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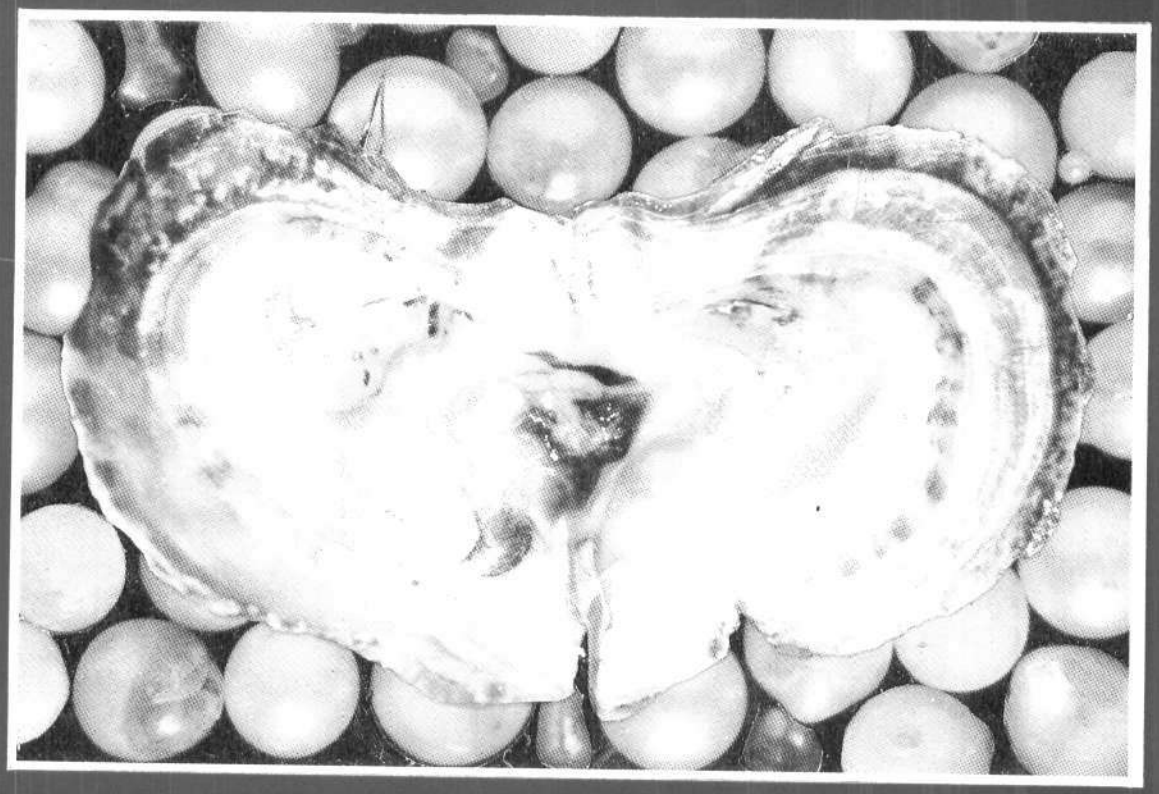

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PROSPECTS OF LARGE SCALE ONSHORE MARINE PEARL CULTURE ALONG THE INDIAN COASTS

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Introduction

Marine pearls are precious gems which are one of the most attractive objects of adoration. The occurrence of natural pearls, also called oriental pearls, in the wild pearl oysters is very rare. Although they generally lack proper shape, the natural pearls command very high price even today. The technology of pearl culture was developed by Japan followed by other countries including India. In India the raft culture technology for pearls was developed and perfected in the Central Marine Fisheries Research Institute (CMFRI) at its Tuticorin Research Centre in the Gulf of Mannar coast. World production of cultured marine pearls from different species, mainly from Japan and China, is estimated to be 75 t, against the projected demand of over 100 t. This gap indicates vast potential for the worldwide production and marketing of pearls. In spite of a sound technology, India has not yet attained the status of a commercial pearl producing country. Although India is endowed with a long coastline, the locations suitable for pearl culture in sea farms are quite limited, and consequently, entrepreneurs have not shown much interest in pearl culture.

In the past five years shrimp farming has taken considerable lead in India, particularly in the states of Andhra Pradesh and Tamil Nadu. However, this industry suffers frequent setbacks due to outbreak of diseases and other problems. This situation has created a great deal of awareness among the entrepreneurs about the need to diversify the species base of Indian mariculture and also the techniques. Against this background, the CMFRI attempted the development of a technology for cultured marine pearls in onshore tanks like any other pond systems under controlled conditions. The results of the experiment, first of its kind, are presented and discussed here.

Procedure for culture experiments

The Indian pearl oyster (*Pinctada fucata*) numbering about 1,200 were transported by train from Tuticorin to Kakinada on 20-01-1995 over a distance of 1,600 km covering 48 hours of journey with 12 hours of halt at Madras for change of sea water. Among the oysters there were 400 implanted oysters and 800 spats. All the implanted oysters suffered mortality within a few hours after reaching Kakinada. About eighty per cent of the spats also suffered mortality. The remaining spats numbering about 140 formed the material for this experiment. Sixteen spats were kept in a cage and suspended beneath the finger jetty of the Kakinada Bay fisheries harbour at a depth of about 80 cm below the surface of water. The remaining spats were spread over the bottom of a cement tank (10 x 5 x 1.2 m) situated in a private shrimp hatchery at Konapapapet (Fig. 1). The tank was provided with a seawater intake, bottom aeration and an outlet drainage. The depth of seawater in the tank was constantly maintained at 30-40 cm (Fig. 2) and the water was changed twice a week. Water pumped from the sea was filtered through slow sand filters and rapid sand filters, and then allowed to pass through chlorination and dechlorination process before letting into the tank. The oysters were fed with a mixed diet of 80% *Chaetoceros* sp. and 20% *Isochrysis galbana* at a density of 10,000 cells per ml two times a day at 0800 and 1800 hrs.

Fig. 1. Onshore cement tank used for pearl oyster culture.

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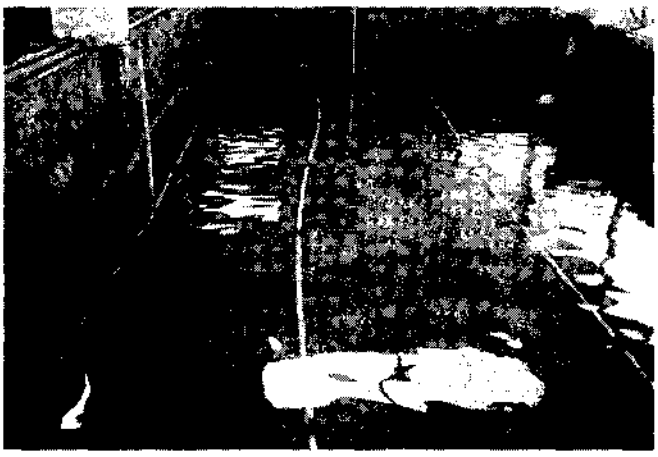

Fig. 2. Onshore cement tank with aerator lines. Pearl oysters and green mussels on the bottom.

The oysters from the finger jetty of fisheries harbour were transferred to the cement tank in April, 1995 to facilitate implantation. Nucleus implantation with 3 mm beads was carried out on 80 oysters by following the standard procedure in the 2nd week of June 1995. The pearl oysters were later shifted from Kakinada to the shore laboratory of the CMFRI at Visakhapatnam, in the last week of September 1995 and kept in a plastic pool, in order to facilitate better monitoring. At the shore laboratory unfiltered seawater from the Visakhapatnam outer harbour was brought and stored in a plastic pool (3 t capacity) and allowed to settle for about one week before use, by which time most of the fouling organisms like barnacles and serpulids got settled in the plastic pool. These two foulers in turn were able to remove some of the other foulers. At the shore laboratory also food consisting of 80% *Chaetoceros* sp. and 20% *Isochrysis galbana* was given daily at a density of 75,000 cells per ml, two times a day at 0800 and 1800 hrs.

Faecal matter from the pearl oyster tank was siphoned out at regular intervals of 12 hours and an equal quantity of seawater replaced in order to maintain the depth of water at 30-35 cm in the tank. X-ray technique was used to separate the oysters retaining the implanted nucleus from those which rejected the nucleus.

The pearl oysters kept in the Kakinada bay were regularly cleaned to remove the foulers till they were shifted to the Visakhapatnam shore laboratory. Similarly, the oysters in the cement tank of the private entrepreneur at Kakinada and the plastic pool at the Visakhapatnam onshore laboratory were gently brushed once a month to remove mild fouling. The plastic pool containing pearl oysters at the shore lab at Visakhapatnam was completely covered with a dark cloth. The ambient salinity and temperature were monitored throughout the period. Length measurements (in mm) were taken along the dorsoventral axis (DVA) to monitor growth. The size of oysters kept in the bay and the cement tank could not be monitored due to logistic problems.

Classification of pearls was made as per their present commercial value. Perfect round pearls were graded as 'A'. Pearls with one or more flaws, but with good nacre coating were graded as 'B'. Improperly coated or half coated nuclei were graded as 'C'.

RESULTS

Hydrographic and ecological conditions

Kakinada bay: Salinity of seawater near the fisheries harbour finger jetty ranged from 22‰ in January 1995 to 32‰ in April 1995. It gradually increased through February 1995 and March 1995 (Fig. 3). Water temperature also gradually increased from 24°C in January 1995 to 32°C in April 1995 through 25°C in February 1995 and 27°C in March 1995. These parameters reflected their seasonal variations, not deviating much from the normal values. The clarity of water was rather poor due to silt and

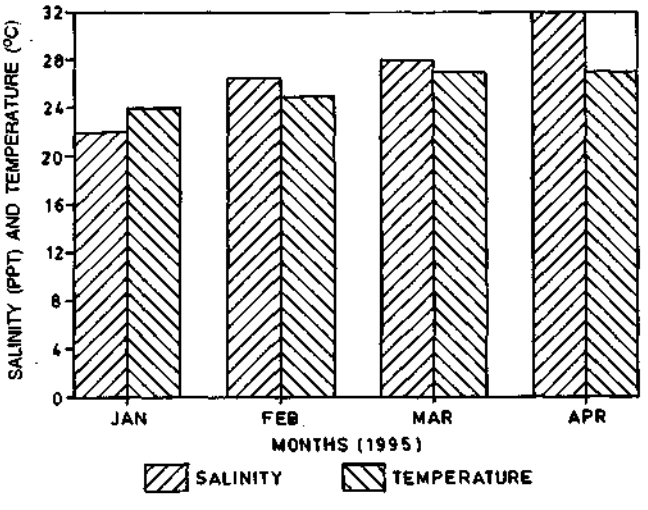

Fig. 3. Monthwise mean salinity and temperature values at Kakinada bay (Pearl oyster culture site).

suspended organic particulate matter, a common characteristic of the highly productive bay. Good natural beds of edible oyster and green mussel were found to exist in the bay where the pearl oysters were kept during the present study.

Cement tank (Kakinada): The cement tank at the Siris Aqua Ltd., Kakinada used for this experiment was one of the many tanks in a shed built in a spacing hall covered above by asbestos roofing. The salinity which was 30‰ in January 1995 gradually reached 34‰ in May 1995, but started declining from June 1995 (33.5‰) to September 1995 (29‰). The water temperature which was 21°C in January 1995 gradually rose to 33°C in May 1995, but then gradually declined to 27°C in September 1995 (Fig. 4). As all the sides above the cement tank were open, there was bright sun light penetrating into the water. This led to the development of the filamentous alga *Lyngbya* sp. on the shells of the pearl oysters and the inner walls of the tank. Apart from the alga, ascidians and sponges were also observed on the oysters on a few occasions. During heavy rains, rainwater entered the tank causing severe dilution, bringing the salinity down to 15 to 18‰ in 10 to 12 hours.

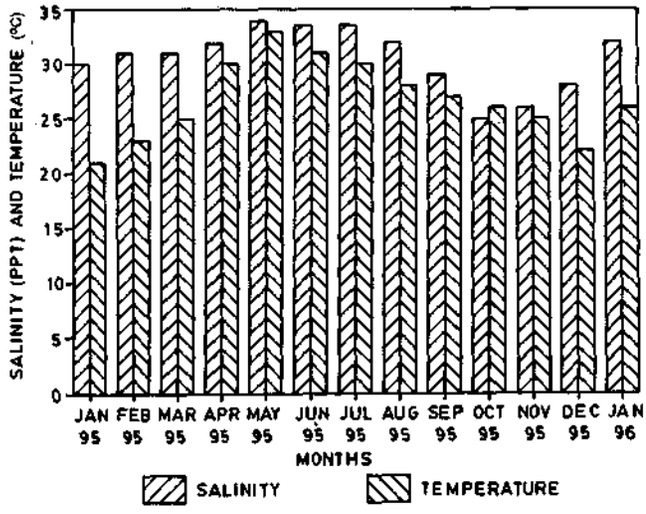

Fig. 4. Monthwise salinity and temperature values in the onshore pearl oyster tanks.

Shore lab. (Visakhapatnam): By the end of September 1995 the salinity was 25‰. However, it came down to 18‰ in the first week of October 1995 for about 5 days and gradually rose to 25‰ by the end of this month. Seasonal fall in salinity for a few days during the northeast monsoon season is a common phenomenon along the Visakhapatnam coast. During

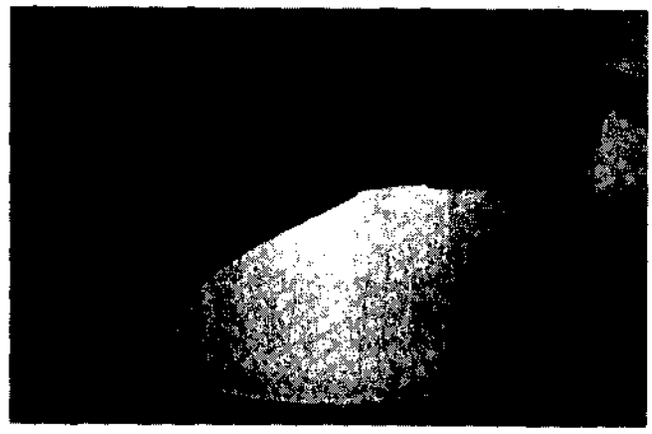

Fig. 5. Plastic pool covered with dark cloth towards the final phase of the experiment at the shore lab. of Visakhapatnam.

November - December 1995 and again in January 1996 salinity progressively increased to 28 and 32‰ respectively. Water temperature was 26°C in October, 25°C in November, 22°C in December 1995, 26°C in January and 27°C in February 1996 (Fig. 4).

There was no settlement of foulers on the pearl oysters due to the measures taken to store seawater before actual use. As the plastic pool was covered with dark cloth (Fig. 5), the filamentous alga *Lyngbya* sp. which settled on the pearl oysters while they were in cement tanks at Kakinada, were totally absent, although the seawater was not filtered.

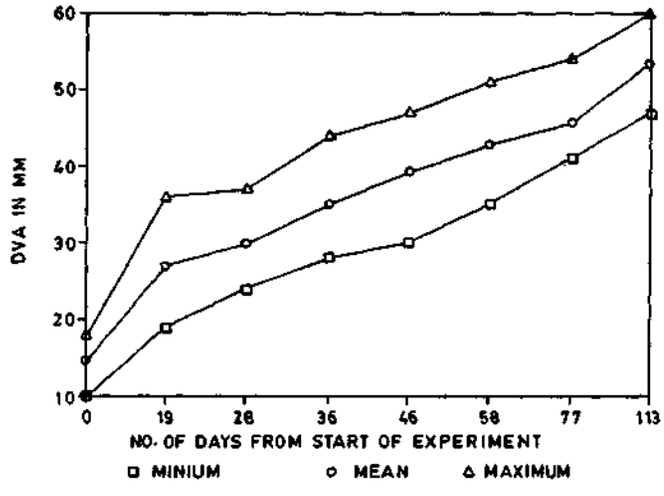

Fig. 6. Growth of pearl oysters (*P. fucata*) in the Kakinada bay (The period 77 days to 113 days pertains to hatchery under artificial feeding).

Growth

Kakinada bay: At the time of stocking in the Kakinada bay, the young pearl oysters ranged from 10 to 18 mm in DVA with a mean value of 14.6 mm. They reached a mean size (DVA) of 27 mm after 19 days and 35 mm after 36 days. The details of mean size and size range are shown in Fig. 6. They reached a mean size of 45.6 mm within a range of 41-54 mm after 77 days. At that stage they were transferred to the cement tank where they reached a mean size of 53.3 mm within a range of 47-60 mm after 113 days of stocking in the bay. The growth was monitored individually. The highest growth observed from the initial 12 mm to the final 58 mm was 46 mm in 113 days, while the lowest growth from the initial 17 mm to the final 47 mm was 30 mm during the same period.

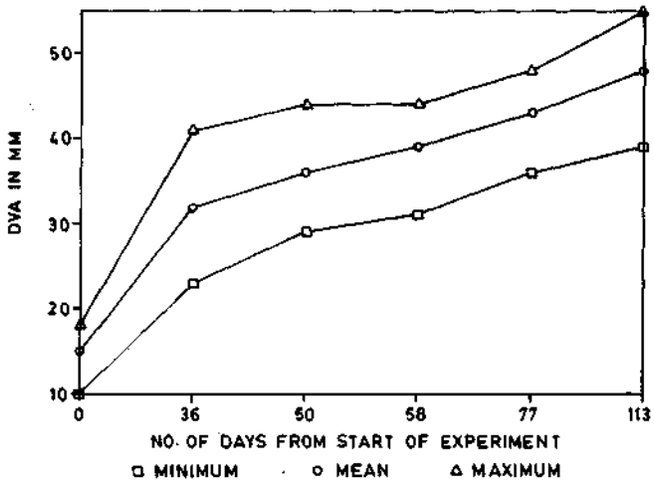

Fig. 7. Growth of pearl oyster (*P. fucata*) in the onshore cement tank.

Cement tank: The pearl oysters in the cement tanks at the time of stocking ranged from 10 to 19 mm with a mean size of 15 mm. They attained a mean size of 37.7 mm after 58 days within a size range of 31-44 mm (Fig. 7). They reached a mean size of 48.31 mm after 113 days within a DVA range of 39-55mm. In the tank also the growth of 30 oysters was monitored individually throughout the period. The highest growth observed from the initial 10 mm to the final 49 mm was 39 mm in 113 days while the lowest growth from the initial 18 mm to the final 39 mm was 21 mm during the same period.

The pearl oysters from the Kakinada bay and the cement tank together kept in the shrimp hatchery attained a mean size of 50 mm at the time of implantation in the first week of June 1995. The size range was 39-60 mm (Fig. 8).

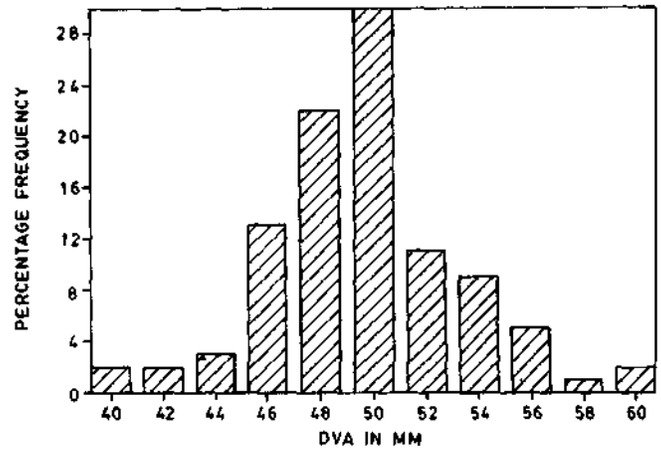

Fig. 8. Length frequency (DVA) distribution of *Pinctada fucata* at the time of implantation.

Feeding

The pearl oysters in the Kakinada bay were left to feed naturally. As the oysters in the cement tank were supplied with filtered seawater, algal feed became essential. They were fed by adding different volumes of *Chaetoceros* culture to maintain the algal cell concentration in the tank at varying levels. In the beginning the algal cell concentration was maintained at 10,000 cells/ml from 21.1.'95 to 26.2.'95 when the average size of the oysters was 15 mm. Subsequently it was increased to 20,000 cells/ml from 21.2.'95 to 12.3.'95 when the average size of the oysters was 32 mm. Later it was doubled to 40,000 cells/ml from 12.3.'95 to 20.3.'95 when the average size of the oysters was 36 mm, and from 20.3.'95 onwards the algal cell concentration was constantly maintained at 70,000 to 75,000 cells/ml when the average size of the oysters was 39 mm. From 26.2.'95 onwards the algal culture contained a mixture of 80% *Chaetoceros* and 20% *Isochrysis*. After implantation also the cell concentration and composition of algae were maintained at the above level (Fig. 9).

Green mussel in pearl oyster culture tanks

The algal cells were maintained at 10,000/ml in the beginning of the experiment. The cement tank held 140 pearl oysters and about 12,000 l water. As the tank was kept open without any dark cover algal blooming occurred

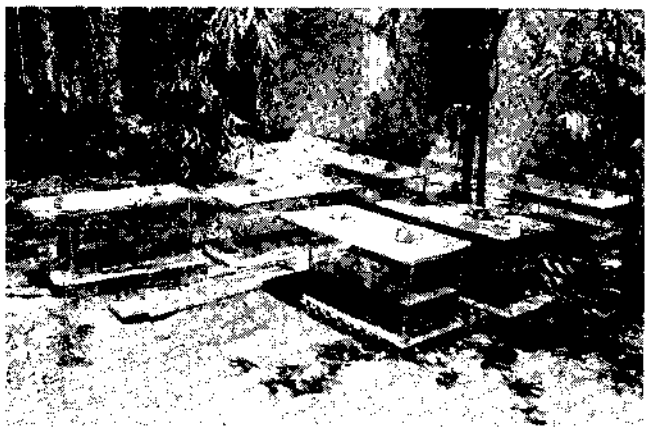

Fig. 9. Outdoor algal culture to feed pearl oysters.

after about 4 days resulting in the mortality of about 40 pearl oysters. In view of the large volume of water and the necessity of maintaining proper algal cell concentration in the tank, 100 green mussels (*Perna viridis*) of about 120 mm length each were spread uniformly on the bottom of the tank intermingled with the pearl oysters (Fig. 2). After the introduction of the green mussel, there was no blooming of algae, and the mortality of pearl oysters was negligible, in spite of doubling the algal concentration at frequent invervals upto 75,000 cells/ml. The mussels were maintained as long as the pearl oysters were in the open cement tank. However, after shifting the pearl oysters to the shore lab of Visakhapatnam in the last week of September 1995, no green mussels were kept along with the pearl oysters, as dark covering was provided to prevent any algal blooming (Fig. 5).

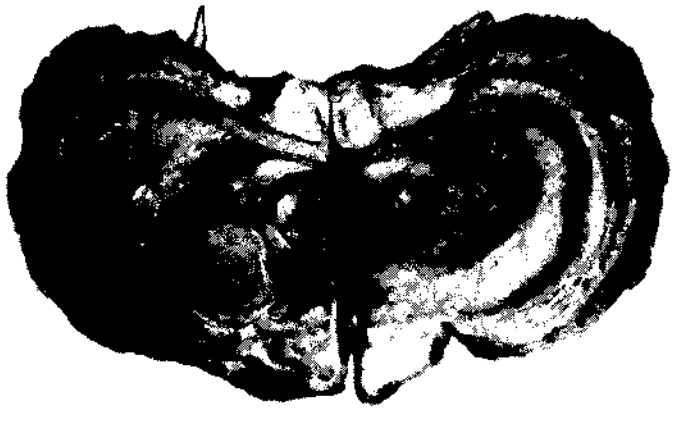

Fig. 10. A fully formed pearl before extraction from the oyster.

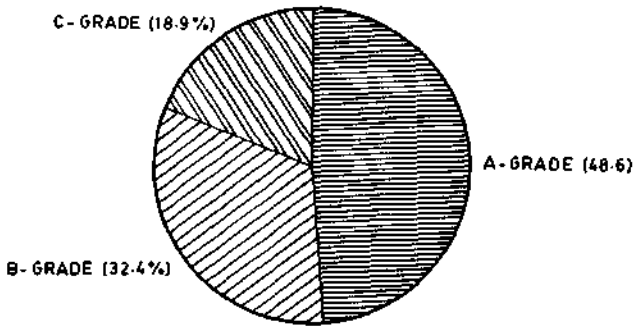

Fig. 11. Composition of different grades of pearl with reference to gross production.

Postoperative culture and harvest

Implantation operation was carried out in the second week of June 1995. The pearl oysters were let into the cement tank one hour after operation. After a few hours they started feeding well and were found attached to the bottom from the next day onwards. There was absolutely no mortality in the next 2 months. During this period 41 oysters rejected the nuclei which were recovered from the tank. Nucleus rejection started one week after implantation and continued for two months. Later two oysters suffered mortality. A sample of about 16 oysters were opened in the last week of December, 1995 to assess pearl formation and quality (Fig. 10). In the first week of February 1996 X-ray images of pearl oysters were taken to segregate the oysters with pearls from those without pearls. The oysters with pearls, including natural pearls (back cover photo) were opened and the pearls extracted. A total of 37 pearls of different grades were obtained from the original 80 implanted pearl oysters. Thus the gross production of pearls worked out to about 46%. The details of pearls, gradewise are presented in Table 1. Grade 'A' pearls formed 48.6%, followed by 32.4% of 'B' grade and 18.9% of 'C' grade (Fig. 11).

TABLE 1. *Details of pearls produced gradewise*

	Total No. of operated oysters	Gross production of pearls	'A' grade	'B' grade	'C' grade
Actual No.	80	37	18	12	7
Percentage	100	46	22.5	15.0	8.7

Natural pearls

Seven natural pearls of size varying from 1 to 3 mm without any particular shape were extracted from 7 oysters. They were extracted from the intestinal area where they were found embedded into the tissue. Most of them were silvery white in colour. Pearl oysters which yielded natural pearls formed 8.8% of the oyster population.

Colour and size

The round cultured pearls extracted from the oysters were uniformly cream or golden yellow in colour unlike the silvery white natural pearls. The diameter of grade 'A' pearls ranged from 3.07 to 3.78 mm with a mean of 3.32 mm, the 'B' grade pearls from 3.16 to 3.35 mm with a mean of 3.25 mm, and the 'C' grade pearls from 2.78 to 3.05 mm with a mean of 2.87 mm. No significant difference was found between the average diameter of the pearls extracted on the 190th day and on the 230th day.

Remarks

The growth of pearl oyster *P. fucata* observed in the Kakinada bay was quite high, compared to the growth in natural seawater conditions elsewhere (Fig. 6). Similarly the growth in the cement tank with phytoplankton feeding (Fig. 7) was also high. Since the maximum growth rate was obtained at 70,000 to 75,000 cells of *Chaetoceros*/ml between the 58th and the 77th day from the start of the experiment (Fig. 7), this algal density can be considered to be optimum. The growth rate observed at this density was almost equal to the growth rate observed at the harbour point. These growth rates are the fastest observed in India, making it possible to obtain adult oysters for implantation in about six months under onshore tank conditions or highly productive high saline brackishwater to marine conditions as prevailing in the Kakinada bay.

Pearl culture operations in India or elsewhere are confined to the open sea. In the present study pearl oysters were grown for the first time under less saline conditions (18 to 32‰) over a prolonged period, in and around the fisheries harbour area of the Kakinada bay and at Visakhapatnam (Figs. 3 & 5). Compared to the open sea conditions, the salinity in the experimental sites was rather low during the monsoon rains (18 to 25‰), but remained at about 30‰ during the rest

TABLE 2. *Tentative economic projections for onshore marine pearl culture*

(A) **Nonrecurring**	Rs.
Cost of land* (1 ha)	10,00,000
Cost of 4,000 m^2 tanks with hard bottom and roof [@ Rs. 250/m^2]	10,00,000
Cost of backyard hatchery	5,00,000
Cost of pumping, aeration and associated structures	3,00,000
Power installation and generator	2,00,000
Cost of algal production system (100 t/day)	2,00,000
Cost of oyster cages and suspending materials	10,00,000
Instruments for lab	2,00,000
For one production cycle	44,00,000
(B) **Recurring** (working capital)	
Wages	6,00,000
Nuclear beads	5,00,000
Instruments for implantation	50,000
Chemicals and glassware	1,50,000
Power charges	50,000
Repairs and replacement	50,000
Total	14,00,000
Repayment of term loan (A) with interest spread over 5 years	1,30,000
Grand total	27,00,000
(C) **Revenue**	
Total gross return for 1,25,000 pearls @ 25% yield and Rs. 40/pearl (Total implanted oysters 5,00,000)	50,00,000
(D) **Net profit** (C - B)	23,00,000
Percentage of profit	85.2

* in the urban vicinity of Visakhapatnam

of the study period. Most of the bivalves are known to tolerate wide ranges in salinity, turbidity and temperature if they are well fed to compensate the stress on account of significant deviations from normal environmental conditions. Thus the productivity of the ecosystem seems to be a key factor in determining the growth of bivalves. This fact could be taken advantage of in onshore tank systems by maintaining phytoplankton density at the optimum levels.

Another important factor often taken into consideration in pearl culture is the optimum depth, where oysters grow well and produce quality pearls. The present experiment has amply proved that the desired growth and pearl production can be achieved at a depth of about 50 cm, and hence, the depth of water does not appear to be a limiting factor. This finding is of critical importance as it paves the way for growing pearl oysters in low cost, shallow, onshore tanks, as construction of deeper tanks is costly.

The problem of borers and foulers is minimum in onshore tank systems, as it is much easier to control all the conditions and eliminate mortality due to predation.

The harvest of uniformly cream coloured 'A' grade pearls which accounted for about 49% of the total number of pearls produced and about 20% of the gross implanted pearl oysters is economically attractive. The other grades could be made more attractive by proper processing. The formation of natural pearls at 8% of the gross implanted oysters is an added advantage in the tank system. The chances of lodging of sand particles or food particles into the pearl oyster body are more in the tank system than in the wild or deeper waterbodies. The potential for producing valuable natural pearls in onshore tanks is advantageous to the entrepreneurs.

The quality and colour of 'A' grade pearls and the very significant increase in the diameter of the pearls during the last 40 days of the experiment indicate that 3 mm pearls can be extracted in about 180-190 days from the day of implantation in the tank culture system.

There is good possibility of segregating the oysters with nucleus from the nucleus-rejected oysters by the X-ray technique. As the nucleus-rejected oysters could be reimplanted, gross pearl production could be enhanced substantially. X-ray could also be used to assess and monitor nacre secretion and the quality of pearls while they are inside the mother oyster. It is thus possible to assess pearl production both qualitatively and quantitatively in advance, for further planning. A computer software programme on X-ray image processing of pearl oysters is being developed by Dr. V.S. Raghava of the Department of Computer Science and Engineering, Andhra University, Visakhapatnam. This programme should be able to make tank pearl culture operations more efficiently.

Onshore pearl culture is less risky and highly lucrative (Table 2) compared to open sea pearl culture. It provides the opportunity to combine all key environmental factors together at the optimum level through good planning and management, thus making the onshore pearl culture highly successful.

Further studies are required to improve the quality and colour of pearls by manipulating the feeds, and by improving the strains of *P. fucata* by selective breeding. There is an urgent need for large scale farm trials for onshore pearl culture to assess more precisely its economics.

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