

Comparative Valuation of On-Bottom and Off-Bottom Mussel (*Perna viridis*) Culture as a Small Scale Enterprise, in Chettuva Estuary at Kerala, India

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Abstract: Mussels are extensively cultivated worldwide with great economic importance. The Indian coast has extensive backwaters and estuaries suitable for mussel farming, still the rationale behind the potential of mussel farming as a village-based small scale farming enterprise has not been critically evaluated. Experimental culture of green mussel, *Perna viridis* (On-bottom and Off-bottom) on a small scale basis was carried out in the present study to analyze the appropriate technique suitable for the estuarine conditions in Kerala, South India. Off-bottom cultured mussels had faster growth rate and a production of 360 kg was obtained. Only 78 kg was harvested from On-bottom culture. The net operating income from Off-bottom culture was US\$ 527.74 and US\$ 70.49 from On-bottom culture. The net cash return from Off-bottom culture was ten times higher than On-bottom culture. The present research ensures that Off-bottom mussel culture is well suited to the estuarine conditions in Kerala, India.

Key words: Mussel Farming • *Perna viridis* • On-Bottom Culture • Off-Bottom Culture • Fixed Suspended Culture

INTRODUCTION

Marine aquaculture is a rapidly growing industry across the globe, driven by the increasing demand for seafood products and declining wild stocks [1, 2]. Bivalves are among the most economically important groups in mariculture, with many species showing low production costs and high profitability [3]. Shellfish farming is an important sector of the industry and, like other forms of aquaculture, is expanding [1, 4]. Among shellfish, mussels are extensively cultivated worldwide and are of growing economic importance. However, constraints on the exploitation of wild mussel resources have necessitated the need for tools to improve the management of mussel cultivation towards increased production [5]. In many cases the optimum farm management practices for new or modified culture

methods are not known. Production costs must be offset by sufficient yield from the aquaculture operation to result in a profit for the farmer [6]. A primary advantage of controlled or cage culture systems is that they improve the capability of growers to manipulate the production system and improve the quality of their product during grow out [7].

The proper selection of culture sites is important when considering mussel culture. Several factors should be carefully considered, which can be grouped as primary and secondary factors. The primary factors, physical, ecological and biological are the most important in the selection of a suitable culture site, while factors such as risks and economics are usually considered secondary [8]. Protected estuarine habitats support the culture of these organisms owing to high natural productivity potential and absence of major predators and competitors [9].

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Both East and West coast of India has extensive backwaters and estuaries, which are suitable for mussel farming during the post monsoon months, when higher saline conditions prevail. Farming activity during this period provides an opportunity for supplementary livelihood and additional income to the coastal rural population [10]. In India the technology for farming the green mussel, *Perna viridis* was developed during 1970s and was subsequently tested for feasibility at various locations along the country's South-east and South-west coasts, by Central Marine Fisheries Research Institute (CMFRI) [11, 12]. However, the technology was not adopted by fishermen because of risk associated with sea farming such as poaching, weather related loss of farm structure from the sea and the lack of awareness [13]. The green mussel is a favored candidate for farming and has been very well domesticated in the estuaries of Malabar [14].

The rationale behind the potential of mussel farming as a village-based small scale farming enterprise in India has not been critically evaluated [13]. Experimental culture (both on-bottom and off-bottom) on a small scale basis was carried out in the present study to analyze the appropriate mussel culture method suitable for the estuarine conditions of Kerala, South India; in terms of mussel growth performance, productivity and economic feasibility.

MATERIALS AND METHODS

Chettuva estuary (10°12'-10°16' N 76° 07'-76°10' E), situated in Central Kerala, South India was selected for the cultivation of mussels. The culture was carried out during December 2009 to May 2010, when high salinity conditions prevailed in the estuary. On-bottom culture and Off-bottom culture techniques, i.e. fixed suspended culture was selected for the present study. Green mussel *Perna viridis* seeds having an average size of 1.9 ± 0.2 cm shell length and 2.23 ± 0.09 g live weight were collected from the wild was used for cultivation.

On-Bottom Culture: On bottom culture was done on the intertidal zone at the estuary mouth region, on the hard substratum. The selected site was nearly 0.8 to 1 m deep from the surface water mark. The bottom was prepared by clearing the weeds and other unwanted materials. 25 kg seeds were sowed at a rate of 5 kg seed/m² for 5 m² area. Care was taken to sow the seeds in a single layer. Biodegradable cotton netting was spread over the sowed seeds to prevent the flow off of seeds with the

water currents and to defend from the predators. The netting was fixed at its edges to the estuarine bottom by means of heavy non-rolling rocks.

Off-Bottom Culture: For fixed suspended culture, coir rope of 22 mm diameter was used and thin nylon ropes were passed through the coir rope for strengthening. The seeding was done on 10 m rope. Nearly 2.5 kg of mussel seeds were used for seeding 1m of the rope, thus 25 kg of seeds were utilized for 10 m rope. The seeds were spread on the cotton biodegradable net which was wrapped around the rope and its edges were stitched together with nylon twine. This was taken to the bamboo frame constructed at the estuary, by means of a canoe. The bamboo frame was constructed at the site with nearly 4 m depth. 10 bamboo poles were vertically fixed approximately 1m apart from each other in a straight line. Ten other bamboo poles were placed horizontally and tightly tied perpendicularly to the vertically fixed poles. The horizontally tied poles of the frame were below the water mark. The seeded rope was suspended 1m below the water mark and was fixed to the frame by tying to the horizontal bars at every meter apart.

Management and Analysis: Periodical checking of the culture was done, 10 individuals were collected randomly from each culture technique at every 30 day interval to analyze the biometric parameters. The growth was estimated from changes in shell length, live weight (total weight of mussel) and wet meat weight (weighing the meat after dissecting it from the shell and blotting the extra water). The shell length (from anterior to posterior axis) [15] was measured with a caliper. Percentage meat yield was calculated according to Okumus and Stirling [16].

$$\text{Meat yield (\%)} = (\text{Wet meat weight} / \text{whole mussel weight}) \times 100$$

Monthly specific growth rate percentage (SGR %) in terms of length and weight was found using the following formula.

$$\text{SGR\%} = [(\ln L_2 - \ln L_1) / (T_2 - T_1)] \times 100$$

Where,

L_1 and L_2 are the mean shell lengths at time T_1 and T_2 respectively.

Weight was substituted to the same formula to find the SGR% in terms of weight [17]. The hydrographical parameters of the water in the estuary were also analyzed during the culture period. Temperature was measured

using Celsius Thermometer, hydrogen ion concentration (pH) using pH meter (ELICO li615 manufactured by India), salinity by means of salinity meter and dissolved oxygen was measured by Winkler's method [18].

To compare the economic performance of the culture methods, the data such as total cost of production, gross returns, net operating income, net cash return, capital recovery factor (CRF = net cash return/capital investment) were computed [13]. For the economic data analysis, the quantity and value of the raw materials used such as bamboo poles, coir rope, degradable cloth, labour charges and so forth, during the crop period was recorded for each culture technique in terms of US\$. Both the On-bottom and Off-bottom cultured mussels were harvested after the 180th day of culture, as the mussels were grown to the marketable size.

RESULTS

The hydrographical parameters of the estuary water of the culture site, at Chettuva showed considerable variation. The temperature showed an increase from 26°C to 32°C as the environment temperature increased with the intensity of summer. The pH became more alkaline. Salinity showed an increasing trend from 27 to 32. Dissolved oxygen showed fluctuation between 7 to 11 mg/l (Table 1).

The length, weight, meat weight and meat yield of *P. viridis* individuals increased in both On-bottom and Off-bottom culture methods. The total weight of the mussel increased from 2.23±0.09 g to 9.36±0.07 g, by the time of harvesting in Off-bottom cultured mussels; the length also increased from 1.9±0.2 cm to 6.5±0.3 cm. A similar trend was noticed on the wet meat weight of the mussel; from an initial value of 0.63±0.05 g, it grown up to 4.24±0.18 g in 6 months. The percentage meat yield varied during each growth stage. It fluctuated between 28.25±0.62 % to 48.18±2.19 %, yet the values mounted from the initial day to the end of the cultural period (Table 2). The On-bottom cultured mussels attained a live weight of 7.36±0.07 g in 180 days and the length increased up to 5.1±0.4 cm. The meat weight also improved and thus the meat yield percentage (Table 3).

The Monthly specific growth rate percentage (SGR %) of Off-bottom cultured *P. viridis* increased with monthly variations with a minimum of 3.06 g on 90th day to a maximum of 4.5 g by the 180th day in terms of its weight. The length also increased from 1.66 cm to 4 cm by 180th day. Compared to the Off-bottom cultured *P. viridis*, the On-bottom cultured mussels showed a slow growth rate. The maximum SGR% in terms of weight was only 3.4 g (30th day) and 2.33 cm (120th day) in case of length. (Figs. 1 and 2).

Table 1: The hydrographical parameters of the water at Chettuva estuary during the culture period

Parameters	Range value
Temperature	26-31°C
Hydrogen ion concentration (pH)	7-8.2
Salinity	27-32 ppt
Dissolved oxygen	7-11 mg/l

Table 2: The Mean value ± standard deviation of the biometric parameters of Off-bottom cultured *Perna viridis*

Days	Live Weight (g)	Shell length (cm)	Meat weight (g)	Meat yield (%)
Initial	2.23±0.09	1.9±0.2	0.63±0.05	28.25±0.62
30 th day	3.39±0.17	2.4±0.3	1.08±0.16	31.85±2.98
60 th day	4.61±0.08	3.1±0.4	1.76±0.07	38.17±0.84
90 th day	5.53±0.13	3.7±0.3	2.48±0.09	44.84±0.56
120 th day	6.78±0.19	4.8±0.2	3.06±0.11	45.06±0.42
150 th day	8.01±0.07	5.3±0.2	3.86±0.21	45.29±1.58
180 th day	9.36±0.07	6.5±0.3	4.24±0.18	48.18±2.19

Table 3: The Mean value ± standard deviation of the biometric parameters of On-bottom cultured *Perna viridis*

Days	Live Weight (g)	Shell length (cm)	Meat weight (g)	Meat yield (%)
Initial	2.23±0.09	1.9±0.2	0.63±0.05	28.25±0.62
30 th day	3.25±0.06	2.3±0.2	1.02±0.04	31.38±0.64
60 th day	4.05±0.13	2.9±0.4	1.60±0.20	39.50±3.56
90 th day	5.01±0.08	3.4±0.3	2.12±0.12	42.31±1.69
120 th day	5.84±0.08	4.1±0.4	2.80±0.14	44.94±0.24
150 th day	6.63±0.17	4.6±0.2	2.98±0.06	47.28±0.09
180 th day	7.36±0.07	5.1±0.4	3.48±0.04	47.94±1.72

Mean ± SD (n=5)

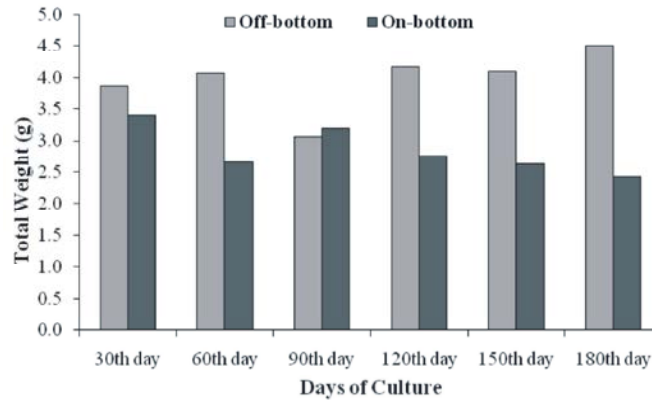


Fig. 1. Monthly specific growth rate in terms of total weight of Off-bottom and On-bottom cultured *Perna viridis*

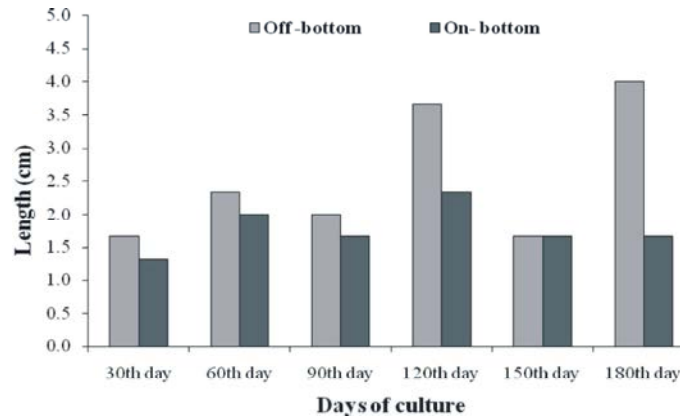


Fig. 2. Monthly specific growth rate in terms of length of Off-bottom and On-bottom cultured *Perna viridis*

Table 4: The economic analysis of Off-bottom and On-bottom culture of *Perna viridis*

	Cost description	Amount for long line culture US\$	Total US\$	Amount for bottom culture US\$	Total US\$
A. Total Capital investment	Bamboo poles	73.60 (3.68/pole)		Nil	27.54
	Rope for tying	1.00 (0.10/m)		Nil	
	Rope for seeding	3.10 (0.31/m)		Nil	
	Canoe rent	2.24		Nil	
	Transport of seeds	27.54	107.48	27.54	
B. Total Operating cost	Minor implements	1.53		Nil	
	Labour for bamboo frame construction	12.24 (6.12/labourer/day)		Nil	
	Labour for site clearance	Nil		12.24(6.12/labourer/day)	
	Biodegradable cotton netting	4.15 (0.41/m)		4.08	
	Mussel seed	7.75 (0.31/kg)		7.75 (0.31/kg)	
	Labour for seeding	30.60 (6.12/labourer/day)		12.24(6.12/labourer/day)	
	Farm maintenance	24.48 (6.12/labourer/day)	12.24(6.12/labourer/day)		
	Labour for harvesting	55.08 (6.12/labourer/day)	24.48(6.12/labourer/day)		
			134.66		73.03
C. Total cost of production (A+B)		242.14	100.57		
D. Sale price		1.84/kg	1.84/kg		
E. Gross returns		662.40	143.52		
F. Net Operating income (E-B)		527.74	70.49		
G. Net cash return (E-C)		420.26	42.95		
H. Capital recovery factor (G/A)		3.91	1.55		

To study the required expenditure and the probable profit and loss for each culture technique, the economic analysis was carried out. The total capital investment for Off-bottom culture was US\$ 107.48, whereas it was only US\$ 27.54 in case of On-bottom culture. The increase in investment of Off-bottom culture was due to the requirement of more implements. The operating cost was also high in case of Off-bottom culture compared to On-bottom culture. This directly reflected on the total cost of production, which was US\$ 242.14 for Off-bottom, while it cost only US\$ 100.57 for On-bottom culture of *P. viridis*. The sales price was US\$ 1.84/kg for shelled mussels during the harvesting period. The mussels were sold in the local and domestic market. Nearly 360 kg of mussels were harvested from the 10 meter Off-bottom cultured rope. Only 78 kg was obtained from On-bottom culture. In the summer season water level decreases and high siltation results in mass mortality of mussels in On-bottom culture. The net operating income from Off-bottom culture was US\$ 527.74 and US\$ 70.49 from On-bottom culture. The net cash return from Off-bottom culture was ten times higher than the On-bottom culture. The capital recovery factor was twice high in Off-bottom compared to On-bottom culture (Table 4). This eventually shows that the production is high in Off-bottom compared to On-bottom culture in estuarine conditions.

DISCUSSION

Growth of marine bivalves is affected by several environmental factors such as water temperature, food supply, salinity, water current velocity; but temperature and phytoplankton availability are the most important factors [19-21]. The water temperature of Chettuva estuary showed an increase from 26°C to 32°C from January to May, with the increase in environment temperature. Laxmilatha *et al.* [10] evidenced higher salinity promotes faster growth rate. Salinity showed an increase from 27 to 32 in Chettuva, with the intensification of summer season and the ingression of sea water and a corresponding increase in the mussel growth was also witnessed.

The length, live weight, meat weight and meat yield of *P. viridis* individuals increased in both On-bottom and Off-bottom culture methods. The live weight of mussels increased from 2.23±0.09 g to 9.36±0.07 g, in Off-bottom culture and 7.36±0.07 g in case of On-bottom. The length also increased from 1.9±0.2 cm to 6.5±0.3 cm and 5.1±0.4 cm respectively for Off-bottom and On-bottom culture. The percentage meat yield varied during each growth stage in both culture techniques. The Off-bottom cultured

mussels showed superior growth performance than its counterparts in On-bottom culture in the present study. Mussels show difference in growth performance in different parts of the same habitat, due to the difference in availability of food, water currents, etc [22]. The Off-bottom cultured mussels were under water with constant water currents throughout the crop period; whereas the On-bottom cultured *P. viridis* were periodically exposed during low tides.

A low specific growth rate was recorded in the On-bottom cultured mussels, which may be due to edaphic factors. The specific growth rate varied from 3.06 g/month to 4.50 g/month in Off-bottom and 2.43 g/month to 3.40 g/month in On-bottom cultivated mussels. Mussel growth rate of 1.13 g month⁻¹ for first six months and thereafter a rate of 0.11 g month⁻¹ were reported from the east coast of India [23]. Garen *et al.* [24] recorded a gradient of length and weight growth as a function of the culture type, Off-Bottom longline mussels exhibited the highest performance while Bottom-type culture showed the lowest in their experiment at Pertuis Breton, France. In the present research an average of 30 kg of mussels/m was harvested from the Off-bottom cultured rope. Only 78 kg was obtained from the whole On-bottom culture site. The dramatic decrease in water level, silt accumulation etc decreased the production rate. Rivonker *et al.* [25] reported an annual production of 33.51kg from raft-cultured mussels. Production rate of 12-15kg/m was achieved in the suspended raft cultured mussels in the south west coast of India. At Vizhijam raft culture experiments yielded 10-12 kg/m in the bay and 15 kg/m in the open sea [26]. A similar level of mussel production was reported from Calicut [27, 28] and Karwar [29]. The green mussel experimental raft culture in inshore waters of Ratnagiri, Maharashtra yielded a production rate of 7 kg/m in 6 months [30]. Culture experiments in Goa by rope culture and raft resulted in tremendous production of 450 tons/hectare/year [14].

Commercial viability of mussel farming was analyzed. The investment for Off-bottom culture was more due to the requirement of more implements, such as bamboo, ropes etc. The operating cost was also high in case of Off-bottom culture compared to On-bottom culture thus increasing the total cost of production. The net operating income from Off-bottom culture was US\$ 527.74 and US\$ 70.49 in On-bottom culture. The net cash return from Off-bottom culture was US\$ 420.26 and from On-bottom culture was US\$ 42.95. This elucidates that profit from Off-bottom culture of mussels is ten times greater than the On-bottom culture. Qasim *et al.* [31] reported an

annual return of 181 % on investment on the raft cultured mussel. Mohammed *et al.* [32] achieved an annual profit margin of 144 % in long line culture of *P. viridis*. In the present study, the capital recovery factor was 3.91 in Off-bottom and 1.55 in On-bottom culture. The Off-bottom culture appears to be more suitable as a small scale activity in the estuarine conditions with regards to the mussel growth rate, yield and net profit.

CONCLUSION

The fixed suspended cultured mussels showed comparatively high growth rate and better production. The profit from the same was nearly ten times higher than the On-bottom culture. The Off-bottom method of mussel farming could be successfully adopted by the coastal people of Kerala, India by setting up small units in the estuary adjacent to their homesteads; and more over the proximity of major mussel markets and high degree of mussel consumption in the area would synergize this endeavor. Furthermore the technology of mussel farming is simple, economically viable and eco friendly, making the technique sustainable and easily adoptable.

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