Technologies And Potential For Seafarming In India, Part I

By P.S.B.R. James

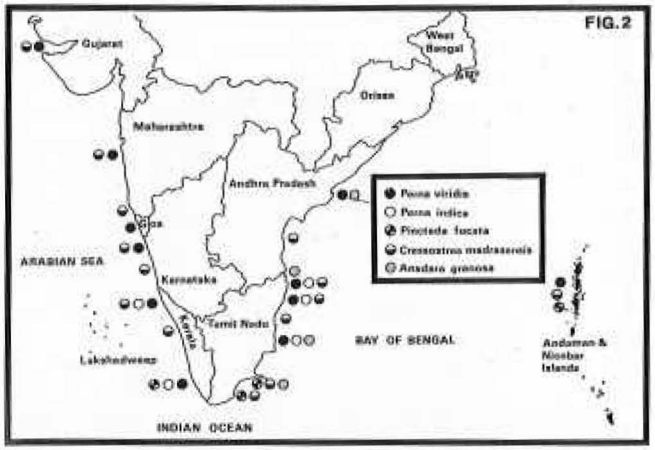
In India, marine fisheries activities are predominantly conducted in the coastal areas. Yielding a total of 2.27 million tons in 1993, coastal fisheries produced their largest harvest to that date. Presently, there are fears that certain resources have been overfished, primarily because of the fishing practices lacking in diversification. This situation has mandated that action be taken to increase harvests from the offshore and oceanic areas. However, progress for offshore fisheries has been hindered due to the intensive capital demands of these operations.

It is estimated that India's Exclusive Economic Zone (EEZ) has the potential to produce 3.9 million tons of marine fish. Subtracting the 2.27 million tons obtained by the coastal fisheries industry, seafarming provides the most viable option to generate the remaining 1.63 million tons. Traditional farming methods have been in vogue for centuries in the country, but improved scientific methods have only been developed in the last two and one-half decades. The Central Marine Fisheries Research Institute (CMFRI) of Cochin, India has developed several low-cost technologies for the breeding and farming of pearl oysters, edible oysters, mussels, clams, finfishes, marine shrimp, crabs, lobsters, seacucumbers, seaweeds, and pearl production in coastal areas. Many technological transfer programs have been conducted and the manpower has been developed to increase marine fish production from the vast coastal areas, lagoons, estuaries, other brackish water areas and derelict saltpans.

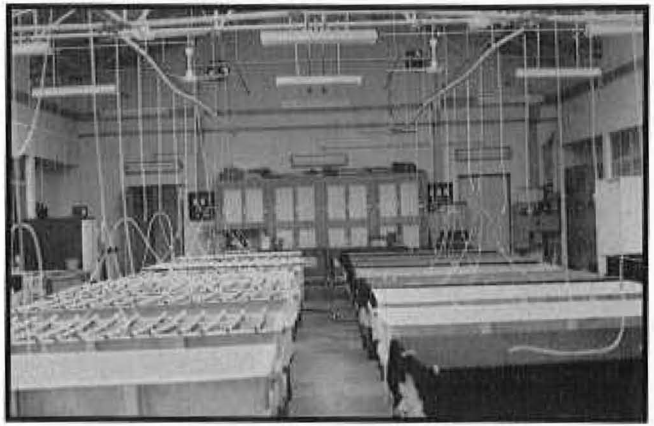
In this article, a brief description of the currently practiced technologies is given with an indication of the potential for seafarming in the country.

Technologies

1. Shellfish hatchery technology: A suitable site location, proper shelter, air supply, a generator, clear seawater of 30-36 ppt salinity, freshwater, a conditioning room, rearing tanks and the necessary scientific equipment constitute the requirements for operating a hatchery facility. These conditions are commonly present for the farming of pearl and edible oysters (Photo No.1). The CMFRI achieved a breakthrough in the hatchery production of the pearl oyster seed, *Pinctada fucata* in 1987 at Tuticorin (Tamil Nadu State, southeast coast) and produced several generations of seed. Ripe pearl oysters were collected from nature and maintained at 25°C. They were fed with mixed algae, dominated by *Chaetoceros* (4 liters/oyster, twice a day). Water was changed daily. Spawning was induced in perspex tanks by gradually increasing the temperature to 35°C with a silica immersion heater and jumbo thermometer. Spawning can also be in-



Potential seafarming areas for molluscs.



A view of the shellfish hatchery of CMFRI at Tuticorin.

duced through chemical stimuli (hydrogen peroxide immersion, ammonium hydroxide injection). Fertilized eggs measured 47.5 um dia. Seawater in the larval rearing tanks was changed on alternate days. Unicellular micro-alga, *Isochrysis galbana* was fed to larvae from the second day. Spat settlement occurred from the 18th to 20th day (300 um size). Extremely careful handling of the spat was conscientiously executed until they reached 3 mm. Subsequently, they were transferred to the field (*Alagarswami et al., 1983*).

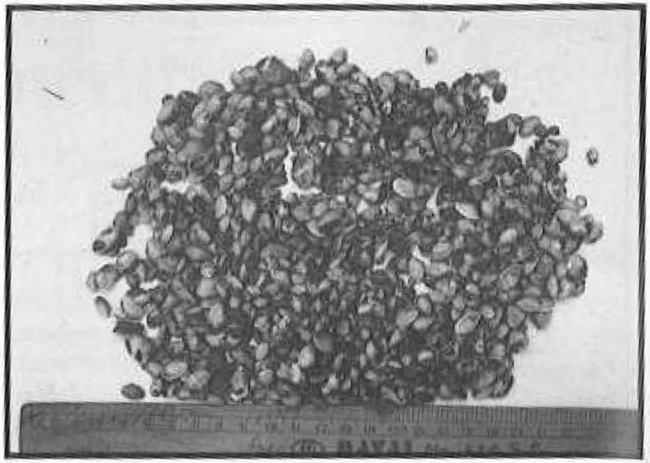
To ensure good representation of both sexes, the edible oyster *Crassostrea madrasensis*, was selected in the 60-90 mm length range. They were placed on synthetic twine-knit PVC frames in pre-cooled seawater (20-22°C) and fed twice a day with 2-3 liters of mixed algal culture, and also pre-cooled (20-22°C). The conditioned oysters were subjected to thermal stimulation by sudden transfer to seawater of 34-35°C, which makes the oysters spawn. The spawning oysters were then placed in trays with filtered seawater at an ambient temperature. After spawning, the oysters were removed from the trays. Fertilization takes place immediately, and the 'D'- shaped larval stage is reached in 20 hours. Other larval stages are completed in 14-18 days. The concentration of algal cells as food varies according to the stage of larva. Clean spat collectors are used to produce attached spat and oyster shells are commonly used for this purpose. The col-

lectors are spread at the bottom in one ton FRP tanks and the eyed oyster larvae are released into the tanks. In the following few days, the larvae settle as spat. Pre-treated shellgrit, 0.5 mm in size, is spread on the bottom over a pre-treated polythene sheet for the production of cultchless spat. The spat are reared for 3 weeks after settlement in the hatchery before they are transferred to the field (*Nair et al., 1984a; Nair et al., 1984 b*).

Viable technology for production of the clam seed, *Anadara granosa, Meretrix meretrix, M. caste* and *Paphia malabarica* (Photo No.2) has been developed by the CMFRI. Spawning occurs both at higher and lower temperatures (34°C-24°C). Spat settle between the 7th and 16th day after spawning, depending on the species. They attain a length of 2-3 mm in 2 months after fertilization and are transferred to the nursery. A survival rate of 15-20% in spat production is considered satisfactory.

Eggs of the cephalopods, *Sepia pharonis* and *Sepioteuthis lessoniana* were hatched and reared to the adult stage. *Loligo duvauceli* eggs were also hatched and reared for 5 days. However, further work has to be done in this regard.

2. Pearl oyster farming and pearl culture: For farming in this category, clean seawater and a gravelly or hard sea bottom should be selected. Water should not be of low salinity, pH should be 7-8, and calcium 400 mg/l. Trace elements should be of normal concentration/composition since the color of pearls is influenced by them.



Hatchery-produced seed of Paphia malabarica.

> The new technology has drastically reduced production cost by developing inexpensive mixed diatom cultures and particulate feeds.

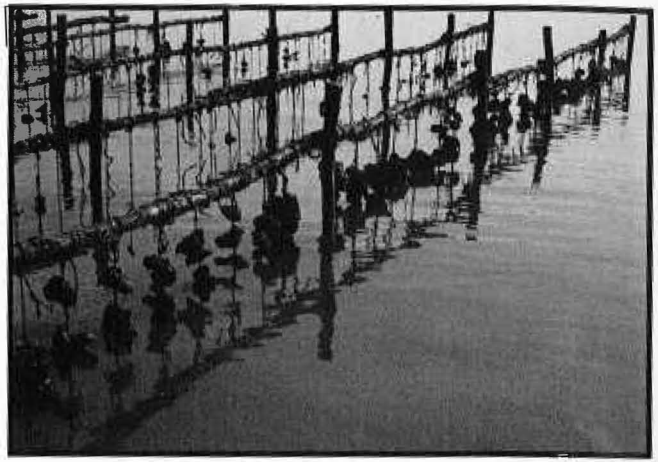
Wooden rafts (6x5 m) are attached to barrels and float at depths above 5 m. Modern materials like PVC pipes and styrofoam floats and racks constructed out of wooden poles and frames can also be used. A third method involves using long lines with a series of large hollow floats in a row, attached to strong ropes and anchored.

Farming involves mother oyster culture from spat to nucleus implantation and post-operative culture. Spat (3-20 mm) are reared in prism-type metal cages covered by velon screen, which are wrapped by old nylon fishing nets to protect against predators. Box-type cages (40x40x10 cm) covered by velon screen on plastic baskets with perforations may also be used to rear spat. The rearing cages or baskets are suspended from the raft/rack with a rope, at about 1 m below the water surface. Pearl oysters are reared in box-type cages with lids (40x40x10 cm) covered with synthetic twine.

The number of oysters to be stocked in the cages depends on their size. Survival in the grow-out system varies from year to year. An eighty percent survival in 10-12 months is considered satisfactory.

A variety of fishes, gastropods and crabs cause damage to oysters. Barnacles, ascidians, bryozans and molluscs cause biofouling. Boring sponges and polychaetes also cause damage. Immersion of oysters in freshwater, treatment with formalin, exposure to air and frequent cleaning reduce such damage (*Anonymous, 1991*).

For pearl culture, healthy oysters (over 45 mm), which are inactive or in the resting reproductive phase, are selected. Spherical shell bead nuclei (2-8 mm) are imported from Japan. Oysters are immersed in seawater with the hinge of the shell downwards. They are prompted to open their valves when menthol powder is sprinkled on them. A wooden plug is used to keep the valves open. Graft mantle tissue is cut into 2-3 mm length sections and 2 mm breadth and kept moist in



Rack-and-ren method of culture of the edible oyster Crassostrea madrasensis.

sterilized and filtered seawater. An antibiotic effect is given to the mantle bits by using eosin, mercurochrome or azumin in seawater. The graft tissue and nucleus are inserted into the spot selected for implantation through the foot and gonad. Multiple implantation is also made in the same manner. The wooden plug is then removed. After surgery, the oysters are placed in fresh, running seawater. The oysters are kept in netlon baskets and hung in FRP tanks for observation for 2-3 days. Dead oysters and the ones which reject the nucleii are removed, while the rest are transferred to the farm in

Rack-and-tray method of culture of the edible oyster C. madrasensis.

40x40x10 cm box-type cages. The pearls reach marketable size in 3-4 months (with 2-3 mm dia nuclei) and in 15-18 months exhibit 6-7 mm dia nuclei. Oysters are brought to the shore and opened individually for pearl collection. In the process, oysters are also killed (*James et al., 1991; James and Narashimham, 1994*).

3. Edible oyster culture: Sheltered areas without strong wave action, intertidal areas up to 5 m depth and with a salinity range of 22-35 ppt are suitable for the farming of *Crassostrea madrasensis*. Oyster spat from the hatchery are put in velon screen bags and suspended from racks in nurseries. After 40-50 days they are transferred to the farm.

The rack and string or ren method (Photo No.3) consists of the construction of racks, as in the case of pearl oysters, in a 1-2.5 m water depth. Shell strings are suspended from the racks. In 1 ha, 125 racks are constructed. After one year each string weighs 7-7.5 kg, yielding an estimated 80 t/ha. Mortality is about 45%.

In the rack-and-tray method (Photo No.4), cultch free single spat (25 mm) are transferred to 40x40x10 cm trays at the rate of 150-200 spat/tray. The tray is knitted with 2 mm synthetic twine and suspended from the rack. After reaching a length of 50 mm, the oysters are segregated and transferred to rectangular trays of 90x60x15 cm size and placed in the racks. Each tray holds 150-200 oysters and each rack occupies 25 m^2 in area. In one year, the oysters attain about an 85 mm length. Production is estimated at 120 t/ha/yr, though the production cost is higher than the ren method. In the stake method of culture, stakes are driven into the sea bottom above which nails hold shells with spat attached. Both nursery (2 m) and grow-out periods (10 m) are covered by velon screen on the stakes. Production is estimated at 20 t/ha/yr (*Nair et al., 1987*).

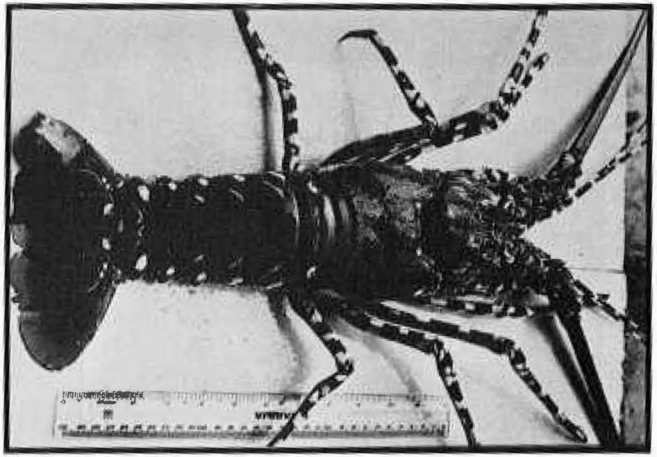
Crabs, fishes, starfishes, polychaetes and gastropods are common predators of oysters and may be controlled by periodic cleaning. Seaweeds and barnacles also cause fouling.

4. Mussel culture: Sheltered areas free from strong wind action, clean seawater devoid of silt, good phytoplankton production, a salinity concentration of 30-35 ppt and suitable substratum (depending on the type of culture) are essen-

quirements in farming the green mussel, *Perna viridis*. fts made up of teak wood or bamboo poles of the size) 8x8 m are used. About 500-700 g of mussel seed (20- n length) are used on one meter length of rope. Mussel are spread over 25 cm wide knitted cotton cloth and coir .5 mm dia) or nylon (14 mm dia) rope is kept over the To prevent slipping, wooden pegs are inserted into the at fixed intervals. The cloth is wrapped over the rope he ends are stitched with cotton twine. The seeded ropes m), are suspended from the raft 0.5 to 1 m apart. The of the ropes should be 2 m above sea bottom. The mus- attach to the rope in 2-3 days. The cloth disintegrates in it 10 days. Production rates at several places in the country ed between 4.4-12.3 kg/m/rope/4-6 months. In 5 months, mussels attain 80-88 mm length and weigh 36.4 - 40 g. h raft supports 100 seeded ropes, the seeded length being . A 6 m rope yields 61.8 kg and an 8x8 m raft yields 6.18 months. Mussel ropes (Photo No. 4) are collected manu- ' from the raft and brought to shore for the removal of ssels (*Nair et al., 1980*).

Crabs, lobsters and fishes are common predators of mus- s. Foulers include barnacles, tubiculous polychaetes, as- ians, coelenterates and bryozoans. Maintenance is done periodic cleaning of all structures.

Clam culture: Clams are cultured at the bottom of tidal eas and the site has to be selected with reference to substra- m, tide and water salinity. The farms may be located in tuaries, bays and sheltered areas close to the shore. Little



The spiny lobster, Panulirus ornatus.

exposure at low tides and minimum wave action are desirable.

Seed of *Anadara granosa* (21.8-25.1 mm average length, 5.53-7.08 g average weight) stocked to a density of 140-175/ m^2 attained 39.2-43.1 mm average length and 25.53-32.9 g average weight at harvest. The retrieval was 83.4-88.6 percent with pen enclosures and 41.5 percent without pen enclosures.

Production rates were 39.0-41.6 t/ha/5.5 m (with enclosure) and 21.0 t/ha/6m (without enclosure) (*Narashimham, 1976*). *Meretrix meretrix* of average length

26.8 mm attained 37.5 mm in 4 months with a survival rate of 75.5 percent. *M. casta* grew from 7.3 mm length to as much as 40.6 mm in one year. The sacred chank, *Xanchus pyrum* could be spawned in the laboratory, and young ones reared up to 30 days. Further work is necessary in this species.

6. Induced maturation, spawning and hatchery technology for marine shrimp: Penaeid shrimps, *Penaeus indicus, P. monodon, P. semisulcatus, P. japonicus, P. latisulcatus, Metapenaeus monoceros, M. affinis, M. dobsoni* and *Paraenaeopsis stilifera* could be made to mature and spawn in captivity by unilateral eye stalk ablation, using an electrocautery apparatus to prevent bleeding (*Muthu and Lakshminarayanan, 1980*). Shrimps were then transferred to a 10 ton capacity, circular maturation pool filled with seawater. The pool was outfitted with a subgravel biological filter for recirculating seawater by airlift pumps. The nitrifying bacteria in the gravel oxidize the toxic ammonia secreted by the shrimps into harmless nitrates. The resultant lowering of seawater pH is compensated by daily addition of slaked lime or sodium carbonate for maintaining a pH of 8.0 - 8.2. Shrimps are fed *ad libitum* with clam meat. In 3-5 days about 80% of females develop into mature shrimps (males attain sexual maturity in brackish waters). Individual, mature females are transferred into 200 liter capacity seawater tanks where their viable eggs hatch out into nauplii. The nauplii are transferred to the hatchery for further rearing (*Mohamed et al., 1983; Muthu et al., 1984*).

P. indicus has been reared to mature and spawn even without eyestalk ablation by maintaining the pH of water at 8.2. Unablated shrimps (160 mm and above) take more time (5-10 days) than ablated shrimps (140 mm). Using the artificial insemination technique, *P. indicus* and *P. monodon* have spawned viable eggs with a very high hatching rate of 90-95%. This has introduced new vistas in selective breeding and genetic manipulation of cultivable shrimp species (*Muthu and Lakshminarayana, 1984*).

The modular-type hatchery consists of FRP/concrete/ plastic rearing tanks, kept under a glass-roofed shed . The settled seawater (30-40 ppt) is filtered through 50-micron-mesh-nylon-bolting silk and used for rearing. A density of 75 nauplii/liter was maintained. Both protozoa and mysis stages are fed exclusively on mixed culture of diatoms, which are grown in 1 ton fiberglass tanks by fertilizing raw seawater with nitrates, phosphates and silicates. When exposed to sunlight, diatom blooms dominated by *Chaetoceros* spp. develop within 24 hrs. The concentration of the diatom culture is regulated at 20,000 cells/ml water and is pumped into rearing tanks. One third to half of the water volume changed daily removes all sediments. Diatoms are fed up to the mysis-3 stage. From PL-1 onwards, particulate feed (composed of meal made out of squilla, shrimp head waste, groundnut oil cake, tapioca and fish meal) is supplied. Particle size was initially 250 microns and was gradually increased for later stages. A survival rate of 50 percent is obtained from nauplius to PL-5 stage when the hatchery phase ends (*Mohamed et al., 1983*). From PL-5 stage, the larvae can be grown in nurseries (concrete tanks/plastic pools of 10 ton water capacity).

he density of larvae in nurseries is reduced to 15 per of water to avoid cannibalism. The same particulate feed, an increase in the size of particles, can be given to lar- as they grow. The PL-20 stage can be stocked in grow- ponds.

he new technology has drastically reduced production by developing inexpensive mixed diatom cultures and iculate feeds. These have replaced pure cultures of phy- ankton and *Artemia nauplii* as larval feeds in the hatch-

7. Salt-pan shrimp culture: Experiments were conducted utilize the saline fallow coastal lands including derelict t-pans for shrimp culture. Seawater in the constructed nds could be completely drained at harvest time, exposing : bottom to sunlight. Average water depth and pH were l-0.7 m and 7.5 respectively. Dried poultry dung or cow ng was spread in the ponds at 750 kg/ha. Naturally avail- le seed of *Penaeus indicus* (15-25 mm) was stocked at 1.2- 5 lakhs/ha. About one fifth of the water in the pond was anged daily. Water temperature was 28.40-28.90°C. Sa- nity of water was above 38 ppt, reaching a maximum of 45-) ppt from April-June. Dissolved oxygen was 3.59-3.79 ml/ Productivity of the ponds was found to be 244-2213 mg/c/ m^3/day, by the light and dark bottle method. During low pro- uctivity, organic and inorganic fertilizers were added to the vater and excessive blooms were reduced by flushing water. For the first 3 weeks no artificial feed was given. Therefore, pelletized feed at 7-10 percent of body weight was adminis- ered twice a day in trays kept at the bottom of the pond. The growth rate varied from 1.36-15.0 mm and 1.4-1.7 g/m and the production was 881-1604 kg/ha/crop. Two crops could be taken annually (*Marichamy and Motha,1986*).

8. Crab culture: Juveniles of the green crab or mud crab, *Scylla serrate* (40 mm carapace width-CW) were collected from the wild and stocked in ponds fenced with wooden barricades. The crabs were fed with trash fish. A stocking rate of 8000/ha gave a survival rate of 31.8%. The crabs attained an average size of 140 mm CW (442 g) in 7 months with a monthly increase of 1.41 mm CW and 61.2 g when cultured for one year, at a stocking density of 820/ha. The survival rate was 28%. Average size attained was 151 mm CW (5819), at a monthly growth rate of 9.6 mm CW (49.5 g).

Berried females collected from the wild were allowed to spawn in the laboratory. Zoea larvae were reared under controlled conditions to reach the juvenile stage using *Artemia nauplii* as feed. Development of the five zoea and megalopa stages took 30 days (*Marichamy and Rajapackiam, 1984*). The larvae of the blue crab, *Portunus pelagicus* were also reared successfully to the first crab stage in 20 days. Further work is needed on this species.

9. Lobster culture: The puerulii of the lobster *Panulirus homarus* were collected in large numbers on tiles covered with coir rope and hung from rafts in the sea. The puerulli were then grown in large cement tanks filled with seawater. Clam and mussel meat were given as feed. They were grown from 45 g to 270 g in 43 weeks. The growth can be accelerated by bilateral eye stalk ablation. *P. homarus* of 45 g can be grown to 150 g in 10 weeks by this method. The estimated

growth of ablated *P. ornatus* is 2173 g (Photo No.5), *P. homarus* 749 g and *P. polyphagus* 779 g per year from an initial weight of 80 g (*Silas, 1982; Radhakrishnan and Vijayakumaran, 1984 a & b; Vijayakumaran and Radhakrishnan, 1984; Suseelan et al., 1993*).

In the absence of hatchery technology for large scale production of seed, naturally available juveniles are used for farming. Juveniles of *P. ornatus* (southeast coast), *P. homarus* (southeast and southwest coast) and *P. polyphagus* (northwest coast) are available in good quantities for farming. The growth rate of spiny lobsters in tropical waters (like in India) is very high. Juveniles of *P. polyphagus* are grown by farmers of the Gujarat state (northwest coast) in pits (30x15x1.25 m) dug out in intertidal zones and covered by monofilament net. The pits get flushed periodically by tides. Crushed trashfish, small crabs, marine worms, clams etc are given as feed. From an initial weight of 30-35 g, the juveniles grow to 100-125 g in 10-13 weeks. *P. homarus* and *P. ornatus* are also now being grown in a similar way along the southwest and southeast coast.

References

Alagarswamy, K., S. Dharmaraj, T.S. Velayudhan, A. Chellam, A.C.C. Victor and A.D. Gandhi. 1983. Larval rearing and production of spat of pearl oyster, Pinctada fucata (Gould). Aquaculture, 34: 287-301.

Anonymous, 1991. Pearl oyster farming and pearl culture. Training manual number 8, 104 spp. Regional seafarming development and demonstration project, Bangkok.

James, D.B. 1993. Seacucumber culture. Handbook on aquafarming seaweed, sea urchin and seacucumber. MPEDA, p. 33-47.

James, P.S.B.R., K.A. Narashimbam. A.C.C. Victor, S. Dharmaraj, T.S. Velayudhan and A. Chellam, 1991. The Indian Marine Pearls - A culture technique for pearl production. 23 spp. CMFRI Cochin.

James, P.S.B.R. and K.A. Narashimbam. 1994. Prospects of oyster culture in Kerala backwaters. Fishing Chimes, January 1994, 13 (10): 47-48.

James, P.S.B.R. and D.B. James. 1993. Ecology, breeding, seed production and prospects for farming of seacucumbers from the seas around India. Fishing Chimes, June 1993, p . 24-34.

James, P.S.B.R. and K.A. Narashimham. 1994. Saltwater pearl fisheries and pearl culture in India - An update. Aquaculture Magazine, p. 41-49, July/August 1994.

Kaliaperumal N. 1993. Seaweed culture. Handbook on aquafarming MPEDA, p.1-22

Mahadevan, S. 1985. Finfish culture.Mar. Fish. Infor. Ser. T&E Ser., No. 62: 1-6.

Merichamy, R. and S. Rajapackiam. 1984. Culture of larvae of Scylla serrate. ibid., No.58: 13-15.

Merichamy, R. and J. Motha. 1986. Prospects of prawn culture in saltpan areas. Ibid., No. 70: 1-7.

Mohamed, K.H., M.S. Muthu, N.N. Pillai, S.K. Pandian and S. Ahmed Ali. 1983. Simplified hatchery technique for

mass production of penaeid prawn seed using formula feed. Indian J. Fish., 30 (2): 320-332.

Muthu, M.S. and A. Lakshminarayana, 1980. Induced maturation and spawning of Indian penacid prawns, Ibid., 24(1&2):170-181.

Muthu, M.S., and A. Lakshminarayana. 1984. Artificial insemination of Penaeus indicus. Curr. Sci., 50(20): 1075-1077.

Muthu, M.S., A. Lakshminarayana and K.H. Mohamed. 1984. pH as a factor influencing maturation of Penaeus indicus in captivity. Indian J. Fish.,31 (2): 217-222.

Narsimham, K.A. 1976 Blood clam culture. R&D series for marine fishery resources management. Central Marine Fisheries Research Institute, Cochin.

Nair, K.N., S. Mahadevan, R. Alagarswami and P.T. Meenakshisundaram (eds). 1980. Coastal aquaculture; Mussel farming progress and prospects. CMFRI Bulletin, No. 29, pp.56.

Nair, K.N., M.E. Rajapandian, A.D. Gandhi and C.P. Gopinathan. 1984. Larval rearing and production of spat of the oyster, Crassostrea madrasensis (Preston) in an experimental hatchery. Indian J. Fish., 31 (2): 233 - 243.

Nair, K.N. and S. Mahadevan (eds). 1987. Oyster culture-status and prospects. CMFRI Bulletin, No. 38, pp.78.

Radhakrishnan, E.V. and M. Vijayakumaran. 1984 a. Effect of eye stalk ablation in spiny lobster, Panulirus homarus (Linnaeus). 1. On moulting and growth. Indian J. Fish.,31 (1): 130-147.

Radhakrishnan, E.V. and M. Vijayakumaran. 1984 b. Effect of eye stalk ablation in spiny lobster, Panulirus homarus (Linnaeus) 3. gonadal maturity. Ibid., 31 (2): 209-216.

Silas, E.G. 1982. Major breakthrough in spiny lobster culture. Mar. Fish. Infor. Ser. T&E. Ser. No.43: 1-5.

Suseelan, C., N. Neelakantan Pillai, E.V. Radhakrishnan, K.N. Rajan, K.R. Manmadan Nair, P.E. Samson Manickam and K.N. Saleela. 1993. Lobsters. Handbook on aquafarming MPEDA. p. 47-54.

Vijayakumaran, M. and E.V. Radhakrishnan.1984. Effect of eyestalk ablation on growth and reproduction in spiny lobster, Pan ulirus homarus (Linnaeus). 2. On food intake and conversion. Indian J.Fish., 31 (1): 148-155.

About the Author

The author is the former Director of the Central Marine Fisheries Research Institute, Cochin, India, and National coordinator for the FAO/UNDP Regional Seafarming Development and Demonstration Project. He is at present working as an aquaculture and fisheries consultant stationed at Cochin.