) of mussel. The optimum sizes of around 10-25 mm mussels should be seeded and the culture period of around 5 months was optimum in a favorable season. The information provided here will certainly make small scale farming of mussels more popular and generate greater employment opportunities and income in the future.

Keywords: *Perna viridis*, Growth, Southern Mon coastal area, Survival, Ye estuary.

Introduction

The green mussel, *Perna viridis* (Linnaeus, 1758) belongs to the Phylum Mollusca, Class Bivalvia and the Family Mytilidae. This mussel is under Order Mytiloida and Genus *Perna*. Despite *P. viridis* distributes in its native tropical waters of the Indo-Pacific region of Asia (Siddall, 1980), it had been recently introduced to the other regions and finally to South Africa (Micklem, 2014). In Myanmar, *P. viridis* distributes along three coastal areas and this species is locally called Yawt Twar and Gone Sein in Rakhine Coastal Region, Be-wun in Mon Coastal Region, and Kha-yu-nyo in Taninthayi Coastal Region.

P. viridis is extensively cultured due to its high productivity, high tolerance to a wide range of environmental conditions and requiring less farm management (McFarland *et al*., 2013). Commercial cultivation of marine mussel *Perna* is extensively carried out in several countries (FAO, 2017) especially in the Southeast Asian region. Thailand and Philippines are the major green mussel producers followed by India, Malaysia and Singapore (Saraya, 1982; Vakily, 1989; Sasikumar, 2007). Nearly two hundred and eighty two thousand tonnes of *P. viridis* is produced worldwide per year through culture (FAO, 2009). The tropical and subtropical marine mussel *P. viridis* achieves marketable size relatively within a short culture period of about 6 months (Sivalingam, 1977; Smaal, 1991; Rajagopal *et al*., 1998a)

The consuming of green mussel in Mon coastal area is only dependent on the natural mussel beds. Rich green mussel beds are in the subtidal rocky substrates and stretches up to in Ye River. Mussels are removed from natural bed, mainly for local consumption as food and for local fishermen income. The mussel fishing is done as off times occupation by the fishermen mainly during 7 a.m to 9 a.m. They collect mussels from intertidal rocks using iron implements like chisels with or without wooden handle or a knife during low tide. Some of them collect the mussels from

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the submerged mussel bed by diving with the aid of air compressor. The green mussel fishery, however, is self-regulated in Sitaw, Ye estuary. The mussel pickers stop mussel picking during the southwest monsoon season because of turbulence and strong current in this season. The peak mussel picking occur during the post monsoon season (September to May) after the self-imposed control on mussel picking during the monsoon months. After fishing, they dispose them off to the customers in fresh condition. In recent years the fishermen exploit mussels from the natural beds even before the mussels reach the harvestable size and the population of mussels on this area is, therefore, being reduced.

Perna viridis meat is one of the chief protein sources for human consumption from marine resources and it is popular for its delicious taste, containing high nutritional values (Taib *et al*., 2016). Some aspects of their biology relevant to fishery and culture have, therefore, been studied by several workers around the world. There are only few researches on the biology and culture of *P. viridis* in Myanmar. Tin Nu (1985) studied the spatfall of *P. viridis* in the present study area. She investigated the monthly growth rate, survival and mortality of *P. viridis* and discussed their relationship with the environmental parameters. Myo Nandar Myint (2014) studied on the spat fall of green mussel *P. viridis* in Myeik coastal waters. She stated the general diagnostic characters of this species. The techniques for mass culture of *P. viridis* are required to fulfill the food requirement for local people and their employment at Myanmar coastal areas. This study aims to investigate the growth performance and survival of *P. viridis* cultivated on rack system in Ye estuary and to initiate the green mussel farming in coastal waters of Myanmar.

Materials and Methods

Study area: The study on the experimental culture of green mussel was conducted at Sitaw, Ye estuary (Lat. 15º 11' N, Long. 97º 48' E), about three-fourth mile to the southeast across the mouth of Ye River, from Zeephyuthaung Village, Ye Township, southern Mon coastal area (Fig. 1). Sitaw is an intertidal rocky shore area and it is known for a daily level fishery of fish, gastropods, green mussel and oyster. The river is mostly rain-fed and the flow is closely related to the seasonal rainfall. During the monsoon season (June-September), the river frequently overflows while during the dry months (November-April), the river often experience periods of reduced flow. During low water spring tide, sand bars are formed in the mouth of river.

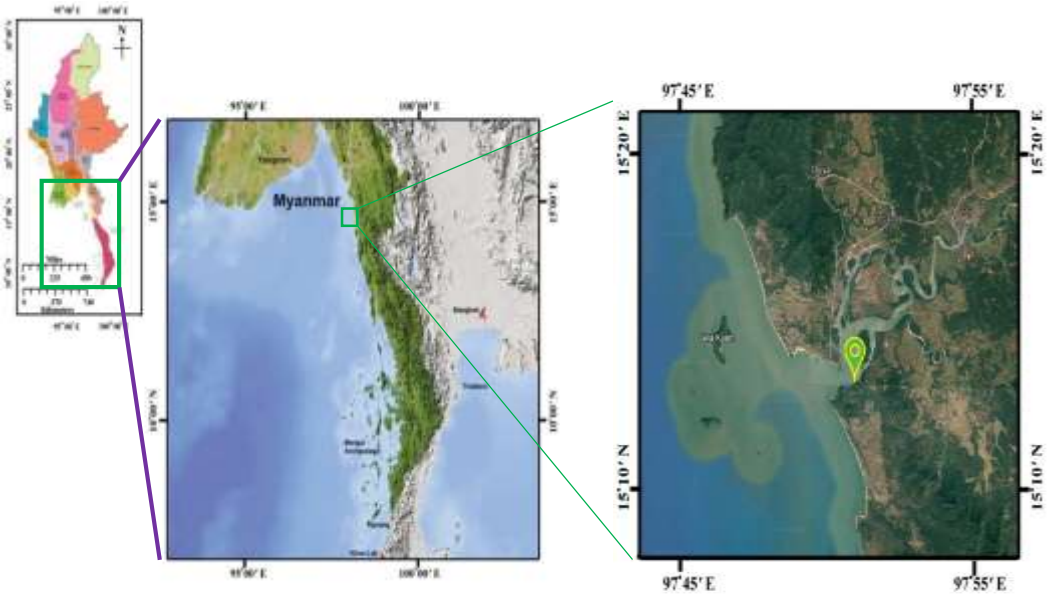

Figure 1 Map showing the experimental rack culture site in Sitaw (Source: Google Maps).

Rack structure and mussel seeding: For studying the mussel growth, a wooden rack (4 m x 2.5 m) was constructed in the subtidal zone of Sitaw, Ye estuary (Fig. 2 A) where water depth was about 2 m at low water spring tide and about 7 m at high water spring tide. Mussel seeds of length about 10 mm (Fig. 2B) collected by using a chisel from their natural habitat in the intertidal rocky shore of Sitaw were cleaned and placed into the cages. The baskets (2ft length ×1.5ft length × 1ft height) were used as the cages for mussel seeding. Then the seeded cages were tied with nylon ropes and suspended in the water column from the rack with the bottom of the baskets about 1 m above the sea bed to study growth rate and survival rate of the mussels.

Figure 2 A-C. Experimental rack culture of *Perna viridis*: **A**) Rack for mussel seeding; **B**) Mussel seeds on the rocky shore; **C**) Measuring shell length.

Envirionmental Parameters: The mean values of salinity, temperature and pH were recorded by using Horiba water monitor, refractometer and pH meter at monthly interval. There was marked fluctuations in the salinity during monsoon seasons. The average salinity of the surface water varied from 6.54‰ in August 2016 to 31.4 ‰ in March 2016 and it also varied from 6.38‰ in June 2017 to 30.50‰ in March 2017. Surface water temperature ranged from 27.5°C to 32.2°C in 2016 and from 27.0°C to 32.6°C in 2017. During the experiment, the pH range of the surface seawater was narrow, from 6.4 to 7.6 in 2016 and from 6.2 to 7.4 in 2017. Seasonal variations in environmental parameters of Sitaw are primarily influenced by the prevailing monsoon regime. During the study period, southwest monsoon commenced by the last week of May and the highest rainfall 1210.8 mm was recorded in August 2016 and 1628.14 mm in July 2017.

Data Analysis

Growth Rate: For the analysis on growth rate of *P. viridis* cultured at Ye estuary, the shell length of each specimen was monthly measured to the nearest 0.01 mm with Vernier Calipers (Fig. 2C) and the length data was divided into 8 mm length classes. As no sexual dimorphism could be discerned externally, no effort was made to study the growth related to sex. The data were analyzed using FiSAT II software by length-frequency data analysis (Gayanilo *et al*., 1996).

Asymptotic length (L_∞) and growth co-efficient (k) of the von Bertalanffy Growth Formula (VBGF) were estimated by means of ELEFAN-1 (Pauly and David, 1981). The emphirical growth curve was fitted to the total length data using the von Bertalanffy's growth equation: $L_t = L_\infty [1\text{-}e^{-k(t\text{-}t_0)}]$ 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_0 = arbitrary origin of growth.The growth coefficient (k) was estimated by the least square method following

Bal and Rao (1994) as b=e* where b is the slope of the equation l_t =1 = a + bl_t, and 'e' is the base of natural logarithm.

Specific growth rates for each month were calculated from the mean monthly length attained by the animal according to the formula of Bal and Jones (1960):

$$\mathbf{SGR} = \frac{\mathrm{Log_e}\, L_2 - \mathrm{Log_e}\, L_1}{T_2 - T_1} \times 100$$

Where, $\mathrm{Log_e}$ = natural logarithm, L_2 and L_1 = the shell length at time T_2 and T_1 respectively and the growth was expressed in percentage per month.

Survival Rate: To determine the survival rate of mussels, every individual of each cage were counted for the number of alive mussel. Any mussel having its valve open or having the smell of decomposition was treated as a dead one. The survival of the mussel was expressed in percentage and was calculated using the formula (Vural *et al*., 2015):

$$S=n/N \times 100.$$

Where, S= the survival rate (%) for each sampling, n = the number live mussels for each sampling and N = the initial number stocking. Finally, at the close of experiment, the entire stock of mussels was collected and survival rates (%) were computed from the initial and final data.

Results and Discussion

Growth Rate: The mean monthly length of *Perna viridis* in this study suggests that the animal attained a length of 90.03 mm in a year and the growth rate was 7.28 mm/month (Fig. 3A & Table1). The highest growth rates in *P. viridis* were reported with a maximum growth rate of 9.3 mm/month in the Parasan coastal waters of Indonesia, (Noor *et al*., 2019) and 10 mm/month on the Philippine seashore (Yap *et al*., 1979). Kamal and Khan (1998) reported that the growth of green mussels inhabiting the Moheshkhali jetty, Bangladesh attained a length of 88.12 mm in a year and the growth rate was 7.34 mm/month. The monthly growth rate of 7.2 mm, 6 mm and 5 mm was observed by Sreenivasan *et al*., (1989), Rao *et al*., (1975), and Qasim *et al*., (1977), respectively, for *P. viridis* by the end of the first year, from Indian natural environments. The growth rate of *P. viridis* in the Turpialito Hydrological Station located in the Gulf of Cariaco, north eastern Venezuela was reported as 7.1 mm/month (Urbano *et al*., 2005). The lowest growth rate in *P. viridis* was reported in Hong Kong waters, with a maximum growth rate of 5.1 mm/month (Cheung, 1933). This comparison reveals that the growth of *P. viridis* cultured in Sitaw waters grows faster than those inhabiting some Indian waters and Hong Kong water while this result was slower than those of Indonesia waters and Bangladesh waters.

Figure 3 **A**-C. Experimental grow out culture at Sitaw: A) Growing mussels; B) Accumulation of silt and invertebrate worms in the cage; C) Attachment of oysters on the cage.

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

Month	Average observed length (mm) (Mean ±S.D.)	Growth increment (mm)	Specific growth rate(%)	Length determined by growth equation $L_t = L_\infty[1-e^{-k(t-t_0)}]$
May. 2016	8.64±0.73	-	90.56	14.26
Jun.	21.37±1.94	11.37	37.76	25.14
Jul.	31.17±1.88	9.80	25.36	34.91
Aug.	40.17±2.02	9.00	19.40	43.66
Sept.	48.77±3.37	8.60	14.00	51.52
Oct.	56.10±4.92	7.33	13.38	58.58
Nov.	64.13±6.34	8.03	8.47	64.91
Dec.	69.80±7.81	5.67	8.03	70.59
Jan. 2017	75.63±8.85	5.83	7.96	75.69
Feb.	81.90±10.55	6.27	6.92	80.26
Mar.	87.77±11.55	5.87	2.54	84.36
Apr.	90.03±11.46	2.26	_	88.05
Mean		7.28		

The tropical *P. viridis* farming has a harvesting phase commences when the mussels reach minimum commercial size. An optimal harvest of marketable size is achieved after a culture period of 6 months (Sivalingam, 1977; Rivonkar *et al*., 1993), while Mohamed (2015), stated the harvestable size reached within 4-6 months. The size of *P. viridis* in Pasaran island waters, Indonesia, can reach 57 mm in six months and 79.8 mm in 11 months cultivation (Noor *et al*., 2019). Cheung 1993 reported that *P. viridis* from Hong Kong waters is only able to reach a size of 60 mm/year due to the contaminated and unhealthy water in the cultivation area. Qasim *et al*., (1977) reported that mussels attained marketable size (60-64 mm) in 5 months by rope culture in natural beds at Goa, India. Rao *et al*., (1975) found that mussels reach 60 mm in length in 6 months on floating buoys at Vengurla Bay in the Arabian Sea. Kamal and Khan (1998) also observed that this species grow to 65 mm in length in 6 months on poles of Moheshkhali jetty at Moheshkhali channel, Bangladesh.

Jakate *et al*., (2009) reported green mussels from initial length of 31.2 mm attained the marketable size shell lengths of 63.3 mm and 62.3 mm on nylon rope and nylon strip substrata, respectively, within 5 months. After 5 months, the growth rate was reduced due to freshwater influx, resulting in final average shell length of 67.3 mm for the nylon rope and 65.5 mm for the nylon strip rens, in 7 months. However, Hickman (1992) reported that the marketable size of *P. viridis* can be achieved only after 12-24 months cultivation period in subtropical mussel farming. In the present investigation, mussels attained 64.13 mm within 6 months (Table 1) that shows the potentiality of the present study site as a culture ground.

The growth increment and the specific growth rate of *P. viridis* were faster at the early age than in the later stages (Table 1). The decrease in growth rate and specific growth rate was observed with increase in shell length. These results were agreed with the findings of several workers for *P. viridis* and similar reduction in growth rates were observed in older mussels (Rivonkar *et al*., 1993; Kamal and Khan, 1998; Rajagopal *et al*., 1998a; Kripa *et al*., 2009; Awan *et al*., 2012). The reason for this reduced growth rate may be the reduction in metabolic activity with age, which accounts for decreased growth rate as seen from reduction in specific growth rate.

Growth performance: The values estimated for the parameters of the von Bertalanffy's growth equation are shown in table 1. Substituting these values in the von Bertalanffy's growth equation, the equations for rack culture could be expressed as $L_t=120.23[1-e^{-1.3(t+0.01381)}]$. From the theoretical growth curves, it can be observed from the rack culture that animal attains a length of 88.05 mm, 111.46 mm, and 117.84 mm at the age of 1, 2 and 3 years, respectively (Fig. 4). The computed growth curve with these parameters has been shown over the restructured length distribution in figure 4.

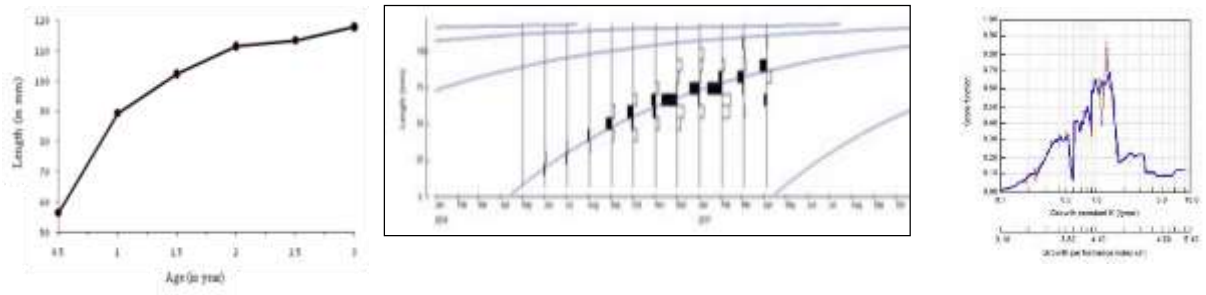

Figure 4 Theoretical growth curve and Von Bertalanffy's growth curves (L_∞= 120.23mm and k= 1.3 year^{-1} for *Perna viridis* superimposed on restructured length-frequency histograms. Black and white bars = positive and negative deviation from 'weighted' moving average of length classes. Number of sample = 60 individuals.)

The asymptotic length (L_∞) suggests the maximum theoretical length of an organism can attain under given rate of growth. The present estimates of L_∞ =120.23 mm is likely to be more accurate estimates for *P. viridis* because the mean monthly length of the mussels varied from 8.64 mm to 90.03 mm (Table 1). In addition, the minimum and maximum length observed from the present rack culture in a year was 62 mm and 115 mm, respectively. This is future supported by the maximum recorded sizes (L_{max} = 115 mm) of the mussels which was very near the estimated values of (120.23 mm). Though variations in L_∞ are related to feeding efficiency, but L_{max}/ L_∞ is constant for a given species.

In the present study, the asymptotic length (L_∞ =120.23 mm) of the cultivated green mussel in Sitaw is closed to those reported in Myeik coastal warters, Southern Myanmar at 118.13 mm (Myo Nandar Myint, 2014) and also closed to those reported in other Asian countries particularly in Malaysia and Thailand at 113.4 mm and 112.0 mm (Taib *et al*., 2016; Tuaycharoen *et al*., 1988). This result also resemble to those reported Bangladesh at 124.6 mm (Kamel and Khan, 1998). This result is higher than those reported at 41.9 mm in India (Rivonkar *et al*., 1993), at 102.4 mm in Malaysia (Al-Barwani *et al*., 2007) and at 101.9 mm in Hongkong (Lee, 1985) while it is lower than those reported at 136.9 mm and 184 mm from India waters (Narasimham, 1981; Hemachandra *et al*., 2017) and at 136.5 mm from offshore waters of Naf River Coast, Bangladesh (Khan *et al*., 2010).

Hemachandra *et al*., (2017) stated that the coefficient "k" (the rate at which the animal approaches the theoretical maximum) can be used to compare between the growth of related species or same species in varied habitats. The "k" value (1.3 yr^{-1}) of the mussel in Sitaw, Ye estuary, was higher compared to those in Myeik coastal waters at 0.37 yr^{-1} (Myo Nandar Myint, 2014), in India waters at 0.25 yr^{-1}, 0.10 yr^{-1} , 0.11 yr^{-1} respectively (Narasimham, 1981; Rivonkar *et al*., 1993; Hemachandra *et al*., 2017), in Thailand at 1.00 yr^{-1} (Tuaycharoen *et al*., 1988), in Hong Kong at 0.30 yr^{-1} (Lee, 1985), and in Moheshkhali channel, Bay of Bengal, Bangladesh at 0.11 yr^{-1} (Kamel and Khan, 1998). The present "k" value (1.3 yr^{-1}) was closed to the "k" values (1.5 yr^{-1} and 1.7 yr^{-1}) from Malaysia waters (Al-Barwani *et al*., 2007; Taib *et al*., 2016). Interestingly, this value was similar to that of *P. viridis* reported from offshore waters of Naf River Coast, Bangladesh (Khan *et al*., 2010).

During the experimental rack culture period, only one dead mussel was observed from 60 seeded mussels in August although the accumulation of silt was occurred throughout the culture period. Therefore, 98.33% survival rate was observed in August and 100% survival was investigated in the other months. The high survival rate of *P. viridis* in Sitaw waters may be due to the environmental conditions of the study site and due to the tolerance of this species. The green mussel is reported to have tolerance for reduced salinities (Segnini *et al.,* 1998; Sallih, 2005). It can grow in water salinity ranging from 5.2‰ to 39.8 ‰ (Rajagopal *et al.,* 1998b). Green mussels in the Indo-Pacific region experience an average annual water temperature range between 12 and 32 ºC (Rajagopal *et al*., 2006), with an optimal range between 26-32ºC (Power *et al*., 2004). The acceptable pH range for most finfish and shellfish species is reported as 6.0-8.2 (Sivalingam, 1977) and 6.8-8.5 (Sasikumar, 2007). Segnini *et al*., (1998) stated that *P. viridis* can colonize even muddy sediments, point to the high level of tolerance of green mussels to high suspended particulate matter. Shin *et al*., (2002) also stated that *P. viridis* can tolerate a high level of suspended particulate matter (up to 1200 mg l).

The fouling organisms such as shrimps, young fishs, oysters, polychaetes, barnacles and gastropods were found on the rack and cages during the present study (Fig. 3B & 3C). The observation of fouling organisms was also reported by Jayalakshmy *et al.,* (2013), Myo Nandar Myint (2014) and Anil *et al*., (2017). The epibiotic barnacles were observed throughout the culture period in Sitaw. Qasim *et al*., (1977), Soundarajan *et al*., (1988) and Karayucel *et al*., (2002) described that fouling of mussels by barnacles was heavy over the culture materials. Bell (2013) reported that there is no negative impact of epibiotic barnacles on the growth of mussels and barnacle epibionts create a new interface between the mussel and its environment and this interaction can affect other members of the community.

The present study area is regarded as a suitable site for mussel fariming because they ranged within the suggested good conditions for mussels (Rajagopal *et al.,* 1998b; Rajagopal *et al*., 2006; Power *et al*., 2004; Sivalingam, 1977; Sasikumar, 2007). The absence of diffuse agricultural input, domestic and industrial discharges in the study area seem to observe the healthy mussels from this area. The ideal values for a suitable culture site are 27 to 35‰ for salinity; 27 to 30 ºC for water temperature; and 7.7 to 8.4 for pH (Aypa; Soon and Ransangan, 2016). Appukuttan *et al*., (2000) observed that the growth of mussels was much faster in the open sea than in estuaries. However, due to lack of security of farm structure and farmed stock in the open sea (Kripa and Mohamed, 2008), estuaries are the preferred locations for mussel farming and 250 estuarine mussel farms are existing in India and Thailand (Mohamed *et al*., 2003; Prakoon *et al*., 2010). Sitaw, Ye estuary, therefore, should be selected for the culture of *P. viridis* and the optimum sizes of about 10-25 mm should be seeded and the culture period of around 5 months was optimum in a favorable season.

Conclusion

The growth rate (1.3 $year^{-1}$) of *P. viridis* observed from the present study is faster than that of reported for the same species from Indian, Thailand, Hong Kong, Moheshkhali channel, Bangladesh and Myeik waters (Myanmar) and a little slower than that of Malaysia waters. However the growth rate was the same with offshore waters of Naf River Coast, Bangladesh. This variation of mussel's growth rate is significantly influenced by initial seeded mussel size, geographic region, and different cultivation methods. The high survival rate (>90%), increase in the lenght of the shell, high asymptotic lenght and growth coefficient value observed from the present study may be due to the environmental conditions of the study site and due to the tolerance of this species. These reults also indicate that Sitaw, Ye estuary is regarded as a suitable site for mussel farming. The information provided here will certainly make small scale farming of mussels more popular and generate greater employment opportunities and income in the future. However,

the natural seed resource on the mussel beds in Sitaw, Ye estuary, cannot support mussel culture industry of some magnitude. Therefore, induced spawning, larval rearing and seed production should be carried out in the hatchery to initiate the mussel farming in Myanmar.

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