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Editor
N. Vasudevan

Authors
Dr. Subir Ghosh, Project Coordinator
Daya Patki, Project Management Specialist
Durga Thigale, Project Management Specialist
Rohit Sawant, Project Management Specialist

Project Team

N. Vasudevan (IFS), Nodal Officer Sindhudurg Project and Additional Principal Chief Conservator of Forests, Mangrove Cell
Lianchawii Chhakchuak, Programme Analyst
Kishore Wankhade, Project Manager
Dr Subir Ghosh, Project Coordinator
Daya Patki, Project Management Specialist
Durga Thigale, Project Management Specialist
Rohit Sawant, Project Management Specialist
Rinky Rajdev, Project Management Specialist
Suvarna Khandare, Finance and Administrative Assistant
Sneha Pillai, United Nations Volunteer
Avadhoot Velankar, Unted Nations Volunteer
Aditi Tandon, United Nations Volunteer

MANGROVE CELL
MAHARASHTRA FOREST DEPARTMENT

BEST PRACTICES IN COASTAL LIVELIHOOD GENERATION

Lessons from GoI-UNDP-GEF Sindhudurg Project (2012-2017)

INTRODUCTION

The UNDP-GEF project on "Mainstreaming Coastal and Marine Biodiversity Conservation into Production Sectors in Sindhudurg", implemented by Mangrove Cell of Maharashtra Forest Department from 2012 to 2017 has resulted in generation of good practices in the areas of planning; sustainable resource use; conservation of coastal and marine biodiversity; climate change and sustainable livelihood. Many of these good practices may be applicable in the sustainable development context of other coastal districts of Maharashtra as well as other coastal States. Considering the emphasis being laid on attaining the Sustainable Development Goals of the UN, it is necessary that these good practices are replicated in other districts of the State as well as in other states of country. Whereas most of these good practices are relevant in the context of other coastal districts within the state as well as to other coastal states of the country, some of these practices may be applicable in the context of sustainable development of non-coastal districts too. In this volume Mangrove Cell brings out the best practices in Coastal Livelihood generation implemented as part of the GoI-UNDP-GEF Sindhudurg Project.

CONTENTS

LIVELIHOOD ACTIVITIES IN SCME

The UNDP-GEF project is being implemented, in the Sindhudurg Coastal and Marine Ecosystem (SCME), which includes the coastal talukas of Devgad, Malvan and Vengurla, the Malvan Marine Sanctuary, the Angria Bank and the marine waters that connect the MMS and Angria Bank. The total population of the project area is estimated to be287,477 persons. There are 166 Panchayats and 316 villages (including 80 fishing villages) in the project area. The per capita income of the district in 2005-06 was INR 32,862 against the state average of INR 42,056. The district income in 2005-06 stood at INR 2,996 crores, when State Domestic Product was INR 438,058 crores, which is just 0.68 percent of the state's income. The population below the poverty line is 29.80, 35.49 and 41.15 percent in Devgad, Malvan and Vengurla respectively, the average being 35.48 percent. The average literacy rate in the 3 talukas is 80 percent, with female and male literacy rate being 71.2 and 90.3 percent respectively. The average population density of the three talukas is 218 persons per square kilometer.

Livelihood activities in the SCME are dominated by marine fishing. Tourism is a growing economic activity. Livelihood activities, other than fishing, include animal husbandry and agriculture. The principal agricultural crops are paddy, coconut, mango, cashew and Kokam. Taking into account the natural resources, the livelihood activities which were promoted in the coastal region of the Sindhudurg district under the UNDP-GEF project are discussed here (table 1).

Table 1. Improved livelihoods for coastal communities of Maharashtra			
Crab Farming	**Bivalve Farming**	**Integrated Multi-trophic aquaculture**	**System of Rice Intensification**
Mangrove area: 222 sq. km Private mangrove: 13000 ha	Resources: 162 creeks (41,636 ha)	Resources: 162 creeks (41,636 ha)	Resources: Paddy growing area in Konkan- 4,13,600 ha
Benefits:	*Benefits:*	*Benefits:*	*Benefits:*
Adaptation to Sea Level Rise	Adaptation to Sea Level Rise -diversification of livelihood through mariculture	Adaptation to Sea Level Rise diversification of livelihood through mariculture	Adaptation to Sea Level Rise through incresed productivity
Additional livelihood activity with focus on women entrepreneurs	Additional source of income through oyster and mussel farming	Additional source of income through fish farming - shift from land based production to sea based farming	Enhanced food security through better drought coping mechanism
Conservation of private mangrove areas through income generating mangrove dependent activity	Reduced pressure on marine fish stock	Reduced pressure on marine fish stock	Mitigation of Climate Change through reduction in emission of methane

MANGROVE CRAB FARMING

BACKGROUND

Mud crab farming is very popular in Asian countries like Bangladesh, India, Thailand, Philippine etc. Mud crab has huge demand and price in international market. Many countries of the world import huge quantities of crabs for consumption, resulting in increasing demand for supply. To meet this demand, aquaculture of crab farming is gaining importance. However, the real benefit of crab farming lies in conservation of the mangrove resource, through such income generating activities as mariculture of crabs in pens and ponds. The importance of mangrove in protection of the shoreline against coastal erosion, flooding and environmental calamities besides providing the much needed nursery ground for early stages of coastal and marine life forms as well as in carbon sequestration are well known. Crab farming is thus playing an important role in conservation of mangroves while meeting the livelihood needs of the coastal communities.

About 40% of the mangroves in Maharashtra are on private lands. These mangroves are always in the fear of being razed down for profitable enterprises. Since mangroves provide healthy breeding grounds for crabs, crab farming activities in mangrove areas help in conservation of mangrove while generating income for the coastal communities. The activity can even be taken up in mangrove areas coming under revenue land under the umbrella of Joint Mangrove Management programme. Sindhudurg district has 6,940 ha of mangrove area, distributed in Devgad, Malvan, Vengurla and part of Sawantwadi taluka. Considering 2 percent of the area may be available for crab farming, the potential area may be 138 ha or 347 acre in Sindhudurg.

Mangrove Crab

There are four species of mud crab, Scylla serrata, S. tranquebarica, S. paramamosain and S. olivacea that are the focus of both commercial fisheries and aquaculture production throughout the world. They are among the most valuable crab species in the world, with the bulk of their commercial production sent live to market.

Fig. 1 Scylla serrate

Fig. 2 Scylla olivacea

Scylla serrata, commonly known as the Mangrove Crab or Green Crab, has an immense market potential all over the world, particularly in South East Asian Countries. Crab is often sold in live, in many international markets. India earns foreign exchange to the tune of around 50 Million US $ by exporting Live Mud Crab captured from the low-lying coastal belts across the country. Thus, natural stocks of mangrove crab in the country are under constant pressure from fishing. To overcome the situation, aquaculture of crab has gained considerable importance. However, non-availability/inconsistent availability of crab seeds (Crab Instar/Crablet)is a major constraint in scaling up the activity. Besides, the natural stocks of crab and its juveniles is dwindling owing to habitat loss, urbanization in the coastal belts and increasing fishing pressure.

Life Cycle

A mature female mud crab produces from 1 to 6 million eggs, with the larger species producing larger numbers of eggs, and larger individuals typically carrying more eggs. Females retain sperms after mating so that 2 or even 3 egg masses can be produced without the further intervention of a male. Once eggs have been spawned and an egg mass produced (Figure 3.b), the time to hatching and the release of larvae is temperature dependent, with a shorter time to release at higher temperatures within the animals natural temperature range, and longer times at lower temperatures.

3.a Male Crab

3.b Female Crab

3.c Berried Crab with Eggs

3.d Immature, Maturing &Matured

3.e Crab Instars

3.f Crablets

Fig. 3 Various Stages in Life Cycle of Crab

Once released, the longevity of each larval stage is temperature dependent, with survival rates linked to both temperature and salinity. As a result, the length of time of the five zoeal stages and the one megalopa larval stage can vary considerably before settlement to the first crablet stage. As the crablets grow, they can moult up to 15 times in the case of S. serrata to reach the size of 150 mm; however, two further moults may still occur prior to death. As the crabs grow, the intermoult period gradually increases.

Crab Farming

Marine Product Export Development Agency (MPEDA) and Rajeev Gandhi Centre for Aquaculture (RGCA) has opened the avenues for commercialization of mud crab hatchery technology leading to organized Mud Crab Aquaculture in the coastal areas of the country particularly among the weaker sections of the society giving them an alternate livelihood option and also strengthens the production base for export of live & value added products such as soft shell crab. Stock Enhancement Program of Mangrove Crab in Mangrove Pens and Tide Fed Farms in Sindhudurg District has been initiated with support from UNDP-GEF project, Sindhudurg.

Crab farming Technology

At present mud crab farming in India is largely based on collection of crablets or crabs from the wild for fattening or grow-out, which has evolved over hundreds of years, hatchery production of mud crabs being a relatively recent innovation, with most research and development taking place over the last few decades.

Fig. 5 Crablets for stocking

A Grow-out Tide-Fed Crab Pond

Harvested Crabs

Farming Systems

Tide-fed Pond farming

Ponds designed for shrimp with a water depth of 80–120 cm, are also suitable for farming mud crab. For construction of tide-fed earthen pond for mud crab farming in mangrove areas, the physical prerequisites for a good site are the same as for a tide-fed shrimp farm.

Unlike marine shrimp, mud crabs can leave water and spend considerable periods of time on land. As a result, if a barrier of some type did not surround a mud crab aquaculture pond, stock would be able to walk out of the pond, which would be a direct financial loss to the farmer. To counter this mud crab behaviour, netting typically surrounds mud crab culture ponds (Figures 6.b). Netting height may vary from 20 to 50 cm in height above the top of the pond. The netting is typically supported by posts and may be topped with Silpauline sheet. The Silpauline sheet topping is added as mud crabs are good climbers and they can climb up netting, but are unable to climb up clear plastic sheeting.

Fig.6a A Tide-Fed Grow-out Pond

Fig.6b A Tide-Fed Pond with netting around

Mangrove pens

Site Selection:

The best sites for construction of mud crab mangrove pens are in areas already known for their good production of mud crabs from a wild fishery. Areas with relatively low tidal ranges are preferred. When choosing an appropriate area to construct a mangrove pen, low to medium density mangroves are preferred to extremely dense mangroves. This is because denser stands of mangrove will be more difficult to construct pens in. Crab fishers may well be prime candidates for mud crab farming development, as they are already familiar in handling crabs, and have existing supply chains the product can be fed into.

Fig 7a. Digging of Channel

Fig 7b. Fixing of Poles

Fig 7c. Enclosing the area with Net

Pen Construction:

The walls of mud crab mangrove pens need to be buried in the mud (30–60 cm) to minimize the risk of mud crabs burrowing under the walls of the pens. Pens are commonly constructed with vertical support posts every 3 m, and horizontal bracing structures to support the walls. To maximize the longevity of pen structures, posts should be made from wood that is most resistant to marine borers or treated to reduce their impact.

Pens should be constructed to minimize damage to mangrove roots, to preserve the health of the trees. In addition, pens need to be constructed and maintained so that they do not change natural drainage and flow of water through the mangroves. When designed and constructed according to these guidelines, mud crab mangrove pens have been demonstrated to be ecologically sustainable. Mud crab pen construction includes the construction of ditches within them. The idea is that water will be held in them at low tide so that crabs can stay immersed when tides are out. One extension manual suggests that 20–30 percent of the area of a pen should consist of such ditches.

Crab Fattening:

After moulting, crab musculature takes some time to grow to fill its new shell, so the crab is referred to as "empty", or a "water crab". Mud crab fattening refers to the process whereby, "empty crabs", are held and fed for a period, often of only a few weeks, until they are full of meat and ready to market. Cellular systems, where crabs are kept in individual containers, can be used for fattening of crabs. Crab fattening systems can either be river, coastal or pond-based. Water quality is essential for such operations. Crabs are kept in high densities, in close proximity to each other, so oxygen demand will be higher than in low-density grow-out systems. For Cellular systems, a good flow of water is essential to maintain good oxygen levels. In ponds, water flow and aeration are both options that can be used to maintain oxygen at acceptable levels (>5 mg/litre).

For cellular systems involving recirculation systems within buildings, for fattening, soft-shell crab production or grow-out, the site requirements are quite different. Such recirculation systems require access to good-quality marine and freshwater sources and appropriate electricity supply, as the demands of such systems are significant.

Fig.9a Battery of Soft Shell Crab boxes

Fig.9b Soft Shell Crabs in a box

Pond Preparation for Stocking:

Prior to stocking, after the previous harvest, ponds should be dried out for several weeks and any repairs undertaken. This ensures any unwanted species are removed from the pond that may be competitors for feed fed to crabs or predate on crablets. Turning over the soil in the bottom of the pond, or tilling, helps in breakdown of organic residues and release of nutrients. Tilling can be combined with the addition of lime to pond floors. Liming can be used to improve the pH of pond sediments, accelerate decomposition of organic matter and improve fertilizer response.

Some ponds used in crab production may be difficult to drain, and may be restocked after harvest without draining. To eradicate competitors or predators for mud crabs from the pond, the water should be treated with tea seed cake or mahua oil cake or rotenone. Brackish water or saltwater being used to fill a mud crab pond should be filtered through a small mesh “sock” or “bag” of approximately 120 µm mesh to reduce the risk of other species entering the pond.

As mud crab culture in low salinity water (5–12 ppt) has been linked to low survival of stock and delayed moulting, ponds should be stocked with brackish to fully saline water (10–35 ppt). The growth of S. serratacrablets has been demonstrated to be optimal at salinities of 10–25 ppt.

Stocking:

Monoculture

A wide range of stocking densities has been tried for mud crabs. Mud crabs are stocked at relatively low densities (0.5–1.5 crabs/m2) with survival rates as high as 67 percent. Stocking mud crabs from 0.5 to 3.0 crabs/m2 is considered semi-intensive.

Monosex monoculture

Male crabs attain a significantly higher final weight than female crabs. As crabs can usually be sexually differentiated by the time they are at the C4–C6 stage by examination of the shape of their abdominal segments, ponds can be stocked for monosex culture from advanced crablets. Stocking with monosex mud crabs can simplify post-harvest processing and may minimize aggressive behaviour between crabs associated with sexual maturity.

Acclimatize

On arrival, crablets can be transported to a growout facility with or without water. If packed in water they may be cooled to 22–240C to prevent moulting on the way to the farm and to lower oxygen consumption. At the farm, crablets should be put in basins (or similar containers) with a small amount of water from the pond for which they are intended to acclimatize. Once acclimatized to the temperature of the water and its salinity, they can be released into the pond.

Monitoring

As in any farming venture, monitoring various parameters related to the crop over time, is necessary for decision-making and operating a more profitable enterprise. These include, water quality; feed consumption; mud crab growth and survival; and mud crab health.

Feed

Mud crabs can be successfully raised on a variety of diets including, low-value/trash fish, slaughter wastes, fish wastes, mussels, snails, shrimp heads, animal hides, entrails, kitchen leftovers and formulated shrimp feeds. Development of formulated feeds for mud crabs is likely to become increasingly important as trash fish and other wild resources come under increasing pressure for use as feed for various types of aquaculture and for human consumption. It has been shown that S. serrata gain weight faster and moult more frequently on diets containing higher protein (up to 55 percent of diet) and lipid (up to15 percent of diet) levels. The same study demonstrated formulated feeds can produce feed conversion rations (FCR) of 1.2 to 2.1:1 for juvenile crabs.

Practical formulated diets have been developed and tested for S. serrata good growth has been obtained on diets with 32–42 percent protein, 6–12 percent lipid and with dietary energy ranging from 14.7 to 17.6 MJ/kg. Other work has demonstrated that between 20 and 40 percent of fishmeal in mud crab diets can be replaced with soybean meal without affecting growth.

Feeding

Feeding rates utilized are often quoted as a percentage of the body weight of mud crabs in a pond. As the quality and nutritive value of trash fish and other natural feeds varies significantly, these figures are difficult to generalize on. The advocated daily feeding rate using trash fish is calculated at the rate of 5-10% of the body weight based on growth stage, temperature and satiation level as reflected from consumption in feeding trays. Feeding frequency is typically once or twice a day, with feeding recommended every day to minimize the risk of cannibalism, which is considered more likely if the crabs are hungry. As mud crabs often seem most active late in the afternoon and early evening, one feed is commonly provided at that time.

Harvesting

Once some of the crabs in a pond are identified as large enough to harvest, harvesting of crabs can commence. Crab pots of various designs can be used to harvest crabs. These are baited with food attractive to crabs. It is found that the largest crabs in a pond tend to enter traps first. As this is the case, ponds can be partially or selectively harvested on a regular basis, progressively removing the larger crabs from the pond. To complete the harvest, either trapping is continued until no more crabs are trapped, or the pond is drain harvested, with crabs collected from the pond's drain or the lowest part of the pond.

Fig. 10. Crab Harvesting at Vengurla, Sindhudurg in the presence of Smt. Leena Nair, IAS, Chairman MPEDA, Shri N. Vasudevan, APCCF (Mangrove cell), Sri Anil Bhandari, District Collector, Sindhudurg, Shri Anil Kumar, Dy. Director, MPEDA, Dr.S.K.Ghosh, Project Coordinator, UNDP-GEF Sindhudurg Project and Smt. Annei Alexander, DGM, NABARD

ECONOMICS OF CRAB FARMING: UNDP-GEF PROJECT, SINDHUDURG (WSA: 1 ACRE)

Technical Assumptions :

Sl. No.	Parameters	UNIT/Material	Specifications
1	Area Proposed for Rearing	Sq.Meter	10000
2	Water Spread Area	Sq.Meter	8000
3	Water Depth of the Pond	Meter	1-1.2
4	Fencing Specifications	RM x M	400 x 0.6
5	Type of Fencing	Material	Silpaulin Sheet
6	Thickness of Fencing sheet	Micron	200
7	Type of Hide Outs	PVC Pipe/Tiles	
8	Hideouts	Nos	2000
9	Catwalk	Nos	8
10	Check trays	Nos	8
11	Stocking Density Proposed	Nos/M^2	0.5
12	Crablet Stocked	Nos	5000
13	Indicative Survival	Per Cent	50
14	Duration of Cycle	Months	8
15	Size Range of Crabs at Harvest	Kg	0.5-0.8
16	Avg. Size at Harvest	Gm	700
17	Indicative No. of Crabs at Harvest	Nos	2500
18	Production	Kg	1750

Feed Requirement and Feed Conversion Ratio

Crab farming in Ponds of 1 Acre (Trash Fish)								
Months	Av. Body Wt. during the month (gm)	Stock (NO.)	Total Stock (kg)	Feeding Rate (% BW)	Feed Quantity /day (kg)	Total Feed /Month (Kg)	Price of Feed (Rs/Kg)	Feed Cost (Rs)
1	20	5000	100	10.0%	10	300		0
2	70	4500	315	8.0%	25	756		0
3	150	4050	608	5.0%	30	911		0
4	250	3645	911	3.5%	32	957		0
5	350	3281	1148	3.0%	34	1033		0
6	450	2952	1329	3.0%	40	1196		0
7	500	2657	1329	3.0%	40	1196		0
8	600	2524	1515	3.0%	45	1363		0
	Grand Total					**7712**		**0**
	Survival (%)					*50*		
	Total Feed Consumed					*7712*		
	Av. Wt. at Harvest (gm)					700		
	Number of Fish					2500		
	Total Harvest (Kg)					1750		
	Incremental Stock					**1650**		
	FCR		1		:	5		

Unit Cost:

A. Capital Cost

S. No.	Particulars	QTY	Unit	Rate (□/Unit)	Amount (□)
1	Construction of Pond – Earth work incl. Lead, Lift & Consolidation	3200	M^3	45	144000
2	Feeder Canal Construction			Lump sum	50000
3	Construction of Inlet(s)	3	Nos.	15000	45000
4	Construction of Sluice with Wooden & Mesh Shutters			Lump sum	100000
5	Cost of Pump 5.0 HP with All Accessories			Lump sum	30000
6	Cost of Temporary Shed for Store with Watch & Ward			Lump sum	50000
7	Cost of Fencing to Pond	400	RM	50	20000
8	Cost of Hide outs	2000	Nos.	10	20000
9	Cost of Temp. Shed for Pump/Motor			Lump sum	30000
10	Cost of Temporary Shed for Store ,Watch & Ward			Lump sum	50000
11	Cost of Catwalks	8	Nos.	2500	20000
12	Cost of Electricity Connection			Lump sum	20000
13	Cost of Water Quality Equipments (Salinity Refractometer, pH Meter etc.)			Lump sum	30000
14	S. Total				609000
15	Contingencies	5	%	609000	30450
	S. Total (Capital Cost)				**639450**

B. Operational Cost

S. No.	Particulars	QTY	Unit	Rate (□/Uni	Amount (□)
1	Pond Preparation			Lump sum	30000
2	Cost of Lime - CaO	600	kg	12	7200
3	Cost of Fertilizers & Chemicals (Lime, Probiotics)	650	kg	15	9750
4	Cost of Bio Fertilizers for Plankton Development	350	kg	30	10500
5	Cost of Seeds (Crablets) incl, Packing, Transport	5000	Nos	22	110000
6	Cost of Feed (Trash Fish) FCR 5 : 1	7500	kg	30	225000
7	Cost of Electricity/Fuel			Lump sum	25000
8	Cost of Plasticwares			Lump sum	5000
9	Cost of Labour - 1 No.	240	days	350	84000
10	Cost of Test Kits (Ammonia, Niitrite etc)			Lump sum	9000
11	Repair & Maintenance			Lump sum	10000
12	Harvesting Expenses	1755	kg	20	35100
	S. Total (Operational Cost)				**560550**
	Unit Cost (A+B)				**1200000**

C. Production and Income		**Designed Production Capacity and Income**				
1	**Item**	QTY	Unit	Rate (□/unit	**Amount (□)**	
2	Expected Production	1750	kg	**750**	**1312500**	
3	**Yearwise Production**					
4	**Item**	**1st Yr**	**2nd Yr**	**3rd Yr**	**4th Yr**	**5th Yr**
5	Capacity Utiliation	75%	100%	100%	100%	100%
6	Production	1313	1750	1750	1750	1750
7	Gross Income	984375	1312500	1312500	1312500	1312500
8	Operational Cost	560550	560550	560550	560550	560550
9	Net Income	423825	751950	751950	751950	751950

Cash Flow Analysis & Viability

Cash Flow analysis of the model has been carried out following the discounted cash flow technique[1]. The analysis includes calculation of Benefit Cost Ratio (BCR), Internal Rate of Return (IRR) and Net Present Value (NPV), Sensitivity analysis and bankability through assessment of Repayment Schedule for borrowed fund. The cash flow has been worked out for a discount rate of 15% and for a period of 6 years. The recurring cost has been assumed only partially for the year 1 & year 5, in proportion to the items of expenditure envisaged at the beginning of the crop for yearo and that associated with harvest and post-harvest for year 5. For the intervening years total expenditure has been considered.

[1]Price Gitinger's book, The Economic Analysis of Agricultural Projects

Economics of Crab Farming							
Cash flow with expected production and 5 Yr. Repayment Period							
Discounting factor			15%				
Year	**0**	**1**	**2**	**3**	**4**	**5**	**Total**
Cost							
Fixed	639450	0	31973	31973	31973	31973	
Recurring	240950	551550	551550	551550	551550	300600	
Total Cost	**880400**	**551550**	**583523**	**583523**	**583523**	**332573**	
Benefit		**984375**	**1312500**	**1312500**	**1312500**	**1312500**	
Net	-639450	432825	728978	728978	728978	979928	
Discount factor	1.00	1.15	1.32	1.52	1.75	2.01	
Present value of Benefit	0	855978	992439	862990	750426	652544	3461833
Present value of cost	880400	479609	441227	383676	333631	165347	2518542
Disc cash flow	-639450	376370	551212	479315	416795	487197	1184241
BCR		1.37					
NPV		1184241					
IRR		82.81%					
Financial Viability		***Viable***					

Sensitivity Analysis

Sensitivity analysis of the model has been carried out by subjecting it to fall in projected productions to the extent of 10% and a combined fall in production of 10% and a 10% fall in sale price. The results show that both production models are viable with BCR and IRR values of 1.24&64.57% respectively for model 1 and 1.11&47.34% respectively for model 2.

Ratios	Model 1. 10% Fall in Production	Model 2. 10% fall in production as well as price
BCR	1.24	1.11
NPV	838058	526493
IRR	64.57%	47.34%
Financial Viability	***VIABLE***	***VIABLE***

ECONOMIC IMPACT:

The area under mangrove in the coastal areas of Maharashtra is 22000 ha. It is proposed to develop 3% of the available area. The program will involve scaling up the activity to 1500 acre area in 5 districts and also set up a crab hatchery for seed supply. This will provide livelihood support to 15000 families, resulting in crab production of 600 mt, generating additional income of the order of Rs. 30 Cr. Per annum. Beside generating much valued livelihood oppertunity for the coastal fishers, it would also help in conservation of Mangrove areas which is an important coastal ecosystem and the nursery ground for1/3rd of all marine organisms and thus contributing to their recruitment and stock enhancement.

Scaling up Crab Farming in Mangrove areas of Maharashtra

The program will involve setting up pilot projects, scaling up the activity to 1500 acre area across the 5 coastal districts of Maharashtra and also setting up of a 2acre pilot project in each district to demonstrate the activity as well as render capacity building. As a part of the project a crab hatchery for seed supply is also planned. The necessary financial support in this regard will be provided by the Mangrove Foundation as well as the Govt. of Maharashtra.

Crab farming		Potential	Target	Unit cost	Amount (INR
1	Crab Farming (Pilot Project)@ 10 acre/district		50	400000	20
2	Crab Farming	1500	1500	300000	450
3	Crab hatchery (10 million instars)	3	1	90000000	90
	Total				560

OYSTER FARMING

Distribution of Oysters

Sindhudurg coast is blessed with a vast network of backwaters and creeks. The numerous estuaries and backwaters along the coast offers significant mussel and oyster resource. In order to utilise this resource and promote mariculture-based livelihood activities, a study was awarded to Colleges of Fisheries, Ratnagiri for mapping the mussel and oyster culture potentials of Sindhudurg. Based on the study,38 villages in the 3 coastal talukas i.e. Devgad, Malvan and Vengurla were identified, having good oyster resource. Oyster fishing grounds along the west coast include Dahanu creek, Satpuri, Palghar, Kelwa, Jaitapur, Versova, Alibag, Purnagad, Boiser, Marve, Ratnagiri, Devgad, Malvan, Cuff Parade, Mahad, Utsali, Navapur, Aramra creek, Gagwa creek, Gomati creek and Azad island.


Jamsande, Devgad


Peerwadi, Malvan


Wadatar, Devgad

The main oyster species that contribute to the Oyster fishery in Maharashtra are, Saccostrea cucullata, Crassostreagryphoides and Crassostreamadrasensis. Oyster fishing has been reported in Alibag, Ratnagiri, Jaitapur and Malvan. In Purnagad creek near Ratnagiri the oysters were found attached to the rocks at a depth of 4 to 5 fathoms. The oyster fishing season is from December to May.


Crassostreamadrasensis


Crassostreagryphoides

Crassostrearivularis Saccostrea cucullata

Reproduction

In the genus Crassostrea, sexes are separate but occasionally hermaphrodites occur. During spawning, ripe eggs and sperms are discharged into the exterior where fertilization takes place. Temperature food availability and salinity are considered as important exogenous factors, in influencing the maturation of gonads. A single female measuring 80-90 mm spawns 10 to 15 million eggs at a time.

Oyster Farming

Oyster is one of the best known and most widely cultivated marine animals. The oysters are highly esteemed sea food and considered a delicacy in USA, Europe and Japan. In India there is a growing demand for oyster meat in some parts of the country. Until recently, oyster farming has been considered as a traditional practice followed only in the temperate countries. The awareness about the vast potentialities for development of oyster farming in tropics is recent. Serious efforts are now being directed in its development under tropical conditions.

Candidate species

Six species of oysters namely the Indian backwater oyster Crassostreamadrasensis, Chinese oyster, C. rivularis, West coast oyster, C. gryphoides, Indian rock oyster, Saccostrea cucullata, Bombay Oyster, Saxostreacucullata, and giant oyster Hyostissahyotis are found in India. The first four species mentioned above are of commercial value.Of the six species of oysters, the Indian backwater oyster C. madrasensis is the dominant species, more widely distributed, is euryhaline and inhabits backwaters, creeks, bays and lagoons and occurs in the coastal areas of the states of Orissa, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka and Andamans. C.gryphoides is also euryhaline and occurs along north Karnataka, Goa and Maharashtra coast. C.rivularis is found along Gujarat and Maharashtra coast while Saccostrea cucullatais found all along the main land coast and Andamans and Lakshadweep islands. Culture of these species is possible at places where the seed is easily available.

Technical Parameters of Oyster Farming[2,3]

The technology of oyster culture consists of two important phases, i. Oyster seed/Spat collection and ii. Grow-out System. The technology adopted in this context is based on the technology advocated by CMFRI as described here.

[2]Edible Oyster Farming in India, Vidya .R, Scientist, MFD, CMFRI

[3]CMFRI Training Manual, Series No: 6/2015

Oyster seed / spat collection

The seed requirement for culture of oyster is met either from natural spat collection or through hatchery rearing. For collection of spat from natural oyster breeding ground, suitable spat collectors or cultch materials are prepared. The spat collectors may be oyster shells, coconut shells, asbestos sheets, mussel shells or other materials. These clutch materials are arranged on Nylon rope or G.I. wire at 25-30 cm intervals and suspended from racks in the creek waters.

How to prepare a cultch

Cultch is the term used for spat / seed collector. Broadly two methods are used for spat collection, i.e. suspended method or tray method.

- Suspended Method: The suspended method of oyster culture cultch made of oyster shells have been found to be ideal. Empty oyster shell sare cleaned manually to remove the foulers and then washed to remove silt. A small hole is made on the shell and these are strung on 3mm dia nylon rope with a spacing of 15 to 20 cm between each shell (5 shells per meter rope). Such strings are called ren. The spaced rens can be used as such for grow out system. For seed collection purposes the shells are strung continuously without spacers (10 to 15 shells per meter) and after the attachment of seed they shells can be removed and restrung at the rate of 5 shells per meter which is the ideal density for grow out.
- Tray Method: If the oysters are to be grown by the tray method then empty shells or lime coated tiles can be placed in the trays for seed collection. Lime coated tiles gave encouraging results and on a single tile, as many as 120 larvae are known to settle.

When to place the cultch for seed collection

One of the main factors that determine the success of the farming operation is the period when the clutches are placed for seed collection. If they are laid in advance of spat fall, they may be covered with silt or settlement of foulers, making the suitable for the oyster larvae to settle. The larval period in *C. madrasensis* is 15-20days. The ideal time for laying the spat collectors in the water is about 7 -10 days after peak spawning (as determined by gonad examination and abundance of early larval stages in the plankton). Strong currents interfere with larval settlement and may result in poor spat collection.

CASH FLOW ANALYSIS

Cash Flow analysis of both the models have been carried out following the discounted cash flow technique[4]. The analysis includes calculation of Benefit Cost Ratio (BCR), Internal Rate of Return (IRR) and Net Present Value (NPV), Sensitivity analysis and bankability through assessment of Repayment Schedule for borrowed fund. The cash flow has been worked out for a discount rate of 15% and for a period of 5 years. The recurring cost has been assumed only partially for the year 1 & year 5, in proportion to the items of expenditure envisaged at the beginning of the crop for year1 and that associated with harvest and post-harvest for year 5. For the intervening years total expenditure has been considered.

[4]Price Gitinger's book, The Economic Analysis of Agricultural Projects

		
Oyster Culture in wadatar	Spat Collector or clutch	Rens suspended from racks

Site Selection

Sheltered areas offering protection from strong wave action are preferred. Intertidal region extending upto 5 m depth can be considered for adopting suitable culture method. Similarly the culture technique is adopted depending upon the type of substratum. On-bottom culture method is substrate specific while off-bottom method has little to do with the nature of substratum. The natural oyster populations of C. madrasens is occur at a temperature range of 21 to 31 ^{o}C.

Farming methods

They are broadly grouped as bottom (on bottom) culture and off-bottom culture. Raft, rack, long-line and stake are used in the various off-bottom culture practices.

On bottom culture

The oysters are grown either in the intertidal or subtidal area directly on hardsubstratum. For intertidal culture a minimum of 16 hours submergence is suggested to ensure adequate food supply. Oyster seed attached to the collectors are planted on the bottom and allowed to grow for the market. This method is yet to be experimented in India.

Off-bottom culture

The various off-bottom culture practices are rack& tray, rack & ren, long-line and stake methods. Small scale bottom culture of oysters by transplanting the spat from the natural beds to shallow areas of convenience has been practiced for some time along the west coast. However, only recently have extensive oyster culture trial been executed. Oysters are cultured in intertidal regions, bays and estuaries and available data indicate that many of these environments in the country are suitable for oyster farming. In Sindhudurg, the following systems of oyster culture have been tried.

Rack and Tray System

The rack and tray method can be profitably employed in shallow coastal waters of the coast. Each rack is composed of two rows of six poles (2.4 m in length) driven into the muddy bottom at an interval of 2 m. Each set of six poles are fixed together by a long pole placed horizontally on top of them; the two rows are connected to one another by a series of short poles placed horizontally between the two long poles. This rack system, which covers an area of 25 m^2, constitutes a suitable platform for suspending the oyster trays. Each rack can accommodate 20 rectangular trays which have a holding capacity of 3,000–4,000 oysters. The rack method has been developed and successfully practiced at Tuticorin.

Rack and Ren System

The rack and ren method is similar to the rack and tray system as regard the construction of the rack is concerned. This rack system, which covers an area of 25 m^2, constitutes a suitable platform for suspending the oyster rens. Each rack can accommodate 300 ropes with 5 levels of oyster settling. Spats settle on collectors, placed near natural oyster beds for oyster farming. Due to the different environmental conditions associated with each grow-out region such as, density of natural oyster beds, current velocity, nutrients in water, primary production, salinity levels, proximity to the bar mouth, pest and predators, the oyster farming technology requires fine tuning. Approximately, 15 oysters are harvested per ren, accounting for 4500 animals from 300 rens per rack. The mortality is about 45%.

Farm Management

Periodic checking of the farms is essential. The main points to be checked are replacement of broken farm structure and re suspending loosened rens which touch the estuarine bottom. High mortality rates have been observed when the rens fall on the ground. To tide over these problems periodic checking is essential. Predaters and foulers are also a menace to oyster farmers. Crabs, fishes, starfishes, polychaetes and gastropods are the predators of oysters. Barnacles are fouler that settles on the wooden structures, trays and oysters. It competes for food with the oysters. It also increases the weight of the ren causing damage to the farm structure. Oysters in the natural bed at Tuticorin have been observed to be infected by the fungus *Perkinsusmarinus*.

Harvest of oysters

The oysters are harvested after a rearing period of 8-10 months. Harvesting is done manually.

Depuration

Oysters, like other filter-feeding bivalves, accumulate pathogenic organisms in their body. Members of the *Salmonella* group cause typhoid fever, while coliforms and vibrios cause gastroenteritis. By depuration the bacterial load is brought down to permissible levels, also faeces, sand particles and silt are removed from the alimentary canal of oysters. The oysters are placed for 24 hours in cleaning tanks under a flow of filtered seawater. About 10-20% of the seawater is continuously replaced. At the end of 12hours the water in the tank is drained and oysters are cleaned by a strong jet of water to remove the accumulated faeces. The tanks are again filled with filtered sea water and the flow is maintained for another 12 hours. Then the tanks are drained and flushed with a jet of filtered sea water. The oysters are held for about one hour in 3ppm chlorinated seawater, and then washed once again in filtered seawater before marketing.

Transport and storage

Oysters kept under moist and cool conditions survive for several days. However it is desirable that they reach the consumer within three days of harvest. Studies indicate that oysters packed in wet gunny bags are safely transported for 25-30 hours without mortality and in good condition.

Shucking

The removal of the meat from the oyster is called shucking. A stainless steel knife isused for the purpose. To render shucking easy, oysters are subjected to freezing the oysters, or immersing them in hot water. However in India steaming the oysters for 5 to 8minutes has been found to be ideal to make the oysters open the valves.

Processing

Oysters are eaten in fresh condition in the half shell in many countries. The oysters are processed in several ways, which include freeing by spreading them in a single layer of trays in an air blast freezer with polypropylene film stretched over each tray. Frozen whole oysters remain in good condition for six months in cold storage at 25°C. The oyster meat can also be smoked or canned

Pilot Project on Oyster Farming

A pilot project was initiated with technical support from the Central Marine Fisheries Research Institute (CMFRI) to demonstrate mussel and oyster culture practices, taking advantage of the natural spat fall in the identified creeks and locations. As filter feeding bivalves feed on the natural food from the marine environment, the entire production practice is based on natural productivity. Such eco-friendly farming practices can be taken up at the designated sites in estuaries and creek areas by the local fishermen groups. Promoting oyster culture will help strengthen coastal livelihood and also address food security, acting as an adaptive means of resilient livelihood for the coastal communities over classic fishing which is declining due to various factors including delayed rainfall, sea level and temperature rise.

Economics and Financial Analysis

Unit cost has been worked out for two models of Oyster Farming as follows.

◊Production of Shell on Oyster ◊ Production of Shucked Meat of Oyster

Unit Cost of Rack and ren method Oyster farm 5x5 m				
A. Fixed Cost				
Sr. No.	Item of work	Quantity	Rate	Amount (Rs)
1	Bamboo poles (nos)	30	320	9600
2	Rope (for farm costruction, 3mm) in kg	2	250	500
3	Rope (Ren making, 3mm) in kg	6	250	1500
4	S. Total (Capital Cost)			11600
B. Recurring Cost				
1	Shell	1500	0.5	750
2	Ren Making	300	1.5	450
3	Construction of Rack (no. of labours)	2	850	1700
4	Installation of spat culch (no. of labours)	1	850	850
5	Harvesting (no. of labours)	4	850	3400
6	Canoe hire charges (days)	5	250	1250
7	Depuration charges @ Rs/kg	1500	7	10500
8	S. total Recurring Cost (Shell on)			18900
9	Fuel Charges (No. of Cylinders)	1	2000	2000
10	Shucking Charges (kg)	105	50	5250
11	Single Oyster declumping	3000	1	3000
12	S. total Recurring Cost (Shucked Meat)			29150
13	*Unit Cost (Shell on Oyster)*			30500
14	*Unit Cost (Shucked Oyster)*			42100

Production and Income

The production of shell-on oyster has been assumed @ 15 oysters per ren. Thus total production for 300 rens works out to be 4500 nos. or 1500kg. Assuming a sale price of Rs 12 per oyster, the gross income from shell-on oyster may be Rs. 54600/-. Considering the meat yield to be 8%, the production of shucked meat may be 120 kg per crop and the gross income may be Rs 60000/-, considering a sale price of Rs 500 per kg for shucked meat.

Production & In come													
	Item	Unit	No of ren	No of Animals / ren at harvest	Total Harvest (No)	Sale Price Rs/No	Sale Amount (Rs)	Av wt. / animal (gm)	Total Harvest (Kg)	Shucked Meat yield /kg of oyster (%)	Yield of Shucked meat (kg)	Sale price of Meat (Rs/Kg)	Income from sucked meat (Rs)
1	Shell on Oyster	25 M2	300	15	4500	12	54000	0	0	0	0	0	0
2	Shucked Oyster	26 M2	300	15	4500	0	0	333	1500	8%	120	500	60000

Cash Flow Analysis & Viability

Cash Flow analysis of both the models have been carried out following the discounted cash flow technique[5]. The analysis includes calculation of Benefit Cost Ratio (BCR), Internal Rate of Return (IRR) and Net Present Value (NPV), Sensitivity analysis and bankability through assessment of Repayment Schedule for borrowed fund. The cash flow has been worked out for a discount rate of 15% and for a period of 5 years. The recurring cost has been assumed only partially for the year 1 & year 5, in proportion to the items of expenditure envisaged at the beginning of the crop for year1 and that associated with harvest and post-harvest for year 5. For the intervening years total expenditure has been considered.

Economics of Oyster Farming (Shell-on Oyster)						
Cash flow for 5 years, as per expected production and income						
Discounting factor		15%				
Year	**1**	**2**	**3**	**4**	**5**	**Total**
Costs						
Fixed	11600	5800	5800	5800	5800	
Recurring	4375	18900	18900	18900	14525	
Total Cost	**15975**	**24700**	**24700**	**24700**	**20325**	
Benefit	**0**	**54000**	**54000**	**54000**	**54000**	
Net	-15975	29300	29300	29300	33675	
Discount factor	1.00	1.15	1.32	1.52	1.75	
Present value of Benefit	0	46957	40832	35506	30875	154169
Present value of cost	15975	21478	18677	16241	11621	83992
Disc cash flow	-15975	25478	22155	19265	19254	70177
BCR	1.84					
NPV	70177					
IRR	181.27%					
Financial Viability	***Viable***					

[5]Price Gitinger's book, The Economic Analysis of Agricultural Projects

Economics of Oyster Farming (Shucked Oyster)						
Cash flow as per expected production and 5 Yr. Repayment Period						
Discounting factor		15%				
Year	**1**	**2**	**3**	**4**	**5**	**Total**
Costs						
Fixed	11600	5800	5800	5800	5800	
Recurring	4375	29150	29150	29150	24775	
Total Cost	**15975**	**34950**	**34950**	**34950**	**30575**	
Benefit	**0**	**60000**	**60000**	**60000**	**60000**	
Net	-15975	25050	25050	25050	29425	
Discount factor	1.00	1.15	1.32	1.52	1.75	
Present value of Benefit	0	52174	45369	39451	34305	171299
Present value of cost	15975	30391	26427	22980	17481	113255
Disc cash flow	-15975	21783	18941	16471	16824	58044
BCR	1.51					
NPV	58044					
IRR	154.06%					
Financial Viability	***Viable***					

Sensitivity Analysis

Sensitivity analysis of both these models have been carried out by subjecting them to fall in projected productions to the extent of 30%. The results show that both production models are viable with BCR and IRR values of 1.28&75.55 respectively for model 1 and 1.06&32.85 respectively for model 2.

Sensitivity with 30% fall in Produ	Column1	Column2
Ratios	Model 1 (Shell-on)	Model 2 (Shucked Meat)
BCR	1.28	1.06
NPV	23926.64	6654.02
IRR (%)	75.55	32.85
Financial Viability	Viable	Viable

Repayment Schedule

The repayment schedule has been prepared considering annual nature of repayment, corresponding the nature of harvest and the prevailing interest rate that may be offered by the financial institutions for this kind of activity (13%). The payback period for the first model is 1.83 year whereas that of the second model is 1.56 year. The repayment schedule for both the models have been drawn for a period of 3 years.

Economic Impact

The activity could be scaled up to 1500 units in 5 districts. This could provide livelihood support to 15000 families, resulting in production of 67.5 lakh oysters, generating additional income of the order of Rs. 8.10 Cr. per annum. Besides generating much valued livelihood opportunity for the coastal fishers, it would also help in improving the ecosystem through its filter feeding mechanism. Women SHG members working under the pilot project, have earned Rs. 50,000 by harvesting 125 kg meat from 6,000 oysters. This women SHG viz. 'Prasidhhi' is among the first oyster farmers in the state.

Scaling up

The possibility of scaling up the program could be on the following lines. The program could support 1500 units of Oyster farming in 3 districts in Maharashtra. Setting up of a bivalve hatchery could further strengthen the activity permitting production of uniform sized and quality produce meeting export criteria.

MUSSEL CULTURE

Distribution of Mussel

Coastal stretch of Maharashtra is endowed with large number of west flowing rivers forming productive estuaries and creeks fringed by mangrove vegetation. The indented coastline stretching across the districts of Raigad, Ratnagiri and Sindhudurg are marked by the presence of narrow creeks offering sheltered areas for aquaculture activities. Considering the potential for expanding bivalve farming in the State of Maharashtra, surveys for selecting suitable sites for farming were conducted by CMFRI survey team in the year 2013, covering coastal areas of Mumbai, Raigad, Ratnagiri and Sindhudurg.

The numerous estuaries and backwaters present along the coastline of Maharashtra State are abound in mussels and clams, the main species that contribute to the fishery are clams such as *Meretrixmeretrix, Marcia opima, Paphiamalabarica;* the green mussel *Pernaviridis.* In Maharashtra State, Ratnagiri and Sindhudurgdistricts have wide distribution of *P. viridis.* Ranade (1964) who investigated the bivalve resources of the state in more detail estimated that out of the total number of 70 creeks along the state's coastline from Thana to Ratnagiri District, 34 were productive, where about 3,600 persons were engaged in clam fishing. *M. meretrix*and *M. opima*contributed nearly 70% of the total production, the rest being accounted by *Paphia sp.,Marcia sp.* and *Donaxcuneatus.* The most productive areas lie in Kalbadevi estuary and Bhatia creek of Ratnagiri District, which accounted for more than half the total production for the state. Tarkarli creek, south of Malvan, is another important clam producing centre where *M. meretrix*is particularly abundant.

The Species

Identifying character of Indian green and brown mussels		
Characters	***P. viridis* (green mussel)**	***P. indica* (brown mussel)**
External colour	Green	Dark brown
Mantle margin colour	Yellowish green	Brown
Ventral shell margin	Highly concave	Almost straight
Middle dorsal margin	Accurate	A distinct dorsal angle or hump present
Anterior end of shell	Pointed beak down turned	Pointed and straight
No. and size of hinge teeth	2 small teeth on the left valve and one on the right valve	One large tooth on the left valve and a corresponding depression on the right valve
Appearance		

Life Cycle

Growth

Green mussel shows a rapid growth rate by length of 8mm-13.5mm per month. Under average culture conditions, green mussel and brown mussel attain a length of 80-88mm with 36.4 - 40g weight and 65 mm with 25-40 g in 5 months respectively The farmed mussels give a better meat yield compared to mussels from the natural bed. The average edible portion of the meat in cultured mussels' ranges from 34.5% - 40.5% where as in the natural bed the meat yield is 27.2%-33.3% of the total weight. Growth by length and weight are probably the most important criteria for assessing the success of the culture system. The growth of mussel is influenced by a number of environmental factors such as water quality, food availability, settling density, water current and tidal exposure.

Reproduction

In mussels sexes are separate and reproduction and larval development are similar to that of edible oysters. The male gonad is creamy white and in females it is pink or reddish. Mussels attain sexual maturity in two months (15-28 mm). The green mussel attains maturity at 15.5 to 28.0 mm.

Spawning period is prolonged, extending from January to September with peak spawning during June-September in Kerala. The peak spawning period of the green mussel at Kakinada is from January to May, at Tamil Nadu and Goa year round, at Calicut August-October and at Ratnagiri June-September and February-March. At Vizhinjam brown mussel spawns from the end of May till September with peak in July-August. The four main stages in the reproductive cycle are spent/resting, developing, ripe and spawning. Fertilization is external.

Larval development of mussels

Mussels release gonadal materials (sperm and eggs) into the water i.e external fertilization. The fertilized eggs develop into trochophore in 6-7 hrs. "D" shaped veliger in 20 hrs. Larvae are free swimming for 15-20 days. Locomotion is with the help of velum. As the larvae metamorphose, the pedal organ develops. On formation of this, the pediveliger, larvae look out for a suitable substratum to settle. The larvae attach to the substratum by means of the byssus threads. The metamorphosis takes place and the secretion begins. The young metamorphosed larvae (plantigrade) is generally called "Spat" the ability of the animal to regenerate the bysus is an advantage for transplanting the animal to new areas in mussel farming operation.

Technique of Mussel Farming[6]

The technology of Mussel culture consists of two important phases, i. mussel seed/Spat collection and ii. farming. The technology adopted in this context is based on the technology advocated by CMFRI as described here.

Site Selection

Open sea and estuarine areas free from strong wave action are suitable for farming. Clear seawater with rich plankton production (17-40g chlorophyll /!,) is ideal for mussel culture. Moderate water current (0.170.25m/ s at flood tide and 0.25-0.35m/s at ebb tide) will bring the required planktonic food and will carry away the excessive build-up of pseudofaeces and silt in the culture area. The water should have a salinity of 27-35 ppt. and temperature of 26 C- 32 C. Site should be free from domestic, industrial and sewage pollution.

[6] CMFRI Training Manual, Series No: 6/2015

Seed Collection and Seeding

Mussel seeds are collected from the intertidal and submerged mussel beds after the peak spawning season (September-November). Normally an experienced person can easily collect 20- 30 kg of mussel in one hour. The average seed size for farming is 15-25 mm and 600 g seeds are required for seeding 1 m length of the rope. Synthetic and coir ropes of 15-20 mm diameter are suitable for growing mussels from the rafts. The seeds are placed around the rope and securely wrapped with knitted cotton cloth. The seeded ropes are suspended from the rafts, 0.5-1 m apart, with the lower free end of the rope about 2 m above the sea bed. An optimum of 60 ropes, each having 6 m seeded length can be suspended from a raft of 6 x 6 m size. The seed mussels get attached to the ropes by means of freshly secreted byssus threads in two to three days and the cloth disintegrates in seawater within about 10 days. After the suspension of seeded ropes the mussel culture farm needs only minimum attention to see that the rafts are in good shape and the ropes with growing mussels are hung properly.



Seeded mussel ropes under preparation

Hatchery production of spat

The basic technology for production of spat of P. *viridis* has been developed by CMFRI at Chennai and for *P. indica* at Vizhinjam. At Goa, the National Institute of Oceanography also has achieved spat production in the case of green mussel. So far large scale production of mussel spat in hatchery has not been tried in our country.

Seeded Ropes of Mussel

Seeded Ropes being Deployed

Seeded Ropes put on the Racks

Initially the seeds were transported from different areas of Karnataka and Kerala. The site specific method of rearing the green mussel by rack (horizontal or vertical) or on bottom method can also be followed. The fishers were trained in the seeding techniques employed in the rope culture method by CMFRI.

Farming Techniques:

Open sea farming

In open sea farming, the depth at the site should be above 5m without strong wave action, less turbulent and with high primary productivity. Long line and raft culture techniques are ideal for open sea farming. Considering the problems associated with open sea farming and taking into account the available resource in Sindhudurg, emphasis was given to protected bays for mussel farming.

Estuarine farming

Compared to open sea, estuarine ecosystems with less turbulent and shallow depth (<4m) are suitable for mussel farming. Culture of mussels on horizontal ropes results in high productivity due to the effective utilization of the primary productivity Rack culture is ideal for estuarine conditions. Fluctuation in salinity during monsoon season and pollution through domestic and industrial waste are the main constraints in estuarine mussel farming.

Farming methods

The farming practice of bivalve molluscs is either on bottom or off bottom culture methods. The bottom culture system is also called the broadcast technique. For the off-bottom culture system, this includes the stake or pole method, rack, raft and long-line method. The rack, raft and long-line method are also called the hanging or suspended culture technique. The stake and rack method are mainly used in shallow, intertidal waters while the raft and long-line methods are generally utilized in deeper, open waters. Many culture techniques are used for growing mussels worldwide. The farming technique presently practiced in Sindhudurg is discussed here.

Method currently used for culturing mussels in Sindhudurg under the UNDP-GEF project is off bottom culture, following Rack & Ren method.

Mussel culture Following Rack & Ren method at Sindhudurg

Construction of Racks at Wadatar Creek, Sindhudurg, Maharashtra

Following this method, mussels were grown on ropes suspended from raft. This method has shown the greatest development in recent years and appears to offer the best prospects for future expansion. There are two basic types of suspended culture, fixed and floating rafts. Suspended culture from fixed rafts is usually practiced in bays or sheltered areas, where the depth is less than 4 m with very little tidal range. This method was followed along the Sindhudurg coast. The fixed mussel raft or park is constructed on top of bamboo posts, piled in 5 rows of 5 each, at a distance of 1 m. 2 m length of the posts are driven into the bottom, 4 m in water and 1 m above the water level. A framework is constructed on top of these posts using bamboo/casurina/eucalyptus poles are tied onto the framework at an interval of 0.6 to 1m for suspending the mussel ropes.

The seed, which get attached to ropes, show faster growth in the suspended column water. If the seed is not uniformly attached, crowded portion always show slipping. To avoid slipping, periodical examination of seeded rope and thinning of the same is essential.

A commercial unit could comprise of 10 rafts, each measuring 5 x 5 m. Each raft holds 100 ropes and the seeded portion in each rope is 1 m. The duration of the culture is taken as six months and a single crop is envisaged during the course of a year since the sea conditions are not generally favourable for a second crop. In estuarine farming, mussels attain 75-90mm in Smonths with an average weight of 35-40g and an average production of10-12 kg/m rope.

Management

Constant vigil is required to see that the raft/rack is in position. Thinning may be done if necessary to avoid loss of mussel and to provide enough growing space. Periodic removal of fouling organisms like barnacles, tubiculouspolychaetes and ascidians is to be done for improved growth.

Harvesting

The harvesting seasons of cultured mussels is mostly during April - May months, before the onset of monsoon to avoid mortality of mussels due to freshwater influx into the backwater system. At present the produce is marketed locally however, production of large volume could attract processors and better price realisation may be possible through depuration and value addition. The economics has been worked out taking into account depuration need and also another model leading to value added product.

	
Harvest of Green Mussels	Ready for the Market

Depuration, product development and marketing

Harvest will be done when the mussels reach marketable size and condition index is high, i.e., before the spawning and onset of monsoon. Normally harvest season is from April to June. Mussel rope is collected manually and brought to the shore for harvest and washed thoroughly using jet wash to remove grit and silt. The mussels separated from the ropes are maintained in re- circulating seawater for 24 hrs and washed again in fresh seawater. This method of depuration is effective in reducing the bacterial load of the mussel meat by 90%.

Products and export

Meat from depurated mussel can be shucked in fresh condition or after boiling or steaming. Further processing of the mussel meat can be done after blanching in 5%salt solution for 5 minutes. A variety of products have been developed in India from mussel meat. These products have been developed by R& D activities of CIFT, Kochi. In the retail market, few mussel products are available. The latest product in line is the condimentin corporated ready-to-eat fried mussel meat in vacuum packs. For further economic utilization, value added products of mussel like seafood cocktails are prepared and marketed by seafood export firms in India. The export of these items from India is showing an increasing trend.

Overseas markets

Mussels are exploited to different countries in the frozen and dried condition. They are also airlifted in the iced condition to the Gulf countries where mussels are in great demand. There is an increasing demand for mussels in the global markets, especially in UAE, China, Mali, Singapore, Sri Lanka, Australia, Greece, japan, Lebanon, Mexico, New Zeeland, and rep. Korea. The export of mussel products shows an increasing trend. With globalization, seafood trade will be subjected to increasingly greater regulation, control, issue related to environmentally sustainable practices. Seafood safety would assume greater significance in the future. Eco-labeling and HACCP certification would be made mandatory for all seafood products. Contaminants frequently monitored include bacterial loads, heavy metals, antibiotics and pesticides, algalblooms for HAB (Harmful Algal Bloom) toxins.

ECONOMICS AND FINANCIAL ANALYSIS

Unit Cost

Unit cost has been worked out for two models of Mussel Farming of Rack and rope culture in estuary for a mussel farm of 5m x 5m, deploying 100 seeded ropes, as follows.

A. Production of Shell on Mussel
B. Production of Shucked Meat of Mussel

A. Production of Shell on Mussel

The unit cost is based on procurement of mussel seed material from Kerala & Karnataka and hence higher cost has been considered which includes cost of transportation. Since acceptability of the depurated mussel is much higher taking into consideration, the health related issues, the cost of depuration has been added to the production cost and the cost of depuration has been assumed taking the prevailing rates in Kerala. This cost may vary from region to region and the same needs to be taken into account.

Unit Cost of Rack and ren method of Mussel Farming (Farm size: 5x5 m)				
A. Fixed Cost				
Sr. No.	Item	Quantity	Rate	Amount (Rs)
1	Bamboo poles (nos)	19	350	6650
2	Nylon rope for raft (3mm/4mm) in kg	1	250	250
3	Rope (Seeding, 12mm) in kg	13	250	3250
4	PVC pipe (2.5 "/3") in m	1	100	100
5	**S. Total (Capital Cost)**			**10250**
B. Recurring Cost				
a.	***Shell-on Mussel***			
1	Cotton netting material (m)	25	40	1000
2	Stitching charges /seed bag	100	7	700
3	Cost of mussel seed (20-25mm) in Kg	100	140	14000
4	Canoe hire charge per trips	5	300	1500
5	Labour charges (farm construction, seeding & harvesting)- No of days	8	850	6800
6	Depuration Charges Rs/Kg	800	6	4800
7	Marketing cost (shell on) Rs /kg	800	10	8000
8	Miscellaneous			1000
9	**S. total Recurring Cost (Shell-on)**			**37800**
10	***Unit Cost (Shell on Mussel)***			***48050***
b.	***Shucked Meat***			
11	Shucking Charges (Rs/kg)	200	30	6000
12	Fuel Charges			2000
13	Marketing cost (Shucked meat) Rs /kg	200	40	8000
14	**S. total Recurring Cost (Shucked meat)**			**45800**
15	***Unit Cost (Shucked Mussel)***			***56050***

Production & Income

The production of shell-on mussel has been assumed @ 8 kg per rope. Thus total production for 100 ropes works out to be 800 kg. Assuming a sale price of Rs 100 per kg, the gross income from shell-on mussel may be Rs. 80000/-. Considering the meat yield to be 25% (upto 30% in Sindhudurg), the production of shucked meat may be 200 kg per crop and the gross income may be Rs 100000/-, considering a sale price of Rs 500 per kg for shucked meat.

Sr. No.	Item	Unit	No of rope	Production (Kg/Rope)	Total Harvest (kg)	Sale Price Rs/kg	Sale Amount (Rs)	Shucked Meat yield /kg of oyster (%)	Yield of Shucked meat (kg)	Sale price of Meat (Rs/Kg)	Income from sucked meat (Rs)
1	Shell on Mussel	25 M2	100	8	800	100	80000	0	0	0	0
2	Heat Shucked Mussel	25 M2	100	8	800	0	0	25%	200	500	100000

CASH FLOW ANALYSIS

Cash Flow analysis of both the models have been carried out following the discounted cash flow technique[7]. The analysis includes calculation of Benefit Cost Ratio (BCR), Internal Rate of Return (IRR) and Net Present Value (NPV), Sensitivity analysis and bankability through assessment of Repayment Schedule for borrowed fund. The cash flow has been worked out for a discount rate of 15% and for a period of 5 years. The recurring cost has been assumed only partially for the year 1 & year 5, in proportion to the items of expenditure envisaged at the beginning of the crop for year1 and that associated with harvest and post-harvest for year 5.For the intervening years total expenditure has been considered.

Economics of Mussel Farming (Shell-on Mussel)						
Cash flow for 5 years, as per expected production and income						
Discounting factor		15%				
Year	**1**	**2**	**3**	**4**	**5**	**Total**
Costs						
Fixed	10250	5125	5125	5125	5125	
Recurring	19850	37800	37800	37800	17950	
Total Cost	**30100**	**42925**	**42925**	**42925**	**23075**	
Benefit	0	80000	80000	80000	80000	
Net	**-30100**	**37075**	**37075**	**37075**	**56925**	
Discount factor	1.00	1.15	1.32	1.52	1.75	
Present value of Benefit	0	69565	60491	52601	45740	228398
Present value of cost	30100	37326	32457	28224	13193	141301
Disc cash flow	-30100	32239	28034	24377	32547	87098
BCR	1.62					
NPV	87098					
IRR	121.38%					
Financial Viability	***Viable***					

[7]Price Gitinger's book, The Economic Analysis of Agricultural Projects

Economics of Mussel Farming (Shucked Meat)						
Cash flow for 5 years, as per expected production and income						
Discounting factor		15%				
Year	**1**	**2**	**3**	**4**	**5**	**Total**
Costs						
Fixed	10250	5125	5125	5125	5125	
Recurring	19850	45800	45800	45800	33950	
Total Cost	**30100**	**50925**	**50925**	**50925**	**39075**	
Benefit	0	100000	100000	100000	100000	
Net	**-30100**	**49075**	**49075**	**49075**	**60925**	
Discount factor	1.00	1.15	1.32	1.52	1.75	
Present value of Benefit	0	86957	75614	65752	57175	285498
Present value of cost	30100	44283	38507	33484	22341	168714
Disc cash flow	-30100	42674	37108	32268	34834	116783
BCR	1.69					
NPV	116783					
IRR	160.89%					
Financial Viability	***Viable***					

Sensitivity Analysis

Sensitivity analysis of both these models have been carried out by subjecting them to fall in projected productions to the extent of 30%. The results show that both production models are viable with BCR and IRR values of 1.13 & 38.55 respectively for model 1 and 1.18 & 56.52 respectively for model 2.

Repayment Schedule

There payment schedule has been prepared considering annual nature of repayment, corresponding the nature of harvest and the prevailing interest rate that may be offered by the financial institutions for this kind of activity. The payback period for the first model is 1.30 year whereas that of the second model is 1.13 year. The repayment schedule for both the models have been drawn for a period of 3 years.

Scaling up

Considering the results of the pilot project and potentials of mussel farming in Maharashtra, a program involve scaling up the activity to 500 units of Mussel farming in 3 districts namely Raigad, Ratnagiri and Sindhudurg could be considered together with setting up of an Oyster hatchery for seed supply. The approximate budget for the same is of the order of Rs.10.75 Cr.

Sr. No.	District	Unit	Unit Cost	Budget (Rs. In lakh)
3	Raigad	50	35000	17.50
4	Ratnagiri	100	35000	35.00
5	Sindhudurg	350	35000	122.50
6	Hatchery	1		900.00
	Total	500		1075.00

INTEGRATED MULTI TROPHIC AQUACULTURE

BACKGROUND

Aquaculture is a viable option for meeting the food security of the burgeoning coastal populace of India, owing to declining wild fish stock and increasing demand for seafood, coupled with increase in pressure on coastal resources owing to sea level rise.

However, coastal aquaculture in India is facing a sustainability issue, primarily being a mono-culture practice, based on farming of shrimp alone, since its inception during 1980s. Although shrimp aquaculture has grown dramatically during the last few decades, there are several issues which, still remain unresolved particularly, the issues related to the environment and consequent disease outbreak. The environment related issues include, discharge of waste water, eutrophication of receiving ecosystem, problems due to the feral population and disease occurrence in the wild stock. Hence a sustainable aquaculture systems need to address these issues.

INTEGRATED MULTI-TROPHIC AQUACULTURE (IMTA)

In order to develop a sustainable aquaculture and to protect the ecological integrity of the coastal ecosystem, the current aquaculture, which is based on single species, needs to be replaced with a multi-species aquaculture system involving components which would utilize the wastes generated within the system through the food chain and the detritus chain. Integrated multi-trophic aquaculture(IMTA), is a system that addresses these issues through a mix of aquaculture species, which thrive at different trophic levels in an aquatic system, comprising of planktivores (feeding on planktonic food, including phytoplankton and zooplankton); detritivores (decomposing plant and animal parts as well as faeces); filter feeders such as bivalves living on particulate suspended organic matter and finally the organisms which live on dissolved nutrients such as sea weeds. IMTA consists of farming of aquaculture species from different trophic levels with a complimentary ecosystem functions. In this farming practice, uneaten feed, nutrients, wastes and energy from one trophic level act as input for the next trophic level and utilized as fertilizer, feed and energy for the next trophic layer. The synergistic interaction among the species results in bio-mitigation of the wastes. Although a distant prototype of IMTA existed in traditional aquaculture forms, the importance of IMTA as sustainable management option has been recognized recently.

Status of Brackishwater Aquaculture in Sindhudurg

District Sindhudurg is the southernmost coastal district of the state Maharashtra with a coastline spanning 121 km and 8000 ha of brackishwater area. A total of 1268 ha of brackishwater area has been developed for aquaculture. Although climate and geography of the district is suitable for brackishwater aquaculture, the potential of this district has not been optimally used. Many farms which were operational during the initial phase of aquaculture are presently defunct, due to incidences of disease outbreak and resultant crop failures. A preliminary assessment of the brackishwater shrimp farming activity in the area indicate that, monoculture of shrimp could not be sustained in these areas, as in the case of other coastal states on the east coast of India.

Therefore, the need of the hour is a sustainable and viable brackishwater aquaculture practice, based on the principles of IMTA.In this context, standardization of IMTA under the UNDP-GEF project was considered to be a necessary intervention for development of coastal aquaculture in Sindhudurg.

PILOT PROJECT ON IMTA

The demonstration of the Integrated Multi-Trophic Aquaculture in Sindhudurg district by Central Institute of Brackish Water Aquaculture, Chennai was carried out in the three talukas of Sindhudurg namely Devgad, Malvan and Vengurla.

Objective

Integrated Multi-Trophic Aquaculture (IMTA) systems was promoted as a sustainable alternative to monoculture of shrimp. The specific objectives of the study were as under.

- To quantify and evaluate the production and ecological characteristics of IMTA systems and to demonstrate waste mitigation and production efficiency of IMTA as compared to existing monoculture production system.
- To estimate the nutrient balance of IMTA farms, and use them as indicator for farm sustainability.
- To demonstrate the IMTA model to brackish water farmers from Sindhudurg.

Methodology

The project envisages carrying out field trials on 5 models of IMTA in farmer's pond as follows:

- Shrimp (F. indicus/P. monodon) plus Mullet and sea weed (land based farm)
- Mud crab plus Chanos/mullet plus bivalves (land based farm)
- Shrimp plus mud crab plus mullet and sea weeds (land based system)
- Integrated mangrove aquaculture; mud crab plus fish (mangrove ecosystem)
- Fish and Bivalve (Cage system)

Each farmer was provided technical support and farming inputs in this regard. Farming inputs were provided for two culture cycles and the five models of IMTA. After conducting survey of the sites, the suitable models were prescribed.

The Technology

Species involved

The species selected for conduct of the trials on IMTA involved, Shrimp (*Penaeusindicus*), mud crab (*Scylla serrata*), finfish (*Mugilcephalus, Chanoschanos*), bivalves (*Pernavirdis*) and seaweed (*Gracileriaverucosa*). In all the experimental trials, monoculture of shrimp wasconsidered to be the control.

Aquaculture Systems adopted

Two different systems were adopted for conduct of the experimental trials as listed here.

Taluka	Ecosystem	Farming Facility	Species combinations
Tambaldeg, Devgad	Open water estuarine area	Round cage: 6 m dia (outer) and 5 m (inner) outer mesh 36 mm and inner mesh is 16 mm	Pearl spot, milkfish, shrimp and bivalves
Kochare	Tide fed Pond	Pen in the Pond, Water spread area 10,000 m2	Pearl spot, milkfish, mullet, shrimp and bivalves
Vengurla	Tide fed Pond	Pen in the Pond, Water spread area 80,000 m2	Pearl spot, milkfish, mullet, shrimp and bivalves
Gad River, Hadi	River	Rectangular Cage 8m x 4m x 1.2 m; outer cage with 40 mm mesh & four inner cages:3m x 2m x 1m of 16 mm mesh.	Sea Bass and Green mussel

Management

Pond Preparation: Ponds were prepared following standard operating protocol for the shrimp culture.
Cages installations: Cages were fabricated as per design and installed, following the set procedure.

Pen Culture of IMTA

Fish species stocked in IMTA

Cage Culture of IMTA

Stocking management:

In all the experiments, shrimp post larvae were nursed initially in the hapa nets for 45 days and other species were stocked subsequently. The stocking density of shrimpswereconsidered@2 individual/m² whereas, stocking density of finfishes were considered at 5.5 individual/m².

Item	Pen in Tide fed pond	Control	Cage in open water	Cage in Gad river water
Species Stocked	Stocking Density (No./ M^2)	Stocking Density (No./ M^2)	Stocking Density (No./Cage)	Stocking Density (No./Cage)
Shrimp (*Penaeusindicus*)	2.0	3.0	200	
Milk fish (*Chanoschanos*)	4.0	0.0	20	
Mullet (*Mugilcephalus*)	0.5	0.0	0	
Pearl spot (*Etropolussuratensis*)	1.0	0.0	252	
Sea Bass (*LatesCalcarifer*)	0.0	0.0	0.0	800
Oyster (*Crassostreamadrasensi*	0.5	0.0	1000	250
Seaweed (*Gracileriaverucosa*)	0.0	0.0	0	

Water Quality Management in ponds

Water exchange and aeration were provided according to the water quality characteristics. Dissolved oxygen (DO) and temperature, measured daily at 0600 h at 25 cm above bottom, middle and 25 cm below water surface, while salinity and pH were monitored weekly at the three depths. Water samples were taken biweekly at 0900–0930hr. for analyses of total Kjeldahl nitrogen (TKN), total ammonia nitrogen (TAN), nitrate nitrogen (nitrate-N),nitrite nitrogen (nitrite-N), total phosphorus (TP), soluble reactive phosphate (SRP), total alkalinity and chlorophyll *a* following standard methods (APHA *et al*.,1985).

Feed & Feeding

Whilst shrimps were fed with commercial shrimp feed, finfishes were fed with fresh feed.Feed quantity were adjusted at 15-day intervals based on fish and shrimp body weights, calculated from periodical sampling and assumed survival percentage of100, 80, 70 and 60% in the first, second, third-fourth and fifth-sixth month of culture, respectively. Fish and shrimp were sampled fortnightly and standard length and body weight were measured.

Production

After 180 days of culture, shrimp, fishes and bivalves were partially harvested, and production performances in the two treatments were evaluated in terms of final average body weight (ABW, g), net weight gain (NWG, g), daily weight gain (DWG, g day)1), specific growth rate (SGR, % day)1), apparent feed conversion ratio(AFCR), survival (%), species-wise production and total production (kg /ha).

Cages ready for harvest

Harvested Mullets

Milk fish and Shrimp harvest

As the final harvest results are awaited, the estimated production is calculated from the average latest body weight and expected percentage survival. Estimated production in the demonstration trials are given in the table _and _. Total production for the pond based systems is estimated to be 4400 kg/ha with a highest estimated production for milk fish.

Estimated productions in pond based IMTA system based on the results of partial harvest

Species	Estimated production (kg per pen of 250 M^2)	Estimated production in cage system (kg/30 M^2)
P.inidicus	10	0
Chanoschanos	50	0
E. suratensis	25	0
M. Cephalus	25	0
L. calcarifer	0	360
Total Production	110	360

Economic Analysis

The results of Economic analysis of both the models indicate the activity to be financially viable however, the same needs to be carried out for some more time before the same can be established conclusively.

Items	Pond Culture (1 Ha)			Cage Culture (30M^2)		
	Qty.	Rate	Amount (Rs.)	Qty.	Rate	Amount (Rs.)
Capital cost	1.00	0.00	100000.00	1	80000	60000
Operational cost			449440			108000
Total Income (Rs)	3300		760000	360	600	216000
Net profit (Rs)			310560			108000
BCR			1.37			1.58
IRR			86.66%			90.84%

Scaling up

The program could involve scaling up the activity of IMTA in 5coastal districts of Maharashtra. Since pen culture potentials in wet land areas would require mapping the existing potentials, the present assessment is based on small scale cage culture potentials in open waters of creeks and estuaries. Accordingly, a tentative assessment is made for setting up 2000 units in 5 districts as indicated in the table. The projected cost is Rs. 200 lakh.

District	Unit	Unit Cost	Budget (Rs. In lakh)
Palghar	200	10000	20
Thane	100	10000	10
Raigarh	600	10000	60
Ratnagiri	500	10000	50
Sindhudurg	600	10000	60
Total	2000		200

System of Rice Intensification

Introduction

The System of Rice Intensification, known as is a climate-smart, agro-ecological methodology for increasing the productivity of rice and more recently other crops by changing the management of plants, soil, water and nutrients.

Until 1990, the impression was that rice yields better only under flooded conditions. Recent reports from International Water Management Institute, Colombo, however suggest that continuous submergence is not essential for obtaining higher rice yields. Further, experiences from studies on SRI in China and Sri Lanka during the last decade have conclusively demonstrated that unflooded soil is ideal for rice plant to grow well and yield better than under conventional method of continuous shallow submergence. SRI which is relatively a new methodology, involves a set of practices that integrate management of plant, soil, water and nutrients. The potential of SRI is fully realized when all the five important practices are adopted together. According to Dr. Norman Uphoff, Professor Cornell University, USA and leading campaigner of SRI, this revolutionary innovative technology was borne out of personal experience of Fr Henry de Laulanie at Madagascar, and not as a development of scientific research. The method has spread to more than 50 countries and replete with many success stories and now efforts are on to generate and establish the scientific mechanisms responsible for the observed crop responses under SRI.

Outline of SRI practice

The System of Rice Intensification (SRI), developed in Madagascar in 1980s basically refers to a particular set of practices which improve plant health and yield. It is an innovation in rice production systems by raising productivity of the land, labour, water and capital. It can produce more paddy yield with less external inputs. Furthermore, SRI is environment-friendly and can be adopted to any type of rice variety (local variety, HYV, hybrid variety). SRI is an innovation that is constituted entirely of knowledge, but not depending on external inputs and materials. SRI is a concept consisting of the following practices.

- Transplant young seedlings, 8-12 days old (2-3 leaf stage), to preserve potential for tillering and rooting ability.
- Transplant at wider spacing at 25 cm x 25 cm. in square planting. Transplant single seedling at each hill with utmost care for seed roots.
- Less use of chemicals (fertilizer, pesticide, insecticide, herbicide), use of organic manure, vermi-compost and FYM.
- Less water use by applying wet-dry cycle of soil moisture.
- Use of cono-weeder to aerate the soil as well as control weeds.
- Lately, the SRI concept is being applied to other crops as well (viz. wheat, sugarcane, millet). It is continuously evolving in terms of its application of the concept to other crops.

The Principles of SRI

SRI which is a relatively new methodology involves a set of practices for plant, soil, water and nutrient management. It is a revolutionary technology in the sense that it tries to change traditional practices especially with respect to water management that existed for thousands of years. The greatest potential of SRI is seen when the six important practices are adopted together.

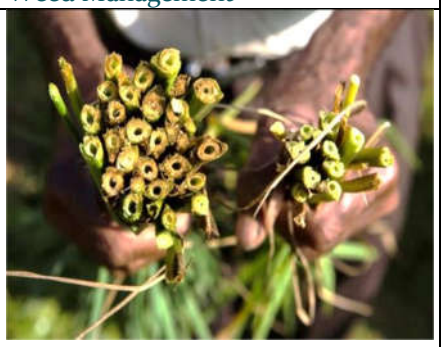
SRI Principles that underlie SRI practices are more important than the practices themselves. Rice is not an aquatic plant. Although rice can survive when growing under flooded (hypoxic) conditions, it does not really thrive in such a soil environment.

- Under continuous submergence, most of the rice plant's roots remain in the top 6 cm of soil, and most have degenerated by the start of the plant's reproductive phase.
- Rice seedlings lose much of their growth potential when transplanted beyond about 15 days of age. This potential is preserved by early transplanting in conjunction with other SRI practices.
- It is important to avoid trauma to seedlings, and especially to their roots, during transplanting. Stresses such as from seedlings' roots drying out will delay the resumption of plant growth after transplanting and reduce total tillering and root development.
- Wider spacing of plants leads to greater root growth and accompanying tillering, provided that other favourable conditions for growth such as soil aeration are provided. With intact root systems, there is a positive correlation between tillering and grain filling.
- Soil aeration and organic matter create beneficial conditions for plant root growth and for consequent plant vigour and health. This results from having greater abundance and diversity of microbial life in the soil, helping plants resist pest and disease damage.

Difference with Traditional Practice

Parameter	System of Rice Intensification	Traditional Rice Cultivation
1. Age of seedlings	Young seedlings are transplanted at 8-12 days old. Seedlings are carefully lifted from the nursery and transported to fields in baskets or on trays for immediate transplanting. Seeding rate: 5-7 kg/hectare	Older seedlings are transplanted at 21-40, days old. Soil is shaken from roots; and seedlings are bundled and transported to fields. Bundles are often left in the open for days. Seeding rate: 50-75 kg/hectare
2. Number of seedlings	1-2 seedlings per hill are transplanted with shallow depth (1-2 cm) into soils that are not flooded. Roots are carefully positioned just under the soil surface to avoid trauma to the roots, thereby avoiding "transplant shock."	3-4 seedlings (even 6-8) are clumped and pressed deep into flooded soils, resulting in closely competing seedlings with inverted roots and anaerobic soil conditions.
3. Spacing of plants	Wider spacing, with hills 20-30 cm apart, set out in a square or matrix pattern to facilitate moving through the field with a weeder, and to expose plants fully to the sunlight.	Close spacing with hills 10-15 cm apart, either in rows or more typically with random spacing.
4.Water management	Non-flooded aerobic soil conditions with intermittent irrigation. Where possible, small applications of water, or alternate wetting and drying during the growth period; just 1-2 cm of water on fields after the plants flower.	Continuous flooding of paddy fields with 5-15 cm of water throughout the growing cycle.
5. Soil fertilization	Organic matter is preferred to the extent feasible but may be complemented with synthetic fertilizers. Combinations can be used to ensure appropriate soil: plant nutrient balance.	Inorganic synthetic fertilizer is applied, largely replacing the application of organic matter, which enhances soil structure and functioning.
6. Weed and pest control	Cono-weeder puts weeds back into the soil to enrich organic content and aerate the topsoil at the same time. Integrated Pest Management (IPM) practices are encouraged. SRI plants are generally more resistant to pests and diseases so require less chemical protection.	Weeding is done by manual weeding or by herbicide applications; Cono-weeders cannot be used in randomly planted fields. IPM is sometimes practiced, but pesticides are usually applied preemptively or as needed.

Steps in SRI Practice

		
Nursery Bed Preparation	Seed sorting & treatment	Seed Germination
		
Seed sowing	Mulching	Seedlings ready for transplant
		
Ploughing the Field	Use of Marker	Transplanting
		
Water Management	Water Management	Weed Management
Application of farm yard manure/compost (10-20 ton/ha) and/or green manure is recommended	 "Amrit Jalam" Required materials: • Cow urine - (1) litre • Cow dung - (1) kilogram • Jaggery (coconut tree sap)- 250 gm • Water (chlorine free) - 10 litre Preparation and Use: Mix all the above materials in a plastic container or an earthen pot. Let them ferment for 24 hours. Dilute this with water in the ratio of 1:10. Filter the solution using a fine cloth.This can be used for spraying. Amrit Jalam can be stored for a period of 30 days. However it has to be stirred daily. When urea is used, the plants grow succulently and or easily susceptible to pests and diseases. When Amrit Jalam is sprayed, it not only gives nitrogen to the plants but also repels harmful insects and micro-organisms.	
Fertility Management	Pest & Disease Management	Harvest

Benefits of SRI

SRI methods have the following benefits and impacts, in general, compared to conventional methods of paddy cultivation:

- ***Positive Yield Attributes:*** 60-80% higher grain yield and 50-75% straw yield, as compared to traditional method
- ***Low water Requirement* of paddy:** Reduction in water requirement by 25-50%
- ***Reduces pressure on Land:*** Higher productivity (40-80%)
- ***Low seed requirement:*** Only 8Kg/Ha seed required, compared to 80 kg in traditional system
- ***Low Inorganic Fertiliser use:*** Dependence on green manure and compost reduces use of inorganic fertilisers
- ***Low pesticide use:*** Owing to low plant density, penetration of sunlight and aeration of the field is proper resulting in low incidences of disease and pests
- ***Greenhouse gas emission:*** Methane gas emission is less because of lack of standing water column
- ***Improved grain quality:*** More grain & less chaff
- ***Grain ripening is quicker:*** Grain ripening is 7-10 days sooner
- ***Improved Food Security:*** Higher productivity from small holdings
- ***Low labour requirement:*** In long run labour requirement reduced
- ***Reduce production costs:*** With increased output and reduced costs (10-20%), farmers'net income is likely to increase
- ***Better Drought Copping:*** Owing to low seed rate, staggered nursery is feasible in the event of unfavourable monsoon

The various benefits accruing out of SRI can be grouped into three broad categories i.e. Benefits for Rural Households, Benefits for Countries and Benefits for the Planet.

Pilot Project on SRI in Sindhudurg

The System of Rice Intensification (SRI) was identified as an intervention in the three coastal talukas of Sindhudurg district of Maharashtra under the UNDP-GEF Project on "Mainstreaming Coastal and Marine Biodiversity Conservation into Production Sectors in Sindhudurg District, Maharashtra State", considering the sustainable dimensions of the production system; its reduced dependence on inorganic fertilizers and pesticides resulting in lesser eutrophication and pollution of coastal ecosystem; its drought coping mechanism and adaptability to withstand vagaries of climate change; as well as its ability to mitigate GHG emission on account of reduced emission of methane compared to traditional paddy cultivation practices. Its attributes related to reduced pressure on land, water and power as well as its improved yield characteristics and better return to farmers are other features which have led the project authorities to consider supporting a pilot project to demonstrate its benefits to the farmers in the three coastal talukas of Sindhudurg (VIZ. Vengurla, Malvan & Devgad). The pilot project was implemented by a CSO i.e. Mayem Panlot Sangh (MPS), Mayem, Sindhudurg.

In all, 268 farmers were introduced to SRI technique over three farming seasons during 2014-2015, covering 85 acres. More than 2500 farmers were exposed to the farming technique under the pilot project. The potential beneficiaries were selected through conduct of village level meetings, group discussions, field visits to demonstrations units. The pilot project covered 23 farmers during Kharif 2014, another 245 farmers during Rabi 2014-15. The results of pilot project is as under (table 1& 2).

Results of Pilot Project (2014-15)

Table 1. Kharif Season (2014)

Taluka	Farmers	Area	Traditional	SRI	Increase
Name	Nos.	Ha	Yield (Kg/M^2)	Yield (Kg/M^2)	%
Vengurla	2	1	0.7	1.1	57.14
Malvan	11	0.21	0.97	1.6	64.95
Devgad	10	0.31	1.2	1.7	41.67
Total	23	1.52	0.96	1.47	53.31

Table 2. Rabi Season (2014-15)

Taluka	Farmers	Area	Traditional	SRI	Increase
Name	Nos.	Ha	Yield (Kg/M^2)	Yield (Kg/M^2)	%
Vengurla	51	8.22	25	80	220.00
Malvan	131	12.08	95	148	55.79
Devgad	63	11.27	501	734	46.51
Total	245	31.57	207.00	320.67	54.91

The paddy farming in the district comprises of traditional system of paddy cultivation and the 'Charsutri' (improved package of practice) advocated by the Konkan Krishi Vidyapith, Dapoli. The broad agronomic

practices of the three systems have been captured in table 3.

Table 3.Comparison of the existing agronomic practices of paddy cultivation with results of SRI under the pilot project

Particulars	Traditional	''Charsutri'' presently advocated	SRI	% increase / decrease SRI over Traditional	% increase / decrease SRI over Charsutri
Seed Rate (kg/ha)	80	15-20	8	9	10
Age of seedling	25-30	25-Oct	15-Sep	16-Sep	17-Sep
Nursery Area M2 /Ha	1000	250	100	-900	-150
Spacing (cm)	Random	25 x 15	25 x 25	26 x 25	27 x 25
No. of seedling per hill	4-Mar	2-Jan	1	2	3
Plant population (lakh plant/ha)	12	2.66	1.6	-650	-66.25
Average grain yield (q/ha)	35	45	65	85.7	44.4
Cultivation Cost (Rs/ Ha)	22392	28000	20018	-11.9	-39.9
Income (Rs/ Ha) @ Rs. 9/kg	27070	40500	45118	66.7	11.4
Profit (Rs/Ha)	4678	12500	25100	436.6	100.8

Table 4.Comparison of the economics of existing agronomic practices of paddy cultivation with results of SRI under the pilot project

Sr. No	Components	Application/ Rate (per Acre)	Cost (Rs)	Application/ Rate (per Acre)	Cost (Rs)
A	**Input cost**	**SRI**	**SRI**	**Traditional**	**Traditional**
1	Seed	4 kg/acre at the rate of Rs. 37/kg	148	16 kg/acre at the rate of Rs. 37/kg	592
2	Organic fertilizer	Lump sum (for nursery)	1000	Lump sum	2000
3	Organic fertilizer for field (FYM)	Lump sum	7250	Lump sum	4500
4	Line Marker	Yes	60	No	0
5	Ploughing field preparation	Yes	1500	Yes	1500
6	Weeding	Cono-weeder cost	1200	Manual weeding	0
7	Pesticides	Lump sum	200	Lump sum	800
8	Supplementary dose Potash	8kg /acre @ Rs.20/ kg	160	NA	0
9	Labour	34 days at Rs.250/ day	8500	52 days at Rs.250/ day	13000
10	*Total Input Cost*		*20018*		*22392*
B	*Grain yield*	*2.5 ton per acre*	*35000*	*1.5 ton per acre*	*21000*
C	*Straw yield*	*10117.15kg*	*10118*	*6070.29kg*	*6070*
D	*Gross Income*		*45118*		*27070*
E	*Net income*		*25100*		*4678*

Inferences

The following inferences may be drawn with the results generated so far.

- Increase in grain yield using SRI over traditional system, ranging from 41-220%
- Increase in grain yield using SRI over 'Charsutri' system is averaging 44.4 %
- Decrease in cultivation cost following SRI over traditional system is averaging 11.9%
- Decrease in cultivation cost following SRI over 'Charsutri' system is averaging 39.9%
- Increase in income following SRI over traditional system is averaging 66.7%
- Increase in income following SRI over 'Charsutri' system is averaging 11.4%
- Increase in profit following SRI over traditional system is averaging 436.6%
- Increase in profit following SRI over 'Charsutri' system is averaging 100.8%
- Decrease in nursery area following SRI over traditional system is averaging 900%
- Decrease in nursery area following SRI over 'Charsutri' system is averaging 150%
- Decrease in plant population following SRI over traditional system averaging 650%
- Decrease in plant population following SRI over 'Charsutri' system is averaging 66%

Conclusion

The results of the pilot project has established the better productivity, economics of SRI over the two system of paddy cultivation in vogue in Sindhudurg. The better production and yield related characteristics and climate change related adaptation and mitigation potentials of SRI render it to be the ideal technology for adoption in the Konkan Region.

SCALING UP SRI IN SINDHUDURG DISTRICT

The results of the pilot project on SRI in the three talukas viz. Malvan, Vengurla and Devgad during 2014-15, had promted the District authorities to consider scaling up the activity in all eight talukas of Sindhudurg and accordingly, in consultation with District Agriculture office, a programme was drawn up to cover 1000 acre of paddy area under SRI in the District. In order to reach out to all the eight talukas in a short span of time and carry out demonstration as well as selection of farmers and their capacity building, a NGO viz. DILASA Janavikas Pratisthan from Aurangabad was engaged. The agency with active support from the District Agriculture office and Agricultural Technology Management Agency (ATMA), could implement the programme in 526 acres of paddy area, involving 1035 beneficiaries (table 5).

Table 5. Coverage of area under SRI during Kharif, 2016

Particulars	Unit	Value
Farmers covered	Number	1035
Area covered under SRI	Acre	526.72
Harvest Data (Sample size)	Acre	43.9

Results

Although the programme involved,1035 beneficiaries, covering526 acres, the harvest data could be recorded from 70 SRI plots covering 43.9 acres and 68 control plots covering 18.6 acres, following traditional practice of paddy cultivation (table 6). The agency will be covering the remaining programme during Ravi 2016-17.

Table 6. Results of scaling up of SRI during Kharif, 2016

Taluka (Sub-division)	SRI / Control plot	No. of Plots sampled	Crop Area (Guntha)	Crop Area (in Acre)	No. of Tillers/ Hill#	No. of Grains / Panicle	Weight of 100 grain (gm)	Grain Yield (gm / M^2)	Straw Yield (Kg/ M^2)	Increase in No. of tillers / hill (%)	Increase in No. of grains/ Panicle (%)	Increase in Grain yield (%)	Increase in Straw yield (%)
Malvan	SRI	10	380	9.5	31.9	192.8	3.1	777.4	2.4	102.2	26.7	28.5	17.0
Malvan	Control	10	69	1.725	15.8	152.2	1.9	605	2.0				
Devgad	SRI	10	198	4.95	20.7	249.8	3.15	887.5	1.975	168.8	55.1	57.69	22.3
Devgad	Control	10	161	4.025	7.7	161.1	2.35	562.8	1.615				
Vengurla	SRI	10	370	9.25	27.7	177.9	3.03	651.4	2.72	57.8	18.4	3.09	9.6
Vengurla	Control	9	95	2.375	17.6	150.2	2.72	631.9	2.48				
Kudal	SRI	10	150	3.75	31.1	188.3	2.9	608.6	1.68	104.3	16.2	19.10	16.5
Kudal	Control	9	52	1.3	15.2	162	2.17	511	1.44				
Sawantwadi	SRI	8	310	7.75	30.63	225	2.76	633.75	1.53	89.9	15.3	23.15	18.9
Sawantwadi	Control	8	115	2.875	16.13	195.1	2.21	514.63	1.29				
Kankavli	SRI	10	110	2.75	29.2	180.6	2.49	622.30	1.34	60.4	13.4	-2	24.3
Kankavli	Control	10	60	1.5	18.2	159.2	2.13	635.00	1.08				
Dodamarg	SRI	6	97	2.425	22	325.17	2.50	714.33	1.24	175.0	75.9	48.05	7.3
Dodamarg	Control	6	97	2.425	8	184.83	1.50	482.50	1.16				
Vaibhavwadi	SRI	6	141	3.525	29.33	172.33	2.93	616.67	1.50	72.5	16.0	10.71	29.8
Vaibhavwadi	Control	6	95	2.375	17	148.5	2.20	557.00	1.16				
G. Total	**SRI**	**70**	**1756**	**43.9**	**27.8**	**214.0**	**2.9**	**689.0**	**1.8**	**92.6**	**30.4**	**23.54**	**17.3**
G. Total	**Control**	**68**	**744**	**18.6**	**14.4**	**164.2**	**2.2**	**562.5**	**1.5**				

The results indicate 92.6 % increase in tillering, 30% increase in grains/panicle, 23.54% increase in grain yield and 17.3% increase in straw yield over that following, traditional practice.

Impact of SRI on Reduction in use of Chemical Fertilisers and Conservation of Biodiversity of Paddy

Use of Chemical Fertilizers

The reduction in use of chemical fertilizers is one of the main benefits of SRI method of cultivation. From the study we have found that there is an overall reduction of 58.37% in the use of chemical fertilizers. The average area under cultivation under rice in Sindhudurg district is 74157 Ha. From the study it is found that by following the SRI method of cultivation there is a possibility of ***reduction of chemical fertilizers use to the extent of 237 Kg per ha***. So by promoting SRI method even in half of the total rice area it is possible to reduce the chemical fertilizers to the tune of ***8.7 million Kg per season***. This is a huge reduction in terms of inorganic fertiliser use and consequent environmental impact. Considering the fact that the fertilizer use efficiency is only around 30-35 % (especially in fertilizers like urea), a large proportion of the fertilizers applied to the crop is draining to the rivers and coastal waters which impacts marine life particularly coral ecosystems which is impacted by algal production due to eutrophication of the coastal waters, reducing sunlight penetration and the euphotic zone. The reduction in flow of nutrients to the receiving waters is a distinct possibility following SRI method of cultivation, resulting in improvement of the coastal environment and the coral biodiversity of the region. There is a simultaneous increase in the use of organic manure (21.12%) also. This will also help in improving soil health and the microbial activities in the soil.

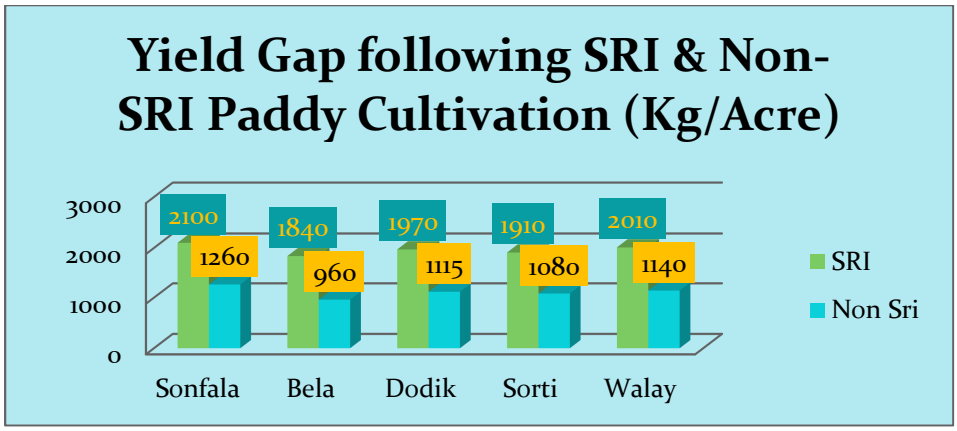
Conservation of Biodiversity of Indigenous Paddy Varieties

Another benefit that can be ascribed to the SRI method of cultivation is the opportunity to conserve the indigenous rice varieties of the region, which will help in restoration of the local gene pool. Sindhudurg district has many indigenous land races like ***Varangal, Kranti, Masuri, Poonam, Parvati, Zili, Balwan, Sonfala, Dodoik, Walay, Sorti, Patni, Yelkar, Bela, Kadabela, LalaPatani, Cochari, Taychung, Aayarat, Kothambir, Gharsal, Wadakolam, Aambemohar etc***.

A comparative study on the yield of indigenous land races under SRI and other methods was conducted based on the data collected from three blocks of Sindhudurg district accounting for 19 farmers, cultivating indigenous land races of rice. It is evident from the study that there is a wide yield gap between SRI and the traditional methods of cultivation. The yield difference is observed to be in the range of 720-1080 Kg/acre in various field situations. On an average, the yield is 76 % more than that under the traditional method of cultivation. Shown below is the yield difference for five indigenous land races of rice following SRI and existing methods of cultivation (Fig.VII).

The farmers are themselves growing local varieties under SRI method and from the case studies conducted among such farmers it is found that the farmers are getting good yield following SRI method of cultivation of the traditional varieties with minimum use of inorganic inputs. Thus the SRI method of paddy cultivation has opened up an avenue for conservation of traditional varieties of paddy.

Fig. 1. Yield gap Following SRI and the traditional methods of cultivation of Paddy



From the above narrated facts it is evident that there is a huge scope for promotion of local varieties under the SRI method of cultivation.

Conclusion

It is evident from the study that SRI method of cultivation of paddy is helping the cause of conservation of biodiversity of the indigenous rice varieties and ameliorate the soil health as well as the aquatic environment through reduction in use of chemical fertilizers and pesticides, and increased use of organic manures.

Way Forward

The ***System of Rice Intensification***, known as SRI, is a climate-smart, agro-ecological methodology for increasing the productivity of rice and more recently extended to other crops by changing the management of plants, soil, water and nutrients. Experiences from studies on SRI in China and Sri Lanka during the last decade have conclusively demonstrated that un-flooded soil is ideal for rice plant to grow well and yield better than under conventional method of continuous shallow submergence. SRI which is relatively a new methodology, involves a set of practices that integrate management of plant, soil, water and nutrients. The potential of SRI is fully realized when all the five important practices are adopted together.

SRI is relevant under the GoI-UNDP-GEF Sindhudurg Project in the context of reduction in eutrophication of coastal waters and pollution due to low level of use of chemical fertilizers and pesticides. Following SRI, emission of greenhouse gas (methane) is 60% less and that of water use is 40% less compared to traditional practices. In traditional method the CH_4 emission is higher i.e. 0.050 Tons per ha. While, in SRI method it is reduced up to 0.033 tons per ha.The system is drought resilient and offers adaptation to erratic and delayed monsoon due to low seed rate, which is 10% of seed used for paddy following conventional practices. Owing to low seed requirement, the farmer can go for a second or even a third nursery in the event of delayed monsoon with progressively shorter duration varieties.

Rice being a staple food of Konkan region and the principal field crop, which is likely to be impacted by any sea level rise or global climate change, the System of Rice Intensification (SRI) will be an important agricultural intervention for the Konkan region in particular and other rice growing areas of Maharashtra in general, towards climate proving agriculture while reducing the coast of cultivation as well as improving the productivity of rice. Thus there exists a good potential for introduction of the new technique of SRI in Maharashtra in dealing with food security, reducing pressure on land & water resources as well as adaptation to climate change and its mitigation.

The Mangrove Cell of Maharashtra was established on January 5th 2012 as a dedicated unit for the protection of mangroves. As the country's first such unit, its creation has led to unprecedented extension of the activities of Maharashtra Forest Department to the coastal areas. The Mangrove Cell has been instrumental in bringing coastal and marine biodiversity issues to the forefront of the conservation agenda. The Cell is the Nodal Agency for the implementation of the GoI-UNDP-GEF Sindhudurg Project.

UNDP partners with people at all levels of society to help build nations that can withstand crisis, and drive and sustain the kind of growth that improves the quality of life for everyone. On the ground in more than 170 countries and territories, it offers a global perspective and local insight to help empower lives and build resilient nations.

The Global Environment Facility (GEF), established on the eve of the 1992 Rio Earth Summit, is a catalyst for action on the environment – and much more. Through its strategic investments, the GEF works with partners to tackle the planet's biggest environmental issues.

The project, in partnership with the Ministry of Environment and Forests and financed by the Global Environment Facility, was implemented from 2012-2017 to mainstream biodiversity conservation into Sindhudurg coastal district's production sectors. It also aimed to generate awareness among local communities on biodiversity conservation amidst the threat of unsustainable fishing practices, rising pollution from fishing vessels and maritime traffic in the region.

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