*Fishery Technology* 56 (2019) : 231 - 241

# Economic Evaluation of Different Aquaculture Systems in Coastal waters of Goa, Southwest Coast of India

**N. Manju Lekshmi[1]*, K. V. Praveen[2], G. B. Sreekanth[1], Narendra Pratap Singh[1], A. Vennila[3], R. Ratheesh Kumar[4] and P. K. Pandey[5]**

[1] *ICAR-Central Coastal Agricultural Research Institute, Goa - 403 402, India*
[2] *ICAR-Indian Agricultural Research Institute, New Delhi - 110 012, India*
[3] *ICAR-Sugarcane breeding Institute, Coimbatore - 641 007, India*
[4] *ICAR-Central Marine Fisheries Research Institute, Versova - 400 061, India*
[5] *College of Fisheries, Central Agricultural University, Agartala - 799 210, India*

## Abstract

The objective of this study was to carry out the economic evaluation of different aquaculture systems in coastal waters of Goa. Break-even analysis was used to compute the economic viability of different culture systems. A survey was also conducted to study the perception of farmers on different aquaculture technologies introduced in coastal waters. Among the four aquaculture systems studied, the semi-enclosed multi-species culture system was the most productive. The highest benefit-cost ratio and rate of return and shortest payback period were observed for the semi-enclosed water system with multi-species culture. Thus, the multi-species culture was found more economically viable compared to the single-species system under similar environmental conditions. Moreover, for the semi-enclosed system, the productivity and survival of species were comparatively higher due to the control of water flow through sluice gates. Goa is rich in semi-enclosed water bodies, which have a history of being used for shrimp farming, but these systems can be utilized for multi-species aquaculture. Perception of farmers on the dissemination of culture techniques revealed that adequate technical support increases their confidence level. This paper posits that there is sufficient scope and feasibility for developing multi-species aquaculture practices in unutilised semi-enclosed coastal areas of Goa by giving adequate technical support to the farmers.

**Keywords:** Conjoint analysis, Farmer's perception, Open water system, Semi-enclosed water system

## Introduction

Aquaculture has emerged as one of the most potent food producing sectors at the global level. This sector plays a crucial role in agriculture by providing employment, food and nutritional security to the rural poor (FAO, 2016). After China, India occupies second position (5.68% of global fish) in the world aquaculture production. Several factors have triggered the growth of aquaculture in the country during the last decade, among which, the increase in demand for fish and the stagnation of capture fisheries are considered to be the most important. With a continuing increase in the world population and economic growth, it is anticipated that the demand for fish will increase to 30-50 MT by 2030 from the current level (Miao, 2013). This enormous increase in demand is expected mainly due to the increase in the consumption rates with better awareness about the benefits of a diet that includes protein-rich fish (Planning Commission, 2012).

The strategies for production enhancement in India includes the adoption of best production practices including proper management of available water resources and utilizing diversified farming practices. The total area suitable for coastal aquaculture in India is estimated to be about 1.2 to 1.4 million ha. At present, the coastal aquaculture in the country revolves mainly around shrimp, which has led to

Received 12 April 2019; Revised 27 July 2019; Accepted 27 July 2019

**E-mail: manjuaem@gmail.com*

**Present address: ICAR-Central Institute of Fisheries Technology, P.O. Matsyapuri, Cochin - 682 029*

under utilization of some potential regions (Ganapathy & Viswakumar, 2001). Although shrimp culture started as a profitable industry, recent outbreaks of diseases have caused a serious problem, which impelled farmers to find an alternative species that could provide comparable profits to shrimp farming (Devaraj & Appukuttan, 2000).

The state of Goa has vast potential for the development of aquaculture through its enormous and underutilized coastal water resources (Mohanta & Subramanian, 2001). Despite the potential and availability of technologies for widespread culture, only a few farmers in Goa are engaged in coastal aquaculture activities (Manju Lekshmi, 2015). The major reason for this appears to be a lack of awareness about where to locate production systems to provide high yields from farming. Great opportunity exists for developing and popularizing practices such as finfish cage culture, bivalve culture, and multi-species farming systems. The capture-based culture fisheries can be taken up using cultivable coastal finfish species such as pearlspot & red snappers and shellfish such as mussels. These species have natural seed availability in the coastal regions, especially in Goa, Karnataka and Kerala.

For the overall development of the fisheries sector of the region, there is a pressing requirement of establishing an environmentally sustainable and ecologically viable culture industry. Single species and multi-species aquaculture systems could be the most potential interventions, provided right species and technology are chosen. Multi-species aquaculture involves cultivating several species belonging to different trophic levels that then utilize different trophic niches in the system (Barrington et al., 2009). This can ensure the sustainability of the system, not only because such culture practices aim at maximizing resource utilization, but also because they possess the capacity to reduce adverse environmental impacts.

Aquaculture systems, need to be established using sound scientific and economic evaluation. This study estimates economic viability of extensive aquaculture systems in coastal waters of Goa. To do this an economic comparison was made between coastal aquaculture systems as open water systems with mussel culture (OWSM), open water system with multi-species culture (OWSMS), semi-enclosed water with mussel culture (SEWM), and semi-enclosed water system with multi-species culture (SEWMS). Different economic indicators were employed in this study including BC ratio, breakeven production, rate of return, payback period, and net present worth (3 years). Further, an assessment was made regarding farmer's opinion on the suitability of these aquaculture technologies.

## Materials and Methods

The study primarily assesses the economic viability of different aquaculture systems propagated by the ICAR-Coastal Agricultural Research Station, Goa. The institute has conducted training programmes on the effective operation and management of the

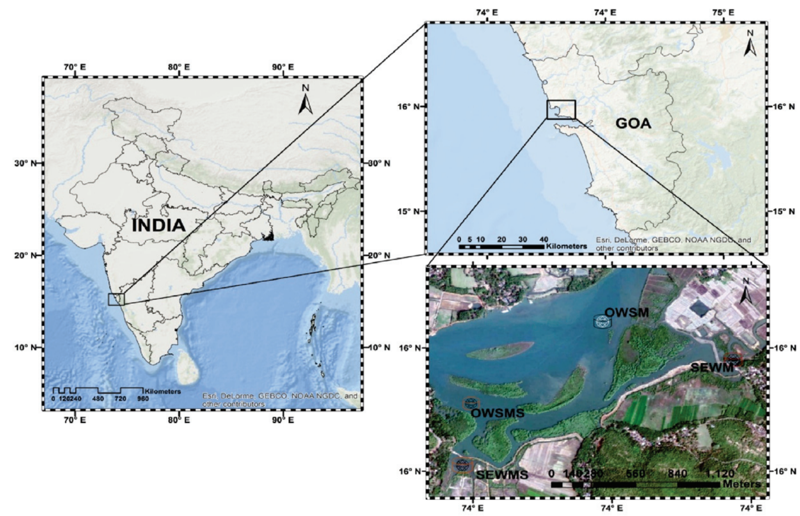


Fig. 1. Map showing the aquaculture sites in coastal water bodies of Goa

different aquaculture systems to the interested farmers. The data used to carry out the economic analysis were primarily synthesised from the systems managed by such farmers who have attended the training programmes and adopted the technologies. The study considers four aquaculture systems: (1) Open water system with mussel culture (OWSM), (2) Open water system with multi-species culture (OWSMS), (3) Semi-enclosed water system with mussel culture (SEWM), and (4) Semi-enclosed water system with multi-species culture (SEWMS) (Fig. 1). The open and semi-enclosed water systems may be defined differently by the researchers. The present study considered open waters in the coastal areas, which has a direct connection with the estuaries and the semi-enclosed systems ("Manas" in Goa) where water flow from the estuaries is controlled by employing sluice gates/regulatory structures (Fig. 2).

The major finfishes that were cultured in the system included the Pearlspot (*Etroplus suratensis*) & red snapper (*Lutjanus argentimaculatus*) and the bivalve-mussel or green mussel (*Perna viridis*). The major advantages for these species are the local seed availability, fast growth rate, hardiness, and marketability. Moreover, mussels being sedentary filter feeders, predominantly feed on phytoplankton, can be cultured in semi-enclosed as well as open water systems with reasonable flushing rate and rich phytoplankton. The experimental details are

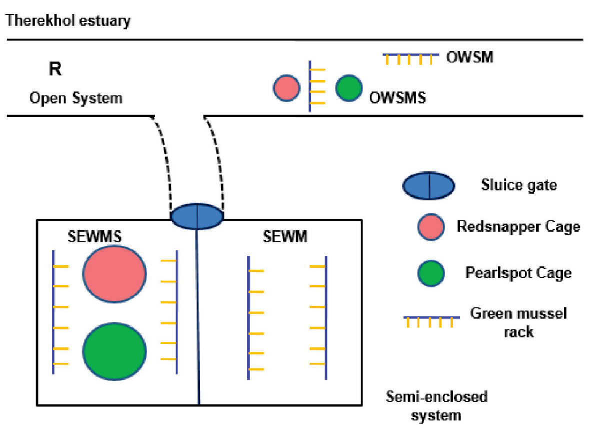


Fig. 2. Schematic representation of different aquaculture systems (*OWSM: Open water system with mussel culture; SEWM: Semi enclosed water system with mussel culture; SEWMS: Semi-enclosed water system with multi-species culture; OWSMS: Open water system with multi-species culture)

described in Table 1. Rack culture technique was adopted for mussels whereas, in multi-species aquaculture, a continuous stocking and harvesting system was introduced.

Traditional fishermen operate bagnets in the Khazan areas called Manas (sluice gate operating areas in Goa) in high tide. Red snapper and pearlspot seeds (average size: Pearlspot, 50 mm; Red snapper, 200 mm) for the cage culture was obtained as by-catch during the bagnet operations. These seeds were separately stocked in the experimental cages (HDPE rectangular cages with dimension: 2 m ×1.5 m × 2 m) that were positioned using bamboo poles. The finfishes were cultured in combination with green mussels for eight months. Mussel seeds (average size, 32 mm) collected from the wild were stocked (1kg per bag) in 15 pre-stitched, cotton mosquito net bags centred with nylon rope (length, 1m, diameter, 14 mm). The bags were hung from the bamboo poles used for fixing the cages. For open water systems also, seeds were collected from the semi-enclosed Manas.

The red snapper was fed with chopped discards (ghost crabs, small weed fishes, and molluscs collected during normal fishing–activities/bagnet operation), pearlspot with periphyton that grew on the split bamboo pieces kept inside the cages, and mussels feed on available plankton.

The cost and returns data were collected from the farmers who managed the different aquaculture systems after attending the training programme of the institute. The data were collected separately for different cycles and hence the total period of study spanned for 2 years (November 2013 to October 2015). Next, to assess the farmers' perception of the common aquaculture systems, another primary survey was carried out during the same period using a designed questionnaire. The data were collected from 30 randomly selected farmers, among all the farmers who have registered their interest in the aquaculture systems with the institute. The survey, using personal interview method, collected data on the farmers' preference regarding aquaculture technologies/systems. The farmers' were asked to rank their responses to the questions on a Likert scale of 1 to 5. The rank 1 was marked for the response 'very poor' and 5 for 'excellent'.

Economics of different culture systems is given on an annual basis as the duration of different practices stretched from November 2013 to June 2015. We

Table 1. The details of culture systems with area, method of cultivation, species, stocking size and stocking density.

| Area | System* | Type of culture | Method & period | Species for culture | Stocking density | Stocking size (length-mm) |
|---|---|---|---|---|---|---|
| 500 $m^2$ | OWSM | Single species | Rack (5*5 m)<br>8 months | Green mussel | 60 bags<br>(1kg/bag)<br>200-300<br>no./bag | 28-32 mm |
| 500 $m^2$ | SEWM | Single species | Rack (5*5 m)<br>8 months | Green mussel | 60 bags<br>(1kg/bag)<br>200-300<br>no./bag | 28-32 mm |
| 3 cages<br>(2*1.5*2 m)<br>500 $m^2$ | SEWMS | Multispecies | Small cages<br>8 months | Red snapper<br>Pearlspot<br>Green mussel | 100 no./cage<br>200 no./cage<br>15 kg | 100 mm<br>50 mm<br>28-32 mm |
| 3 cages<br>(2*1.5*2 m)<br>500 $m^2$ | OWSMS | Multispecies | Small cages<br>8 months | Red snapper<br>Pearlspot<br>Green mussel | 100 no./cage<br>200/cage<br>15 kg | 100 mm<br>50 mm<br>28-32mm |

*OWSM: Open water system with mussel culture; SEWM: Semi-enclosed water system with mussel culture; SEWMS: Semi-enclosed water system with multi-species culture; OWSMS: Open water system with multi-species culture

considered this period to represent two-cycles. The economic analysis of the aquaculture practices was done using parameters such as fixed cost, operating cost, gross revenue, annual profit, rate of return, payback period, and breakeven price. Total cost was arrived by the sum of annual fixed cost and annual operating cost. Operating costs include all costs incurred when the farms are under operation; fixed costs are those incurred even if there is no culture operation. Fixed costs include interest on initial investment and depreciation on the permanent assets. Depreciation was calculated according to the life expectancy of each item in the capital investment. The economic feasibility and efficiency of different production systems were assessed using the following formulae:

Total cost = Annual fixed cost + Operating cost

Net operating income = Total Income - Operating cost

Net returns = Total Income- Total cost

Benefit-Cost ratio = Total Income / Total cost

Economic feasibility of the culture systems was assessed using break-even analysis. For this, selling price, fixed costs and operating costs were calculated to reflect changes in costs and prices to maintain profitability. The break-even production was calculated using the formula

BP = TFC/ (Average farm-gate price per unit- Average variable cost per unit)

Where BP is the break-even production and TFC is the total fixed cost.

The rate of return (RR) and payback period for each culture practice was calculated using the formulae;

RR (%) = [NR/Ci] x 100

Where,

NR is the net returns, and Ci is the capital investment

Payback period (P) is the length of time required to recover the initial cash outlay on the project the shorter the payback period, the more desirable the project.

P is estimated follows;

P =I/B

Where,

P = Payback period of the project in years

I = Investment of the project (in rupees), and

B = Annual net cash revenue (in rupees)

Net present worth is the worth of the incremental net benefit or incremental cash flow stream. The net present worth may also be computed by finding the difference between the present worth of the benefit stream less the present worth of the cost stream. It may be interpreted as the present worth of the net income stream generated by an investment. All independent projects with a zero or greater net present worth when discounted at the opportunity cost of the capital can be considered to be economically viable. It is calculated as follows:

$$\sum_{t=1}^{t=n} \frac{B_t - C_t}{(1 + i)^t}$$

Where, $B_t$ = Benefit in each year

$C_t$ = Cost in each year

t = 1,2,3,……n

n = number of years

I = interest (discount rate)

The farmers' perception of different aquaculture systems or technologies promoted by the institute was captured using the Likert scale and tabular analysis. The farmers were asked to rank the different technological components or indicators as per their perception. The share of responses supporting and rejecting the benefits or advantages of the technologies are reported. Further, the preference of farmers for certain aquaculture technologies is dependent on many factors. Conjoint analysis has been used to determine the features and services that an aquaculture technology should offer to the farmers to influence their adoption (Green & Srinivasan, 1978). The farmers were asked to rank combinations of different levels of the selected factors given to them in cards. These rankings were used in the conjoint analysis to find out the most important factor/factors that technology should possess for it to be successful. First, we defined the four most important attributes that constitute the utility of the technology. The attributes identified were simplicity, technical support, area suitability, and profit. Each of these attributes was assigned two levels (Table 2). Considering all the attributes and levels 16 stimuli were formed (for 4 attributes with

Table 2. Attributes and levels of aquaculture technologies for conjoint analysis.

| Factor | Levels | |
|---|---|---|
| Simplicity | Simple | Complex |
| Technical support | Available | Not available |
| Area suitability | Highly suitable | Moderately suitable |
| Profit | High | Moderate |

Table 3. Stimuli description/Card list given to farmers for ranking.

| Stimulus | Card ID | Simplicity | Technical support | Area suitability | Profit |
|---|---|---|---|---|---|
| 1 | 1 | Simple | Available | Highly suitable | High |
| 2 | 2 | Simple | Available | Moderately suitable | High |
| 3 | 3 | Complex | Not available | Highly suitable | High |
| 4 | 4 | Simple | Not available | Highly suitable | Moderate |
| 5 | 5 | Simple | Not available | Moderately suitable | High |
| 6 | 6 | Complex | Available | Moderately suitable | Moderate |
| 7 | 7 | Complex | Not available | Moderately suitable | Moderate |
| 8 | 8 | Complex | Available | Highly suitable | Moderate |
| 9 | 9 | Complex | Available | Moderately suitable | High |
| 10 | 10 | Simple | Not available | Moderately suitable | Moderate |
| 11 | 11 | Complex | Not available | Moderately suitable | High |
| 12 | 12 | Simple | Available | Moderately suitable | Moderate |
| 13 | 13 | Simple | Available | Highly suitable | Moderate |
| 14 | 14 | Complex | Not available | Highly suitable | Moderate |
| 15 | 15 | Complex | Available | Highly suitable | High |
| 16 | 16 | Simple | Not available | Highly suitable | High |

two levels, 2x2x2x2= 16 combinations can be formed). The list of the 16 stimuli is presented in Table 3. These stimuli were given to 30 farmers, as 16 cards and they were asked to rank each stimulus. The scale of ranking was from 1 to 16, 1 for the most preferred stimulus and 16 for the least preferred stimulus. Then part-worth or utility of each level of different factors was found out using the SPSS software.

## Results and Discussion

The land value was one of the major components of the capital investment for all the systems considered. Average value/ lease value of land or opportunity cost of an open water system and semi-enclosed systems was considered in our study. The other costs for the culture systems includes the erection of strong bamboo rack structure for mussel culture and cage installation for multi-species culture. Annual fixed cost calculations considered a rate of 50% depreciation for bamboo poles, nylon rope, coir rope, and nylon cages. This higher rate of depreciation was considered based on feedback from farmers. Interest for capital investment was computed at 10% rate per annum (Table. 4). The annual fixed cost was highest for multi-species culture systems owing to the involvement of cage structures (Table 4), when compared to single species (mussel) culture system. In this study, the maximum annual fixed cost was corresponding to SEWMS (Rs. 0.1 lakh). Thus, while considering the annual fixed cost for the coastal aquaculture, all the systems analysed in this study were economically feasible.

The major operational costs for the culture systems included the transportation cost catch, and cost of harvesting and marketing. The former accounted for about 29% of total operating costs, whereas contribution of costs for harvesting and marketing were nearly 15%. The seed cost, which accounted for more than 15% in the case of mussel culture, reduced considerably in the multi-species culture (10%). Labour for construction of racks and expenses on muslin cloths were the other major components of operating cost. The study has not considered family labour charges in economic analysis. While there was no feed cost incurred for single species culture systems (SEWM and OWSM), a marginal cost (Rs. 1000) was incurred for multi-species culture systems (OWSMS and SEWMS). There was no feed cost involved in mussel culture since the species generally utilises the plankton available within the culture environment (Tables 4, 5 and 6). In multi-species system, red snapper was fed with chopped trash fish, whereas pearlspot graze upon the periphyton; and the mussels utilised plankton within the culture system.

Rate of return was the highest in SEWMS, whereas it was the lowest in OWSM. The payback period was almost 9 months in all the systems except in the case of OWSM in which it was 12 months. Even though the net profit and other indicators were higher of SEWMS, the break-even production (physical quantity) was also highest in the former system. To reach the break-even point, a physical production of 104.9 kg (average of all the three species cultured) was required in SEWMS, whereas it was the lowest in OWSM (65.9 kg). Net present worth for 3 years was calculated to test the feasibility of these culture systems. All these four systems showed positive net present values and hence were found to be economically feasible. However among these systems, the highest net present worth was obtained for SEWMS (Tables 4 and 5).

Our analysis suggested that most of the farmers were satisfied with the experimented aquaculture technologies (Table 7). Twenty-seven per cent of the participants rated the technologies to be excellent, 33% rated them as very good and, 30% as good. More than three-fourth of farmers felt the technologies to be highly useful. The aquaculture technologies also helped the farmers to increase their income. The livelihood of 37% of the farmers improved because of these technologies although none of them was interested in making aquaculture a primary occupation. However, about 74% of the farmers were interested to make these technologies as their secondary occupation. The farmers were in agreement that the technologies were less labour-intensive. Thirty-seven per cent of farmers are well aware and 60 % of farmers had very good knowledge of the experimented technologies. Only 4% of the farmers had the opinion that the technologies were too complex to adopt. More than half of the farmers felt these technologies to be economically viable and easy to adopt. The period of culture is very much convenient for 60% of the farmers. Majority of the farmers are satisfied with the technical and monitoring support. Sixty-three per cent of the farmers is not facing any difficulties in marketing the cultured fishes, which is a comparative advantage because it is a continuous stocking and harvesting system and farmers can harvest based on local demand.

The results of the conjoint analysis are provided in Tables 8 and 9. Results indicated that stimulus 1 was the one that imparted the highest utility to the farmers. The utility value calculated for this stimulus (7.637) is higher than the utilities for all other stimuli. Stimulus 7, the utility of which was calculated as (-7.637), was found to provide the least utility to the farmers. The utilities provided by all other stimuli lie in between these two extremes. While observing the individual levels, we found that technical support available was the level with the highest part-worth value (3.979). The farmers were willing to compromise on the area suitability of the technology to a certain extent as evident from the comparatively less part-worth value (0.958). The

Table 4. Comparative economics of open water system and semi-enclosed system with mussel culture and multi-species culture (Rs. per 500 $m^2$ per year).

| Particulars | Cost for OWSM | Cost for SEWM | Cost for OWSMS | Cost for SEWMS |
|---|---|---|---|---|
| Capital Investment | | | | |
| Land | 10000 | 12500 | 10000 | 12500 |
| Bamboo poles | 2500 | 2500 | 1500 | 1500 |
| Nylon rope | 2800 | 2800 | 1800 | 1800 |
| Coir rope | 200 | 200 | 500 | 500 |
| Nylon cages | | | 6000 | 6000 |
| Others | 1000 | 1000 | 1000 | 1000 |
| Total capital investment | 16500 | 19000 | 20800 | 23300 |
| Annual fixed cost | | | | |
| Lease value of land | 2000 | 3000 | 2000 | 3000 |
| Interest @10% per annum | 1650 | 1900 | 2080 | 2330 |
| Depreciation | | | | |
| Bamboo poles (50% per annum) | 1250 | 1250 | 750 | 750 |
| Nylon rope (50% per annum) | 1400 | 1400 | 900 | 900 |
| Coir rope(50% per annum) | 100 | 100 | 250 | 250 |
| Nylon cages | | | 3000 | 3000 |
| Others (50% per annum) | 500 | 500 | 500 | 500 |
| Total depreciation | 3250 | 3250 | 5400 | 5400 |
| Total Annual fixed cost | 6900 | 8150 | 9480 | 10730 |
| Operating Cost | | | | |
| Labour for Rack construction | 1500 | 1500 | 1500 | 1500 |
| Muslin cloth | 1500 | 1500 | 375 | 375 |
| Mussel/finfish seed | 1680 | 1680 | 720 | 720 |
| Harvesting and Marketing | 1500 | 1500 | 2000 | 2000 |
| Feed | 0 | 0 | 1000 | 1000 |
| Others | 1000 | 1000 | 1000 | 1000 |
| Transportation | 3000 | 3000 | 3000 | 3000 |
| Total operating cost | 10180 | 10180 | 9595 | 9595 |
| Total cost | 17080 | 18330 | 19075 | 20325 |
| Production (kg) | 225 | 292.5 | 169.37 | 201.1 |
| Average farm gate price (Rs./kg) | 150 | 150 | 261.73 | 265.66 |
| Gross income | 33750 | 43875 | 44330 | 53425 |

simplicity of the technology and the profit were found to be more important, than area suitability, from the farmers' point of view, as indicated by their part-worth values. Availability of technical support followed by simplicity of technology and net returns were the most important attributes, which were considered by the farmers. The attribute; area suitability had relatively less preference from the farmers' point of view (Tables 7 and 8).

The production from different culture systems was found higher compared to the common extensive and semi-intensive shrimp culture systems. SEWMS was the most productive system among the aquaculture systems in this study. The published reports on coastal shrimp culture systems indicated that the average production from one hectare area had varied from 500 to 1500 kg (Menon, 1954; Gopinath, 1956; George et al., 1968; George, 1974; Nasser & Noble, 1992; Jayagopal & Sathiadhas, 1993; Kumar & Panikkar, 1993). Generally, the annual fixed cost for shrimp farming ranged from Rs. 0.3 lakh in an extensive system to Rs. 1.9 lakhs in semi-intensive systems (Sathiadhas et al., 2009). Thus, the SEWMS system in this study can be an economically viable option for coastal aquaculture practices.

Economic indicators such as rate of return, payback period, breakeven production, BC ratio, and net present worth etc. were worked out well for all the aquaculture systems studied. A comparison of the net operating income, BC ratio, and net profit denoted that SEWMS has been the most profitable aquaculture system. Besides, multi-species culture has been considered to be more profitable than single-species culture systems. Though green mussel is in high demand, a single-species culture of green mussel would not be advisable because of its

Table 5. The species wise survival, production and returns from different aquaculture systems.

| System | Species | Number of seeds | Survival rate | Total survival (no) | Average individual weight at harvest (g) | Total production (Kg) | Unit price (Rs./kg) | Return (Rs.) |
|---|---|---|---|---|---|---|---|---|
| OWSMS | Red snapper | 100 | 0.65 | 65 | 0.85 | 55.25 | 400 | 22100 |
| | Pearlspot | 400 | 0.71 | 284 | 0.18 | 51.12 | 250 | 12780 |
| | Mussel | 3500 | 0.6 | 2100 | 0.03 | 63 | 150 | 9450 |
| Total | 169.37 | | 44330 | | | | | |
| SEWMS | Red snapper | 100 | 0.7 | 70 | 1 | 70 | 400 | 28000 |
| | Pearlspot | 400 | 0.72 | 288 | 0.2 | 57.6 | 250 | 14400 |
| | Mussel | 3500 | 0.7 | 2450 | 0.03 | 73.5 | 150 | 11025 |
| Total | 201.1 | | 53425 | | | | | |
| OWSM | Mussel | 15000 | 0.5 | 7500 | 0.03 | 225 | 150 | 33750 |
| SEWM | Mussel | 15000 | 0.65 | 9750 | 0.03 | 292.5 | 150 | 43875 |

Table 6. Economic indicators

| Economic indicators | OWSM | SEWM | OWSMS | SEWMS |
|---|---|---|---|---|
| Net operating income (S lakhs in 500 $m^2$ $year^{-1}$) | 0.23 | 0.33 | 0.34 | 0.43 |
| Net profit (₹ lakhs in 500 $m^2$ $year^{-1}$) | 0.16 | 0.25 | 0.25 | 0.33 |
| B:C ratio | 1.98 | 2.39 | 2.32 | 2.63 |
| Rate of return (%) | 71.03 | 146.05 | 139.52 | 140.64 |
| Payback period (Year) | 0.99 | 0.74 | 0.82 | 0.70 |
| Break-even production (kg) | 65.9 | 70.7 | 101.55 | 104.90 |
| Net Present Worth for 3 years ('000 ₹) | 58.04 | 78.97 | 76.37 | 94.74 |

seed scarcity (wild seeds only) (Laxmilatha & Sivadasan, 2007; Laxmilatha et al., 2009). In multi-species systems, selection of species for culture followed the local seed availability and market demand. In the semi-enclosed system, productivity and survival of species will be higher due to the control of water flow through sluice gates. The flow control would be leading to a high nutrient load and favourable conditions for the cultured species. Hence, properly managed, multi-species aquaculture through the inclusion of filter feeders in semi-enclosed systems accelerates aquaculture production without detrimental side-effects.

The multi-species culture systems demonstrated the maximum average farm gate price in comparison with mono- species culture systems. The reports on coastal aquaculture systems showed the farm gate price for shrimp culture and crab fattening were only superior to the systems in the present study (Anil & Suseelan, 2000; Sathiadhas & Najmudeen, 2004). However, the feed cost for the shrimp and crab aquaculture was significantly higher compared to the culture systems considered in this study. Moreover, the average farm-gate price for shrimp was highly varying in different culture systems (Sathiadhas et al., 2009). The mono- species culture of mullet and pearlspot yielded lower farm gate price compared to the cultural systems in this study (Sathiadhas & Najmudeen, 2004). Therefore the multi-species culture system experimented in this study can be a good option to tap the coastal aquaculture potential in a big way.

In this study, all the culture systems demonstrated a reasonably high rate of return (>100%) and short payback period (<1 year). These economic indices denote that all the systems considered in this study were economically viable. The SEWMS system showed the highest rate of return and the lowest payback period. In semi-intensive shrimp farming systems, the payback period was more than one year and the rate of return was 90% (Sathiadhas & Najmudeen, 2004). Moreover, earlier reports also showed that the rate of return and payback period for semi-intensive shrimp farming was not found to be economically viable (Kumar & Panikkar, 1993; Sukumaran et al., 1993).

Cost for feed in the culture systems was relatively low in comparison with the aquaculture systems for shrimp, crabs, and mullets (Sathiadhas & Najmudeen,

Table 7. Perception of farmers towards aquaculture technologies introduced (%)

| Particulars | Excellent (5) | Very good (4) | Good (3) | Poor (2) | Very poor (1) |
|---|---|---|---|---|---|
| Satisfaction | 27 | 33 | 30 | 7 | 3 |
| Usefulness | 27 | 47 | 23 | 3 | 0 |
| Income increase | 30 | 43 | 10 | 13 | 4 |
| Livelihood improvement | 37 | 30 | 17 | 13 | 3 |
| Primary occupation | 0 | 23 | 20 | 40 | 17 |
| Secondary occupation | 37 | 37 | 20 | 6 | 0 |
| Labour intensive | 0 | 37 | 53 | 10 | 0 |
| Awareness level | 37 | 60 | 3 | 0 | 0 |
| Simplicity | 23 | 53 | 20 | 4 | 0 |
| Economically viable | 30 | 57 | 13 | 0 | 0 |
| Culturally compatible | 23 | 63 | 14 | 0 | 0 |
| Technically compatible | 30 | 57 | 13 | 0 | 0 |
| Culture period convenient | 30 | 30 | 30 | 10 | 0 |
| High input cost | 37 | 43 | 17 | 3 | 0 |
| Lack of technical support | 67 | 33 | 0 | 0 | 0 |
| Market available | 63 | 37 | 0 | 0 | 0 |
| Area suitability | 43 | 37 | 20 | 0 | 0 |

Table 8. Utility estimates

| Attributes | Levels | Utility Estimate | Std. Error |
|---|---|---|---|
| Simplicity | Simple | 1.492 | 0.247 |
| | Complex | -1.492 | 0.247 |
| Technical support | Available | 3.979 | 0.247 |
| | Not available | -3.979 | 0.247 |
| Area suitability | Highly suitable | 0.958 | 0.247 |
| | Moderately suitable | -0.958 | 0.247 |
| Profit | High | 1.208 | 0.247 |
| | Moderate | -1.208 | 0.247 |
| (Constant) | | 8.500 | 0.247 |

2004). Therefore, the multi-species culture systems in semi-enclosed water bodies will be an excellent option for improving coastal aquaculture production with high returns in a short period. The state of Goa possesses a wide scope for development of aquaculture through its enormous and underutilized coastal water resources. Despite this rich resources and availability of technologies, a few people in Goa (less than 25) are engaged in coastal aquaculture activities. The major bottleneck seems to be the lack of knowledge and awareness about the awareness of the coastal aquaculture technologies. Till date, the coastal aquaculture of the state is restricted to extensive and semi-intensive shrimp farming. Although shrimp culture started as a profitable farming practice, the outbreak of diseases had resulted in a serious hold-up, which impelled the farmers to find an alternative that could promise comparable profits to shrimp farming. We suggest the development of sustainable aquaculture systems for poor and small-scale farmers living along the coastal regions.

Precise measurement of the total benefits of the adoption of different aquaculture technologies is a difficult task considering its ecological and social dimensions. In this paper, we have attempted only the economic evaluation of four different aquaculture systems promoted by the public sector, using the primary data from the farmers who are benefitted from the institutional training programme. However, we admit that the findings of the study could not be generalised considering the limited sample size used to arrive at the results, and also the fact that the institutional guidance was available to the farmers throughout the study. When the technology is completely adopted by the farmers, the possibility of ecological imbalances (species compatibility issues), and managerial capacities of the farmers and several other socio-economic factors will come into play, which were not described in this study. Still, the findings are relevant considering the dearth of information on the economic viability of coastal aquaculture systems in the region. We found that different culture systems varied in yield potential, with the multi-species culture system in semi-enclosed waters yielding the highest economic benefits for the farming community sustainably. The multi-species culture systems were found to be more profitable in comparison with monoculture systems. Moreover, the farmers' perception of these technologies also proved that the technical support for an effective culture technique would reasonably increase the confidence level of farmers in the aquaculture practices. Thus, we posit that establishing multi-species culture systems in semi-enclosed water bodies will be an excellent option for improving coastal aquaculture production with high returns in a short period. Therefore, this system can be a good option to tap the coastal aquaculture potential in a way that improves the economy of the local region.

## Acknowledgements

The authors are grateful to Director, all staffs of ICAR-Central Coastal Agricultural Research Institute and Director, ICAR-Central Institute of Fisheries Education, Mumbai, Dr. Shamila Monteiro (Former Director of Fisheries, Govt. of Goa) and other staff of the Fisheries department for their support and guidance in this study. We express our heartfelt thanks to Fishermen, Goa who assisted with site selection and sampling.

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