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Indian experience of large scale cultured marine pearl production using *Pinctada fucata* (Gould) from southeast coast of India: A critical review

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Original Article

Abstract

In India, research on marine pearl culture was started in 1972 and the first cultured marine pearl from *Pinctada fucata* was rolled out a year later through the earnest efforts of Central Marine Fisheries Research Institute, Kochi (CMFRI) at its Tuticorin Research Centre. Subsequently, improvements of the technology were made by various scientists involved at different centres of CMFRI focussing on different issues of marine pearl culture. Information on different aspects of marine pearl culture such as surveys for stock position, ecology of pearl beds, small scale experimental culture of mother oysters, surgical nucleation and spherical pearl and designer pearl production ('mabe') has already been published in various sources including few instances of technology transfers to entrepreneurs/fisher folk. Though, the experimental results were encouraging, anticipated technology transfer did not take place subsequently. Hence a large scale marine pearl culture demonstration was carried out and viability of the technology was redemonstrated at the Regional centre of CMFRI, Mandapam Camp during 1997 - 2003 through an ICAR Revolving Fund Project which resulted in wealth of information regarding different aspects of marine pearl culture.

In the present account, the lessons learnt based on the published information as well as the data (unpublished) obtained in the large scale culture are analysed and classified under the critical activities of pearl culture and presented in the form of a 'non systematic critical review' essentially to arrive at the status of marine pearl culture in India.

Keywords: *Pinctada fucata, India, seed production, large scale pearl production, marketing, review*

Introduction

In India, the first spherical cultured pearl was produced from *Pinctada fucata* at the Research Centre of CMFRI at Tuticorin in 1973 (Alagarswami and Qasim, 1973) and also succeeded in developing a hatchery technology for the seed production of this species (Alagarswami *et al.*, 1983). Since then CMFRI has been experimenting, refining and transferring technology to the end user i.e., entrepreneurs and fishfolk (Mohamed, 2013). Subsequently, in CMFRI and elsewhere, research on various aspects of pearl culture was conducted and a wealth of information on the biology (Chellam, 1987), ecology (Mahadevan and Nagappan Nair, 1978; Nagappan Nair and Mahadevan, 1987; Victor and Velayudhan, 1987), resources (Alagarsami, *et al.*, 1987; Chellam *et al.*, 2003), small scale hatchery seed rearing (Anuradha and Alagarsami, 2003;

Jetani *et al*., 2003; Panikkar *et al*., 2003; Linoy *et al*., 2013 and Lipton *et al*., 2003), growth, predation, fouling and boring in farming (Pandya, 1975, Chellam, 1978, Alagarsami and Chellam, 1978, Dharmaraj and Chellam, 1980, Chellam *et al*., 1983, Dharmaraj *et al*., 1987; Chellam, 1988, Ramachandran *et al.,* 2003; Saidkoya *et al*., 2003; Valayudhan *et al*., 2003; Mohamed *et al*., 2003) and smaller magnitude of cultured pearl production (Alagarsami, 1977; Alagarsami and Chellam, 1980; Dharmaraj and Sukumaran, 2003 a and b), experimental sea ranching (Chellam *et al*., 1987) was obtained.

Though few entrepreneurs i.e. Tamil Nadu Fisheries Development Corporation (TNFDC) and Southern Petrochemicals Industries Corporation (SPIC) in 1983, later TNFDC singly in 1991 - '94 and in 1995 - 2000; Indo - Japanese venture - Oriental Kitachi Aquaculture Ltd (ORKI), Indian Tropical Agro Products Ltd, Tuticorin; Master Pearls, Chirala and Pearl beach Hatcheries, Vishakhapatnam took up pearl culture but they could not progress beyond few years because of various reasons. Similarly, the village level programmes implemented at Valinokkam Bay (1991 - 92) and village linked programme in collaboration with M.S. Swaminathan Research Foundation (MSSRF) at Mundalmunai village near Mandapam did not continue beyond the project periods for different reasons (Mohamed, 2013).

In order to redemonstrate and establish the viability of pearl culture technology, a Revolving Fund project was taken up at the Mandapam Regional Centre of CMFRI, under funding from Indian Council of Agricultural Research (ICAR), New Delhi at a cost of Rs. 30 lakhs as seed money. The project had to be operated (including cost of farm structures, operational expenses and wages of project staff), achieve production and revenue generated to pay back the (grant) seed money to ICAR in 5 equal instalments over a period of six years. The project was implemented effectively from 1997 to 2003. However, at the end of the project period, it could repay only about 45.5% of the seed money in the form of sale proceeds of pearls and mother oysters produced, and training imparted under the project and Rs. 16.5 lakhs spent on infrastructure development. The project also had a balance of unsold inferior quality pearls valued at Rs.5.5 lakhs in addition to very valuable information gathered and lessons learnt.

The complex nature of data obtained in these experiments and trials had compelling reasons for a need in collating the already published information by authors and unpublished data generated under the ICAR Revolving Fund project executed at RC of CMFRI, Mandapam Camp, (1997 - 2003) along with the recent experience gained in demonstration and transfer of pearl culture technology to fisherfolk in east and west coast and Lakshadweep Islands, India (Jagadis, 2013) for a critical analysis to assess the status of the marine pearl culture scenario in India. In this *'non systematic'* review article, the past and present experiences are critically analyzed and the results favourably points out for a successful pearl culture in suitable areas especially, in Gulf of Mannar. A schematic diagram of association and activities by different agencies for effective implementation are also depicted for a possible sustained development of marine pearl culture in India.

Hatchery production of seed

The first and foremost requirement in any farming system is the availability of quality seeds. In the context of insufficient natural availability of seed, hatchery production of seed become inevitable. For understanding the potential and problems of large scale seed production under hatchery condition on continuous basis, seed production trials in large scale was carried out in several conventional hatchery runs during the period 1997 to 2002 adopting the method outlined by Alagarswami *et al.* (1983, 1987) and the results obtained are given in Table 1.

Over these years a total of 115.6 million larvae were produced and reared which resulted in an estimated initial settlement of 82 lakhs spats (less than 0.5mm DVM) which accounts for an annual average of 8.8% of total larvae reared and further rearing for another 2 months yielded 37.1 lakhs transplantable spats of 5.0

Table 1. Year wise hatchery spat production in *Pinctada fucata* at southeast coast of India, during 1997 - 2002

Particulars	1997	1998	1999	2000	2001	2002	Cumulative Average
No. of larvae reared (lakhs)	120	481	150	140	130	135	193
Initial settlement (lakhs)	14.55	15.35	12.9	13.6	13.5	12.1	13.7
% of settlement	(12.1)	(3.2)	(8.6)	(9.7)	(10.4)	(9.0)	(8.8)
Transplantable spats recovered (lakhs)	5.94	4.57	6.25	4.89	4.75	5.37	5.3
% of initial settlement	40.8	29.8	48.4	36.0	35.2	44.4	39.1
% of total larvae reared	4.95	1.0	4.2	3.5	3.7	4.0	3.6
Size range (mm)	3 - 8	3 - 6	3 - 6	4 - 8	3 - 8	3 - 8	3 - 8
(ave.)	(4.5)	(5.0)	(4.5)	(5.5)	(5.0)	(5.5)	5.0

mm DVM average. The percentage recovery of transplantable spat worked out on total larvae reared was 1.0 to 5.0 (Av.3.6) and initial settled spats was 29.8 to 48.4 (Av.39.1%).

The results of larval rearing trials in 1988 clearly indicate that the percentage of initial settlement and transplantable spat recovery was very poor which is attributed to high stocking density of larvae (=3 times) of the average of the rest of the years. Excluding the results of 1998, larval rearing in the hatchery was capable of producing an average of 4.0% of transplantable spats of the total larvae reared and 41% of the initial settled spats. It also indicates that such conventional hatchery system with a holding capacity of 12 to 15 million larvae is quite viable for producing and supplying an average of 5 lakhs transplantable spats annually.

During the larviculture, disease/ciliate infections were evident and resulted in culture crashes. Preliminary observations on the usage of antibiotics i.e. Chloremphenical at the rate of 25 mg/l water with sieved larvae (=2 - 3 lakhs) with an exposure time of 10 minutes are found to be encouraging in keeping the larvae healthy (Pers. obs.). Lipton *et al.* (2003) has observed microbial load in the culture system resulting in mortality and poor spat settlement. These observations emphasise the need for an adoption of systematic pathogen elimination, improvement of filtration and purification system which could play a critical role in the higher and healthy larval settlement. This will certainly enhance sustained spat production in large scale in hatcheries and also the quality of the spats.

Growth and production of mother oyster

Chellam *et al.* (1987) has conducted experiments on growth of implanted oysters at Veppalodai and Tuticorin Harbour farm and suggested that there is large difference in the growth rate and attainment of maximum size is attributable to differences in the habitat namely greater depth, low silting, lesser fouling and calm sea conditions favour good growth in harbour farm. Strong coastal current is also responsible for retardation of growth at Veppalodai. Overcrowded culture conditions also could result in retardation of growth. Matsui (1958) recommends a stocking density of 70 - 100 oysters/m^2 in 5 - 10 meters depths in Japan. Chellam (1987) has studied in detail the growth of pearl oyster at Veppalodai farm in terms of various dimension and groups and infers that growth is moderate in shallow waters and also influenced by intensity of fouling and boring. Chellam *et al.* (1983) also found that the gastropod *Cymatium singulatum* proves a menace in farming of nucleated oysters.

Jagadis *et al.* (2006) has found that a standard stocking density of 1000 spats/bag of 1.5x1.0 m up to a size of 30 mm.5.0 g and culling after 6 months and subsequent restocking and culture at 125 nos/cage for another 5 months is essential for developing suitable sized oysters of 45 mm/12 g and above for 4 mm nucleus implantation. The gross percentage of similar sized oysters was found to be 82% under large scale culture condition in 'rack method' at Gulf of Mannar, southeast coast of India. Though this growth rate of oysters is found to be shortly slow for *P. fucata*, the resulting mother oysters are suitable for nucleation of 3 - 4 mm nucleus. Jeyabaskaran *et al.* (1983) also suggested that high salinities (29 - 34 ppt) reduced the growth of oysters in farms in Gulf of Mannar. Kripa, *et al.* (2007) infers that mortality of farmed oysters at farm conditions in west coast is more related to turbidity than any other environmental condition.

Apart from these, the reason for slower growth in bivalves is linked to the stocking density. Hence it is suggested that the farm should comprise of smaller and separate sections erected wide apart for each of the activity. This is expected to yield better growth rate since the stocks maintained are minimized in each section and water flow and feed availability are not restricted. An increased growth rate would result in enhanced percentage production of mother oysters suitable for pearl production from the stocked spats. The results obtained clearly indicate that the shallow coastal areas can be effectively used as sites for establishing mother oyster culture farms if otherwise suitable.

Nucleation, post operative culture and pearl production

The success of cultured pearl production depends on the three vital criteria i.e., percentage survival at harvest, nucleus retention percentage and quality pearl production percentage.

Single implantation on oyster was done with 3 - 5 mm shell bead nucleus and reared through a culture period ranging from 240 to 270 days and harvested. The year wise results of cumulative pearl production are given in Table 2. In the year 1997, trial implantation with single lead technician was done on 4,497 oysters with 3 - 5 mm nucleus. The post operative survival was 66.3% and of the surviving oysters, 70.9% retention of nucleus and was found finally 1,865 (62.5%) commercial grade pearls were produced.

In subsequent years, the stock size grew and the number of nucleated oysters at a given year of culture ranged from 32,447 to 48,246 (farm size = 1,000 sq m), and the cumulative data for survival ranged from 34.5 to 65.4% (average of 52.4%) and the retention rate was 36.5 to 50.3%

(average of 44.1%) indicating relatively higher percentage of mortality compared to Chellam, (1987). Horiguchi and Maegava (1978) have observed a lower mortality rate and nucleus rejection in operated Akoya oysters farmed at Ago Bay, Japan. The higher mortality and rejection rates in the present farming is possibly attributed to the relatively smaller sized oysters used (ave. DVM=45 mm) and the relatively higher stocking density.

On looking at the results obtained for the commercial grade pearls of Grades A, B and C together ranged from 9.3 to 22.7% annually with an average of 14.6% for all diameter pearls excluding the trial result. Out of this the major portion of pearls during these years was of 'C' grade (7.4 to 14.4%: ave. 10.7%). The good quality pearl (A+B) together accounted only for 4.0%. The vast difference in the percentage of quality pearl (A, B and C) production in present farming was primarily due to the highly varying results (0.8 - 10.5 %) achieved cumulatively over the period by the three technicians (Fig. 1 and 2) as well as the high stock size (ranging from 32,447 to 48,246 nos) (Table. 2). From Fig. 3 and 4, it is evident that the 1st year's result was very encouraging compared to that of the subsequent year's results in case of all grades of pearl production.

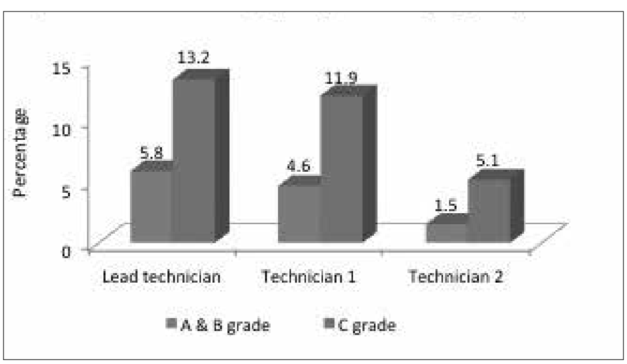

Fig.1. Technician - wise average pearl production (All grades) during 1998 - 2001

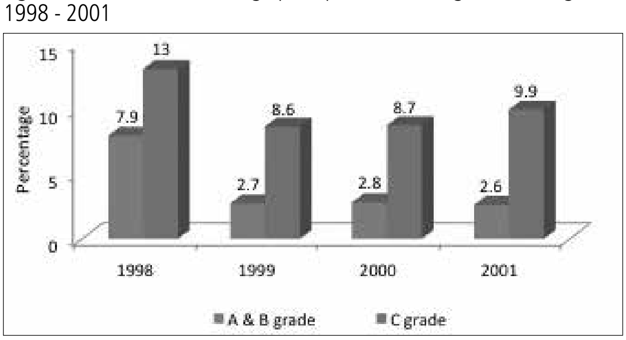

Fig.2. Year - wise cumulative average pearl production (3 Technicians) during 1998 - 2001

The standing stock size (Av.2.0 lakhs oysters of assorted size) in the farm was also a limiting factor for production of good quality pearls as all the activity was done in one farm and

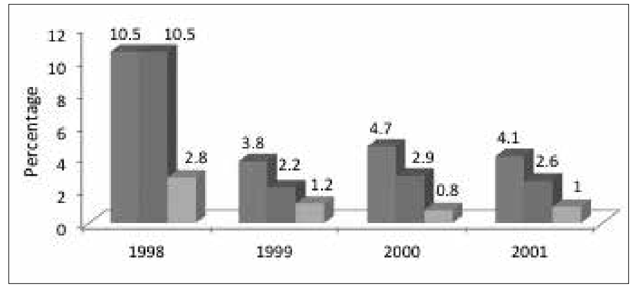

Fig.3. Technician wise/ Year wise "A&B" grade pearl production during 1998 - 2001

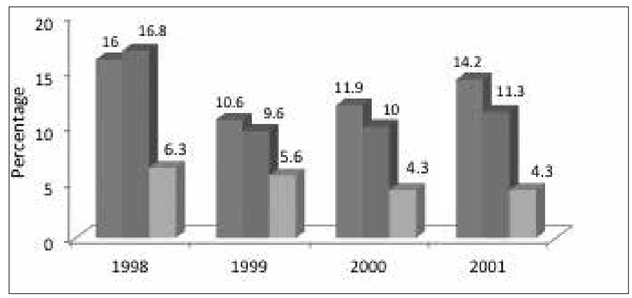

Fig.4. Technician wise/Year wise "C"grade pearl production during 1998 - 2001

repeatedly over longer period. The crowded stocking might have restricted the free flow of water and food availability to the oysters apart from very high silt accumulation and turbidity in the farm. This corresponds to the observations of Horiguchi and Maegawa (1978) which suggests that turbidity was a limiting factor for quality pearl production.

Katada (1959) opines short exposures to low salinity adversely affected growth in nucleated oysters and they had long term effects on nacre secretion in the pearl sac. Ohwada and Uemoto (1985) observed at least 21 ppt is required for normal pearl production. Ota and Fukushima (1961) attributes prevailing salinity range of 25 - 27 ppt suitable for unaffected quality pearl production. Based on these observations, the large percentage of poor quality pearl production in this farming is not due to salinity as the prevailing farm salinity throughout the culture was well above 30 ppt and could only be attributed either to graft quality, oyster condition or farm size. Ota and Shimizu (1961) found that exposure of oysters to air for up to an hour during shell cleaning results in transient disruption of nacre secretion on the pearl surface and also draws attention on nucleated oyster management during culture. Though the long term exposure has negative effect on the pearl formation as observed and warrants management of nucleated oysters, such situation has not arose in the present culture as fouling was found to be negligible. According to Matsui (1958), some culture grounds yields pearls of good quality, whereas others do not and opined that repeated culture on the same ground often affect the quality of pearls. While, the present result confirms this observation, a question also arises that *'does this*

Table 2. Year - wise cumulative pearl production in *P. fucata* at southeast coast of India, during 1997 - 2001

Year	Implanted Nos.	Survival Nos (%)	Retention Nos (%)	Quality pearls Nos(%	Grade'A' Nos (%)	Grade'B' Nos (%)	Grade'C Nos (%)	Trash Nos (%)
1997*	4497	2981	2114	1865	512	566	787	249
(Trial)		(66.3)	(70.9)	(62.5)	(17.2)	(19.0)	(26.4)	(8.4)
1998	38,619	25,265	12,617	5,723	966	1,222	3,535	4,456
		(65.4)	(50.0)	(22.7)	(3.8)	(4.8)	(14.0)	(17.6)
1999	48,246	26,370	10,408	2,835	230	375	2,230	8,750
		(54.7)	(39.5)	(10.8)	(0.9)	(1.4)	(8.5)	(33.2)
2000	46,842	16,168	5,917	1,501	99	213	1,189	5,360
		(34.5)	(36.5)	(9.3)	(0.6)	(1.3)	(7.4)	(33.2)
2001	32,447	19,259	9,690	3,026	134	462	2,430	6,664
		(59.4)	(50.3)	(15.7)	(0.7)	(2.4)	(12.6)	(34.6)
Total	1,66,154	87,062	38,632	13,085	1,429	2,272	9384	25,230
		(52.4)	(44.3)	(15.0)	(1.6)	(2.6)	(10.7)	(29.0)

+Percentages are worked out on the basis of surviving oysters at Harvest

* Trial (1997) excluded for calculations

results indicate the monotony of continued nucleation over long period' has any influence on the quality pearl production and along with the scientific reason of repeated cultures on the same ground leading to the deteriorated and diminishing results in terms of numbers and quality. Though the quality of the pearls is in general believed to be determined by various factors like the health of oysters, environment, the skill of the technician and the food and mineral richness of the culture area, Lucas (2008) opines that despite considerable research, the studies were unable to quantify any clear relationship between environmental parameters and pearl quality and it requires more research. Considering the excellent result of the trial (Table 2) on vital aspects like survival of nucleated oysters (66.3%), retention of nucleus (70.9%) and cumulative quality pearl production (62.5%) which can be taken as an indicative nature of the good probability for pearl production, in the shallow regions of Gulf of Mannar provided size of the farm, farm management and stock limitations are taken care.

Marketing and revenue generation

Marketing of the cultured pearls was done at Mandapam RC of CMFRI after evaluating the grades adopting Shirai (1970) and reproduced by Alagarswami (1987). The preference of the public was for the premium quality pearls in spite of its cost (Rs.1500/g), while low quality pearls had lesser demand. A pearl sale at CMFRI, Kochi was conducted in 2002 for 2 - 3 days where media advertisements were given and pearls worth Rs.2.2 lakhs were sold of which 55% was A and B grades indicating the preference and marketability of cultured spherical pearls in local market. The disadvantage of small size of pearls obtained from *P. fucata* of Gulf of Mannar area (dia 4 - 5 mm) was not a marketing constraint at least domestically, provided that the quality is either A or B grade as proven by the marketing experience.

Considering the above experiences it could be concluded that marine pearl culture in India is constrained due to its unsuitable topography of the coastline which is a major disadvantageous factor as compared to Japan and Australia for establishment of pearl farming units in ideal locations (Alagarswami, 1974). Failure in continuing the farming beyond certain period and lack of feedback from them for failure in the case of entrepreneur, difficulty in obtaining sustained funding by SHG's and sourcing and maintenance of regular stock of oysters, relatively long gestation period and in consistency in production of good quality pearls are considered to be the main lacunae for effective transfer of technology and continued adoption.

However, taking into consideration of many of the positive aspects of the technology such as availability of natural resources in Gulf of Mannar (Chellam *et al.*, 2003), effective and viable technology for production of spats of oyster, growth and development of mother oyster (Chellam, 1988; Velayudhan *et al.*, 1996; Victor *et al.*, 2001 and Jagadis *et al.*, 2006), the production of Akoya pearls from *Pinctada fucata* from southwest coast of India (Kripa *et al.*, 2007), coupled with the interest shown in the adoption of culture pearl technology by fisherfolks of Mandapam coast as an alternate income generation activity (Victor and Jagadis, 2007) and reasonable level of success in production of commercial grade pearls (4.3 to 7.7%) by the trained fisher folks of Sipikulam, Tuticorin (Jagadis, 2013) are encouraging elements for diffusion of technology. The results of the capacity building of fisherwomen, through demonstration, training and independent operation in spherical pearl production at Mandapam and Tuticorin, establishment of SHG's at Kollam, Kerala and Kalpeni Island in Lakshadweep, India and inclusion of 'pearl culture activity' in Fisheries funding programmes of Lakshadweep administration are the valuable and positive outcome (Jagadis, 2013). Lateral research and development in value added pearl ('mabe') production techniques (Mohamed *et al.*, 2003 and Anil *et al.*, 2003; 2007), and indication of faster growth of oysters in west coast (Mohamed *et al.*, 2006) are additional encouraging factors.

In short, the negatives and positives learnt out of our experience are:

The Negatives

- Hatchery production of seeds in a very basic and conventional method and vogue nursery rearing which resulted in lower quantum of spat and mother oyster production,
- Unorganised farming ie., all activities done in one farm of 1000 sqmt area.
- Not a comparatively suitable farming area by topography and biological need as elsewhere in temperate countries,
- Naturally smaller sized oysters and lesser productive open sea area.
- Stock status, collection and supply in an organised manner
- Non existence of proper sustained funding for the activity

The Positives

- Strong scientific support in the form of CMFRI for training on various aspects
- Good response of the fisherfolk in adoption and attitude in learning and doing
- Proven ability of fisherfolk in 'spherical' and 'image' pearl production during the capacity building
- Good demand for quality pearls in local market

All these indicates that there is a way out and scope existing for a systematic development of small commercial pearl farms in Gulf of Mannar and other suitable coastal areas in India as depicted in the flow chart (Fig. 5) with the effective involvement of fisherfolk / entrepreneurs along with state fisheries department, National Fisheries Development Board (NFDB), Marine Products Export Development Authority (MPEDA) and CMFRI.

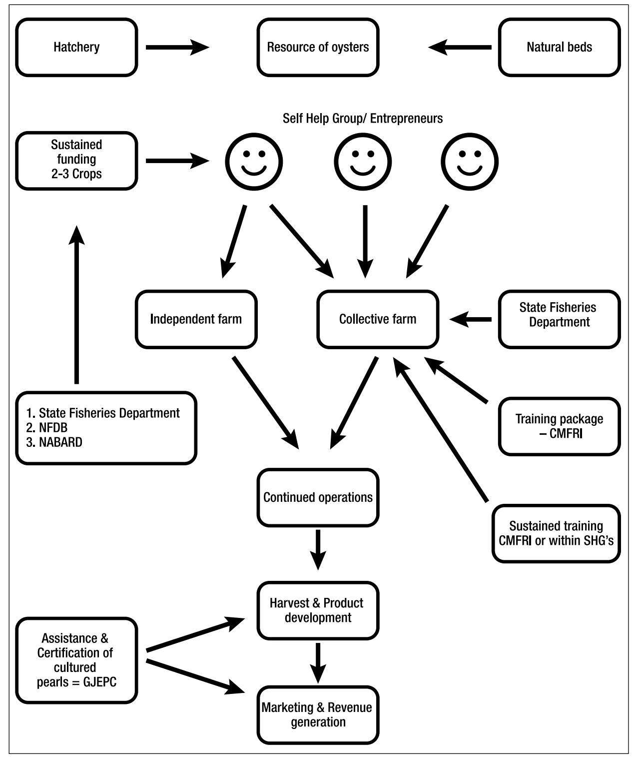

Fig.5. Schematic flow chart for a sustained marine pearl culture programme

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