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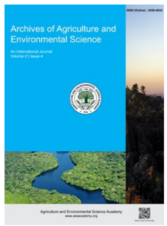

ORIGINAL RESEARCH ARTICLE

CrossMark

Growth performance and survival of oyster, *Saccostrea cucullata* (Born, 1778) and green mussel, *Perna viridis* (Linnaeus, 1758) cultivated in Bangladesh Coast

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ABSTRACT

Oyster and mussel farming along the coasts and the desire to increase fishing revenue have created a boom in these types of farms. An experiment on culture of edible oyster (*Saccostrea cucullata*) and green mussel (*Perna viridis*) was performed at Gangamoti estuary in Kuakata, Bay of Bengal coast of Bangladesh from December 2021 to March 2022 to find out the appropriate culture method of the oyster, *S. cucullata* and green mussel, *P. viridis*. Initially, the average shell heights of *S. cucullata* and *P. viridis* were 8.8±1.62 and 6.9±1.89 cm, respectively; where average weights were153.4±13.23 and 84.78±11.78 g, respectively. After the culture period, oysters shell height and weight grew up to 9.1±1.98 cm and 163.2±12.54 g, respectively in rectangular basket and 8.9±1.45 cm and 157.2±11.31 g, respectively in velon screen bag. In case of oysters, the rectangular basket and velon screen bag displayed the minor progress in specific growth rate, 0.09±0.01 and 0.07±0.03, respectively. But green mussels did not show any growth rate. Oysters cultured in rectangular basket showed total mortality at day-90 and velon screen bag at day-75. Green mussels showed 100% mortality within 21 days of culture. Our experiment was the first attempt to culture these two mollusks in the Kuakata coast of Bangladesh. However, further intensive researches would be required to evaluate the culture feasibility of these two mollusks' species in the Kuakata coast of Bangladesh.

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INTRODUCTION

Bivalve mollusks i.e., oyster, mussel, clam and scallops have an outer covering with a two-part leaned shell and limp body. Mollusk can breathe through their gills and being filter feeders, they have a pivotal role to play like an aquatic engineer (Barman *et al*., 2022). Bivalve mollusks are very significant to aquatic and marine ecosystems by giving asylum to many creatures. Many countries of the world are dependent on the oyster industry to boost their national economy (Vakily, 1992). The ripple in cognition has been imputed to this genre skill to boost food safety (Asare *et al*., 2019; Osei *et al*., 2020). Oysters can be traced in the coastal waters of temperate, sub-ecliptic and ecliptic areas (Grabowski *et al*., 2008). There are many ecological processes that oysters are pursuing as ecosystem manager (Alexandra *et al*., 2010). Bangladesh empowers with bays and several estuaries that have the suitability for oyster aquaculture and can supply animal protein for poor people (Hasan *et al*., 2021). They are deliberated as remarkable species that provide residence, harbor and rations and are worthy tools for the waning brackish water biological community (Sanjeevraj, 2008). For oyster culture, the oyster spat is the main factor and can be recruited from specific hatcheries. Oyster spat collection from the natural substrate is quite customary for oyster production. On the other hand, Asian green mussel, *Perna viridis*, is a massive and quick growing thermal water oceanic bivalve and is widely allotted in the sub-ecliptic and ecliptic areas of the Indo-pacific region (Tan and Ransangan, 2017). It is a chief applicant for coastal aquaculture due to its high growth rate, fecundity and regeneration ability (Laxmilatha, 2013). World mussel aquaculture production has been thriving firmly since the 1950s reaching two million tons in 2019, valued at 4.8 billion USD (FAO, 2020). Green mussel aquaculture supplies substitute for growing population and provides animal protein for in-shore people. Bivalve like *P. viridis* cultivation is self-regulatory culture system, which required minimum amount of input due to its rapid availability in nature. To produce alternative way of creating animal protein, green mussel production in Bangladesh can be magical form to minimize malnutrition. Successful cultivation process of green mussel has been practiced in many Asian countries for a long time (Al-Barwani *et al.*, 2013). Regular availability of green mussel is limited in southeastern shore, mainly in the Moheshkhali channel and the Naaf river creek (Shahabuddin *et al.*, 2010). Marine water of Bangladesh is suitable for the gathering as well as the culture of *P. viridis* (Asaduzzaman *et al.*, 2019). This study targets to establish the appropriate culture method for *S. cucullata* and *P. viridis* in the mid southern region of Bangladesh for the very first time, whereas the growth and survivability of these species are the crucial factors.

MATERIALS AND METHODS

Study area and period

The experimental field cultivation of *S. cucullata* and *P. viridis* was performed at Gangamoti estuary (21˚48'21.3" N and 90˚08'44.5" E) in Kuakata seashore, on the mid-southern coast of Bangladesh (Figure 1) for 90 days from December 2021 to March 2022.

Collection of spats

Healthy spats of *S. cucullata* and *P. viridis* were collected from Marine Fisheries and Technology Station, BFRI, Cox's Bazar. After collection, oyster and green mussel were cleaned to eradicate unwanted sediments and epibionts. The spats were transported into the Kuakata coast in an icebox under proper aeration. The research was conducted in accordance with the ethical standards of the Bangladesh Fisheries Research Institute. The experimental protocol and guidelines were maintained according to the animal welfare and ethical committee of Bangladesh Fisheries Research Institute, Bangladesh. The research and use of animals for the experiment have been authorized by the ethical committee.

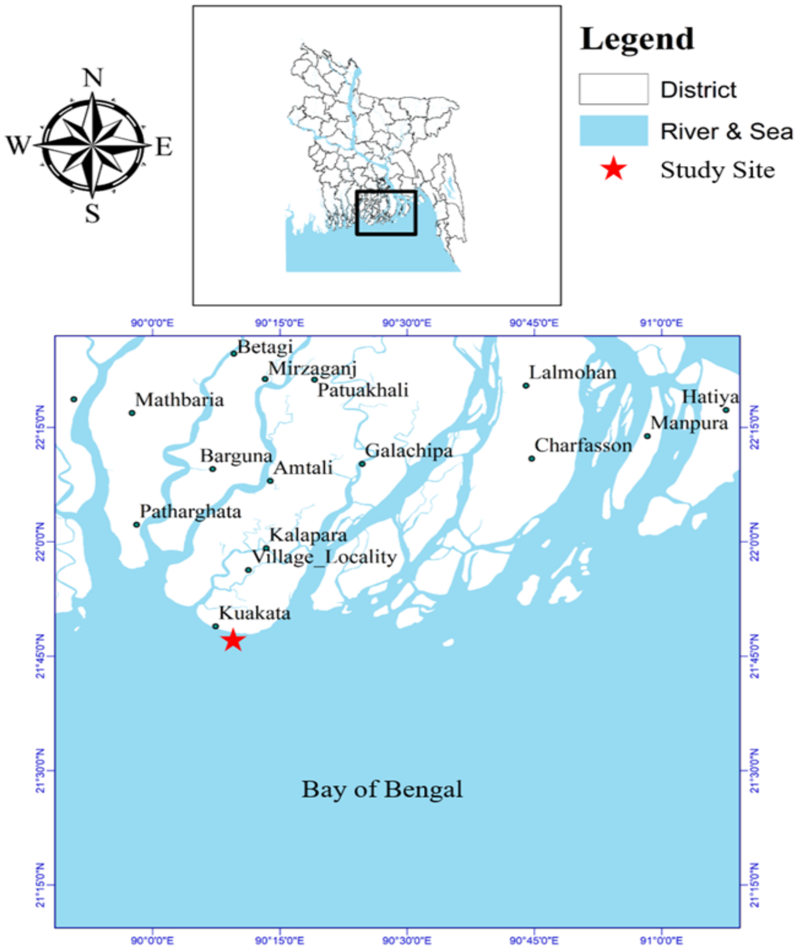

Figure 1. *Culture site is located on the Gangamoti estuary of Kuakata coast, Bay of Bengal, Bangladesh.*

Establishment of culture setup

There are many culture methods practiced for oyster and green mussel all over the world. Due to rough wave action in Gangamoti estuary, the off-bottom culture method was followed. Many Asian countries like India, China, Thailand and Hong-Kong practiced the bamboo-rack culture method in adverse conditions widely. Single bamboo-made rack with sixteen floating drums (20 kg weight/drum) was placed in the estuary. The size of the raft was 8 m long and 3 m wide. Six rectangular baskets and six velon screen bags were suspended from the bamboo rack. Three baskets and velon screen bags were used for *S. cucullata* and another three baskets and velon screen bags were used for *P. viridis* culture. Each basket and velon screen bag contained50 numbers of oyster and mussel spats. The experiment was administered with an initial number of 300 spats for both species.

Oyster and green mussel growth

At the very beginning, the average shell height of *S. cucullata* and *P. viridis* was 8.8±1.62 and 6.9±1.89 cm respectively. The enhancement of oyster and green mussel was recorded monthly by the assessment of the shell height (Gosling, 2015). Shell height was conducted because it has greater correlation with meat growth (Osei, 2020). On the other hand, the average weight of the *S. cucullata* and *P. viridis* was 153.4±13.23 and 84.78±11.78 g respectively. The growth of each oyster and green mussel was surveyed, in terms of height and weight, using a digital balance with accuracy of 0.01 g. Growth rate was calculated using the following formula (Kinder and Williams, 2013).

$$\text{Daily weight gain (g/day)} = \frac{P2 - P1}{t2 - t1}$$

Where, P_1 and P_2 are the mean shell weight at time t_1 and t_2, respectively.

$$\text{Specific growth rate (SGR \%)} = \frac{\ln \text{final weight} - \ln \text{initial weight}}{\text{Number of days}} \times 100$$

Survival

Survival of the oyster and green mussel was accomplished by enumerating the fortnightly number of live oyster and mussel and manifested as percentage of the initial number stocked.
The percentage survival was computed as follows (Kinder and Williams, 2013).

$$\text{Survival rate (\%)} = \frac{\text{Final number of surviving oyster and mussel}}{\text{Initial number of oyster and mussel}} \times 100$$

Monitoring of water quality parameters

Water temperature, salinity, transparency, pH, and dissolved oxygen (DO) were measured fortnightly. Temperature and salinity were measured with a standard thermometer and a hand Refractometer (Atago, Japan), respectively. Water transparency was measured with a Secchi disk (30 cm in diameter) and water pH was determined with a pH meter (S327535, HANNA Instruments, Romania). The Hanna multiparameter was used to measure dissolved oxygen (Model: HI98194, Romania).

Statistical analysis

Analysis of variance (ANOVA) was applied to ordain the significant changes in shell height and weight of *P. viridis*. When significant differences (*P<0.05*) were found, Tukey's HSD test was done for post hoc comparisons. Pearson correlation analysis was done to determine the relationship between water quality parameters and specific growth rate of *S. cucullata* in rectangular basket and velon screen bag respectively. All the statistical analyses were done using the Statistical Package for the Social Sciences (SPSS) version 25.0.

RESULTS AND DISCUSSION

Environmental factors

Oyster and green mussel cultivation require the use of appropriate hydrological conditions. Table 1 showed the results of hydrological parameters in the Gangamati estuary on Bangladesh's Kuakata coast over the period of the study. All the hydrological parameters were within the optimum range, but the salinity level and water transparency were lower than the optimum level.

Growth parameters of oyster and green mussel

Oysters which were not survived in the culture system in the bamboo rack method not to be measured, due to massive natural mortality phenomena. Figure 2 showed that oysters cultured in the rectangular basket and velon screen bag, both demonstrated 8.8±1.62 cm shell height. Oysters cultured on the rectangular basket grew up to 9.1±1.98 cm shell height in 90 days. On the other hand, oysters cultured on velon screen bag reached a size of 8.9±1.45 cm at the end of 75 days culture period. From Figure 3, rectangular basket and velon screen bag demonstrated with the same shell weight of 153.4±11.67 g. Oysters cultivated on rectangular basket and velon screen bag grew up to 163.2±12.54 and 157.2±11.31 g respectively. Table 2 showed the initial shell height and weight of the *P. viridis* in a rectangular basket and velon screen bag that remained the same. The results demonstrated that after 21 days of stocking in the culture system, shell height and weight in a rectangular basket resembled with the initial measurement, whereas *P. viridis* in velon screen bag exhibited the same result. No significant differences were followed in shell height and shell weight of *P. viridis*.

Correlation among specific growth rate (SGR %) and water quality parameters

The specific growth rate of rectangular basket was found to be significantly positively correlated with water transparency and negatively correlated with salinity and dissolved oxygen, pH and temperature, the majority of the other parameters had a non-significant correlation. The specific growth rate was found to have a substantial negative correlation with salinity whereas negative association with pH and dissolved oxygen in velon screen bag (Table 3).

Table 1. Water quality parameters at the Mid-southern Kuakata coast of Bangladesh.

Parameters	Culture site	Optimum
Water Transparency (cm)	55.65±0.5	110-140 (Asaduzzaman *et al.*, 2021)
Salinity (ppt)	19.80±0.8	27-35 (Asaduzzaman *et al.*, 2019)
Water Temperature (°C)	28.20±0.3	22-32 (FAO, 2021)
pH	7.63±0.2	8.1-9.3 (FAO, 2021)
DO (mgL^{-1})	5.90±0.2	>5.7 (FAO, 2021)

Values are means ± SE.

Table 2. Growth performance of *P. viridis* in the Kuakata coast of Bangladesh.

Days	Shell height (cm)		Shell weight (g)	
	Rectangular basket	Velon screen bag	Rectangular basket	Velon screen bag
01	6.9±1.89^{a}	6.9±1.56^{a}	84.78±11.78^{a}	84.78±10.67^{a}
07	6.9±1.67^{a}	6.9±1.34^{a}	83.14±9.78^{b}	84.23±10.12^{a}
14	6.9±1.34^{a}	6.9±1.22^{a}	84.42±12.14^{a}	84.29±10.47^{a}
21	6.9±1.21^{a}	6.9±1.21^{a}	84.31±11.98^{a}	84.26±10.43^{a}

Different superscript in a same column indicates significant variation (P<0.05).

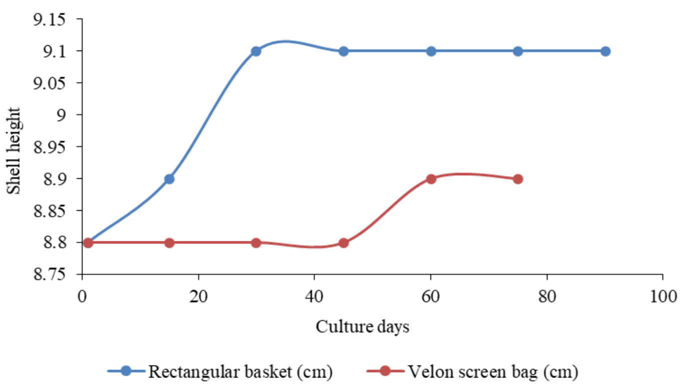

Figure 2. *Growth (Shell height) of S. cucullata in the Kuakata coast of Bangladesh.*

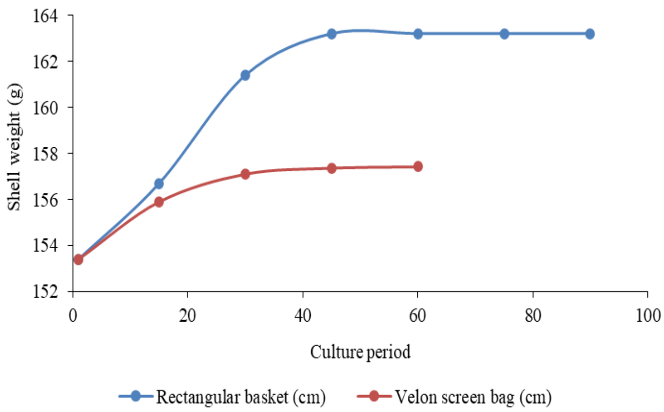

Figure 3. *Growth (Shell weight) of S. cucullata in the Kuakata coast of Bangladesh.*

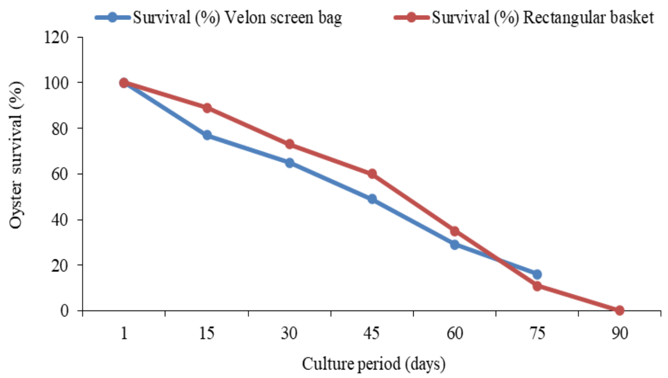

Figure 4. *Survival of S. cucullata cultivated in the mid-southern coast of Bangladesh.*

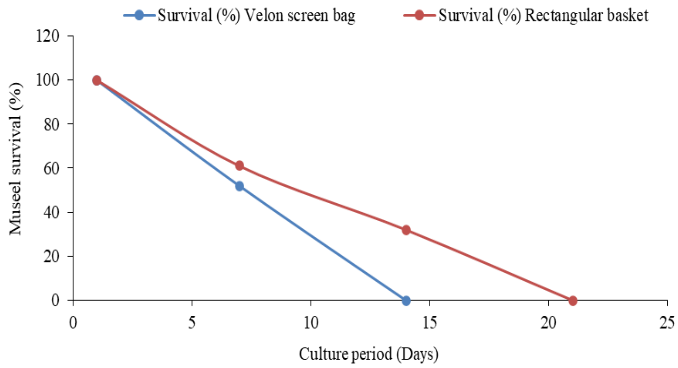

Figure 5. *Survival of P. viridis cultivated in the mid-southern coast of Bangladesh.*

Survival

Figure 4 showed the result that 77% and 89% survival of *S. cucullata* ensued at day-15 with rectangular basket and velon screen bag respectively, whereas 50% mortality was observed with both cases at day-45. Oysters cultured in velon screen bag showed total mortality at day-75 and in rectangular basket at day-90. Survival of *P. viridis* cultured in the Kuakata coast showed a similar pattern. After stocking of *P. viridis*, an increase in mortality (50%) was seen at 7th day of culture in both culture system and 100% mortality occurred at day-14 and day-21 in velon screen bag and rectangular basket respectively (Figure 5).

Water quality parameters recorded during the study period are shown in Table 1. Temperature is one of the important factors for oyster and mussel culture. The filtering dynamism of the oyster depends on water temperature (Hasan *et al.*, 2021; Ward *et al.*, 2000). The rate of water transport, feeding, respiration, gonad formation and spawning possession affects by the temperature effect (Naik and Gowda, 2013). During the study period, the recorded temperature was 28.20±0.3°C, but Hasan *et al.* (2021) had the temperature ranging between 27.35±0.74 to 27.67±0.76°C in Cox's Bazar, which was suitable for the growth and recruitment of oyster spats. Khan *et al.* (2020) observed maximum temperature 27.8°C during *P. viridis* culture. Physiological variation i.e., shells closing and low filtering of oyster ensued due to low salinity (Metz *et al.*, 2015). Asaduzzaman *et al.* (2021) expositioned the maximum salinity 27-35 ppt for *P. viridis* and Hasan *et al.* (2021) found 21.64 to 26.33 ppt for the suitability of oyster culture. Asaduzzaman *et al.* (2019) also reported that the maximum salinity for *P. viridis* was 29.8 ppt in the Moheskhali channel. In this study, the average salinity found was 19.80 ppt which is slightly lower than the references which could be the reason for early mortality. Nell and Holiday (1988) recorded the highest growth rate of *Crassostrea madrasensis* at salinities of 23-29 ppt and survival rates at 27-39 ppt.

As a filter feeder species, green mussel and oyster negatively coincide with high turbidity. The suspended particles create turbidity that blocks and damages the delicate gills and result in lower production of green mussel (Soon and Ransangan, 2014). Turbidity is to blame for the reduced transparency on the Kuakata coastline. Water transparency level in oyster and mussel culture was recorded at 110-140 cm in the Moheskhali channel by Asaduzzaman *et al.* (2020); whereas the average water transparency level was 55.65 cm in the experimental area. For successful reproduction and growth, oyster community must maintain a pH of less than 9 (Mathew, 2008). The average pH of the experimental area was 7.63; whereas Asaduzzaman *et al.* (2021) showed the highest pH value was 7.92 for green mussel culture in the Moheskhali channel and Hasan *et al.* (2021) recorded 7.68 for oyster culture in the same area. Hence, Minhaz *et al.* (2020) stated the pH range in between 6.4-8.2 during oyster farming in Cox's Bazar coast. The Dissolved oxygen (DO) level may not influence the farming system of green mussel and oyster, but the feeding activities need an apex level of oxygen (Naik and Gowda, 2013). DO concentration of the studied area was relatively stable (5.90±0.2 mgL^{-1}) and on the other hand, Asaduzzaman *et al.* (2020) recorded the maximum DO level for mussel culture was 6.1-7.0 mgL^{-1} in North Khurshukul, Cox's Bazar and Hasan *et al.* (2021) stated the average DO level for oyster culture was 6.99±0.32 $mg.L^{-1}$ in Cox's Bazar. Gammanpila (2021) found the highest mean value of DO was 5.7±0.34 mgL^{-1} in *C. madrasensis* culture on Sri Lanka Coast. Oyster and green mussel, not surviving in both culture systems, were not measured and calculated. *S. cucullata* spectacled the identical dynamism in survival rate, the rectangular basket (77%) and velon screen bag (89%) at 15^{th} days of culture period respectively but in sober fact, 50% mortality exhibited at day 45. On the contrary, Osei *et al.* (2021) recorded a waning pattern of survival with 5% mortality per month in *Crassotrea tulipa*. The cultured oyster subsisted for 90 days at rectangular basket and 75 days at velon screen bag whereas Gammanpila (2021) pointed out the survival rate (90%) in 120 days culture period with the salinity of 20.86±0.74 ppt. Here the salinity pattern resembled the present study (19.80±0.8 ppt) but the survivability pattern becomes like maintaining the waning principle. In both culture systems, 50% mortality seemed at day 14 in *P. viridis* and massive natural mortality occurred on day 21. South *et al.* (2017) stated that more than 80% survival rate showed much better results on green mussel growth and reproduction whereas Ramachandran *et al.* (2002) calculated 52% survival rate for three months culture system in Kovalam shore near Chennai. The study of Picoy-Gonzales and Laureta (2022) showed that salinity in green mussel culture should be more than 15 ppt and total mortality occured at day 20 which is more or less similar to our present study. The shell height of *S. cucullata* (8.8±1.62 cm) was analogous in both culture items as Osei *et al.* (2022) manifested the shell height of oyster, 3.23±0.43 cm, with the initial shell height of, 0.32±0.03 cm at 90 days of culture period which is lower in our present study (9.1±1.98 cm and 8.9±1.45 cm). In addition, lower salinity and higher turbidity become the prime factors for oyster and mussel culture. All other environmental factors are important but growth, survival, recruitment and reproduction have greater consideration of salinity and turbidity.

Conclusion

The present study uncovered that the growth and survival rate of oyster and green mussel are massively subjected to environmental parameters i.e., salinity and water transparency. Moreover, domination of salinity becomes the prime factor for mollusks culture all over the world while salinity influx is slightly lower in Kuakata region by virtue of huge run-off from adjacent rivers in southwest region. However, the off-bottom culture process can be sustainable in Kuakata coast while the potential culture area of the coast should be trending by further research.

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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