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REVIEW OF PROSPECTS FOR LOBSTER FARMING

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Capture fisheries have reached a peak in production, and stock enhancement or aquaculture appears to be the only hope of meeting the ever increasing demand for high value seafood like lobsters. For aquaculture, the pressing need is to solve the dilemma of promoting expansion while at the same time demanding the development of environmentally sound technologies and farming practices (Mace, 1997). Lobsters have excellent market demand and price and especially live lobsters are the most preferred. Customers in affluent countries are ready to pay more for fresh seafood. Lobsters are exported in different forms; live, frozen tails, whole frozen, whole-chilled, whole-cooked and frozen and as lobster meat. The live lobster trade increased from 1.3 % during 1993-94 to 12.7% during 2003-04 period. The foreign exchange revenue from export of lobsters alone amounts to Rs.53 crores during 2003-04. Due to the increasing demand, lobsters of all sizes are caught and marketed

and the resource is under extreme fishing pressure. Though Government of India has brought regulation on size of export of four species of lobsters, undersize lobsters are caught in the absence of any regulation for fishing and are still exported illegally. They fetch very low price and therefore result in loss of revenue to the fishermen. These lobsters if fattened can fetch higher price and can be legally exported. Until hatchery technology is commercialized, value addition to the lobsters, is possible through short term fattening. Holding low value lobsters with a view to value adding and harvesting wild puerulii for commercial grow-out appear to be technically as well as economically feasible (Mohan, 2001).

Interest in aquaculture of lobsters has grown worldwide in recent years as the lobster fisheries in many countries are overexploited (Kittaka, 1997, Phillips and Evans, 1997). In addition, high value of live lobster (US \$40) has created intense interest in lobster farming. Among the spiny lobsters, tropical species have more favourable characteristics and are amenable to farming conditions. Tolerance to high stocking in controlled conditions communal living without cannibalism, acceptance of pelleted feed and strong market demand are some of the characteristics, which makes lobster as a widely accepted aquaculture species. However, for sustainable aquaculture practice, hatchery production of seeds is vital, which is yet to be achieved, though larval phase of a few species have been completed. The biological and technical feasibility of lobster farming is discussed in this paper.

Fattening of low value and undersize lobsters for product enhancement

Ongrowing wild caught seed lobsters are widely practiced in Vietnam, the Philippines and Indonesia. Farming is typically on a subsistence scale (limited by the availability of seed) although the magnitude of production in Vietnam is collectively very large (1000 tonnes annually). In Australia and New Zealand, lobster seed cannot be taken for aquaculture except under strict and limited pilot license conditions. However, there is some in sea and on



land holding of legal size lobsters for weight gain and/or more favourable (niche) marketing. In India there being no restriction on fishing, large quantities of juveniles and undersize lobsters are caught and marketed. Though there is good potential for fattening to legal size, there is very little attempt. While some entrepreneurs have shown interest, availability of healthy, quality seed is a major constraint.

On growing involves holding undersized lobsters, which fetch low price or not accepted legally for export, for short period until they attain legal size. These lobsters could be held in tanks, ponds or cages fed with natural or artificial feed. Growth could be further enhanced remarkably through eyestalk ablation and by proper feed and water management. Since live lobsters fetch high market value, these can be marketed to targeted markets in Southeast Asian countries.

Seed availability

Among the shallow water species occurring along the Indian coast, *Panulirus homarus*, *P. ornatus*, *P. polyphagus* and *Thenus orientalis* are the most promising species. These species can be easily distinguished by the colour and morphological features. The hatchery production of *T. orientalis* has already been accomplished. The larval culture of the spiny lobster species occurring in India is yet to be successful though some headway has been made. Therefore farming or fattening of lobsters will have to depend upon either the post larvae (puerulii) or the undersized lobsters caught in artisanal gears. In India, lobsters appear as by catch in trawls operated in Maharashtra, Gujarat and Tamilnadu. The quantum of juveniles caught in trawls is low. Artisanal gears such as trammel nets, gill nets and traps are also used for fishing in inshore areas. Lobsters in gill nets and especially more than 50% of catch in trammel nets are undersized and cannot be legally exported. These are either illegally exported or consumed internally. The secondary holding centres keep the lobsters under highly stressed condition due to paucity of space

and seawater facility and therefore the lobsters become weak and highly stressed. They may contact disease even if brought and stocked for on-growing.

Breeding and hatchery production

Captive breeding of *P. homarus*, *P. polyphagus*, *P. ornatus*, *P. longipes* and *P. versicolor* has been achieved by different laboratories in India. Adult lobsters maintained in broodstock holding system mate and breed when optimum environmental conditions and feed are provided. Repetitive breeding is reported in *P. Homarus*. Juveniles of *P. homarus* and *P. ornatus* were reared to maturity in captivity and successful breeding achieved. Egg bearing lobsters procured directly from fishermen are also suitable for egg hatching and rearing. However berried lobsters procured from secondary holding centres are often infected and not suitable for hatchery operations. Phyllosoma larvae of *P. homarus* have been reared to stage 6 in 60 days. Recently larvae were reared to stage 8 in 42 days on a mixed diet of *Artemia* and plankton. Similarly larvae of *P. ornatus*, *P. polyphagus* and *P. versicolor* have also been reared through early stages. Significant advances have been made in Japan, Australia and New Zealand in culture of phyllosoma larvae of a number of temperate and semi-tropical species of lobsters to settlement. Japanese were the first to succeed in completing the larval phase of five temperate species and one semi-tropical species. Larvae took 132 to 319 days to complete the larval phase in different species. The number of instars was 17 for *Jasus* spp., 9 for *Palinurus elephas* has 25 (estimated) for *Panulirus japonicus*. Survival ranged from 0.01 to 10%. Phyllosoma larvae of *P. Cygnus* and *J. verreauxi* were also reared to settlement by the Australians and the New Zealanders. The method developed in northern Japan to culture phyllosoma larvae of five species of cool-temperate spiny lobsters combines the features of upwelling water, co-cultured microalgae and use of mussel gonad as food. The feeding behaviour of phyllosoma larvae shows that they are primarily predators. Recent work has shown that the contamination of culture water



by microorganisms such as the fouling protozoans *Vorticella* sp. can greatly reduce phyllosoma survival. Feeding with fish larvae reduced the larval period by half (65 days) in *P. elephas*. However, commercial feasibility of seed production technology is still doubtful for most of the species because of the prolonged larval phase (> 300 days) and poor survival. Until hatchery technology is perfected, lobster farming will have to depend upon naturally available seeds.

Collection and ongrowing of puerulii

Spiny lobsters after completing its long larval life metamorphoses into postlarvae (puerulus), which swims towards the shore and settle in nearshore seagrass/seaweed habitats. They transform into postpuerulus and settle into benthic dwelling juvenile lobster. In the wild, levels of puerulii settlement vary depending on the species and geographic area, which also depends on the spawning stock. Commercial harvest of puerulii and early juveniles from the wild as suggested by the Australians may be possible where there is heavy settlement in the inshore habitat. However, the feasibility of such a proposal is to be examined in other areas, as there is apprehension that this will have serious long-term implications on sustainability of wild resources. Partial harvesting of puerulii from dense settlement areas is suggested as high mortality rates were experienced by juvenile lobsters between settlement and entry into the commercial fishery. This will benefit the wild resource as well as those interested in farming of lobsters. Commercial collection of southern rock lobster puerulii for aquaculture has already commenced in Tasmania. In India, studies conducted off Kovalam near Chennai show that puerulii of three species, *P. homarus*, *P. polyphagus* and *P. ornatus* settle in rocky areas. However, the intensity of settlement is not very high enough to suggest harvesting for ongrowing. There is no information on settlement density of puerulii anywhere along the Indian coast.

Indian lobster fishery is poorly managed as this is a low volume resource and therefore fishing regulations are not strictly enforced. Destructive gears like trammel nets operated in inshore areas bring in large quantity of juveniles and sub adult lobsters which fetch only low price. The undersized lobsters procured from the fishermen were exported until the Ministry of Commerce and Industry, Government of India notified Minimum Legal Size (MLS) for export in 1997. Illegal export of lobsters below the MLS is still in vogue. Since there are no regulation for fishing lobsters in any maritime state, fishermen continue to bring the lobsters entangled in the nets and sell it to exporters. Nearly 50% of the lobsters caught in trammel nets are undersized. In Gujarat, gill nets operated in the reef areas also bring undersized *P. polyphagus*, which are sold, for a very low price. Along the southwest and east coast of Tamilnadu, an estimated 25 tonnes of undersized lobsters are landed annually. By catching these undersized lobsters, the total loss of revenue to the fishermen is to the tune of several crores. The MLS for *P. homarus* is 200 g and for *P. polyphagus* 300 g and those below the MLS, which are prohibited from export, can be fattened to the legal size and fetch higher price.

Collection, maintenance and transportation of juveniles

Fishermen either keep the lobsters in wet sand until the traders come and pick it or sell it to local merchants. These traders either keep them in holding tanks with recirculation facility (most of them with inadequate water reuse facility) or keep them in cages kept in rock pools until collected by the exporters. Since only larger lobsters with high price are given more care, the undersized low price lobsters are kept under high stress in very poor quality water. Therefore they are weak and are easily susceptible to diseases. They are unsuitable for fattening purposes. When there are transported to long distances they become further weak and on stocking dies gradually. The green colour of the lobster is lost and their shell becomes reddish in colour, which is indicative of



stress. If the undersized lobsters should be useful for fattening, fishermen and traders should follow certain protocols so that they could supply healthy seed to the entrepreneurs. Juveniles are especially susceptible to stress and therefore they should be kept in water soon after they are brought to the shore. It is better to keep them buried in cool moist sand in shade rather than keeping at high densities in poor quality water. Maximum care should be taken so that their appendages are not lost while removing from the net or they are not injured below the abdomen. During holding in unhealthy condition they are infected by deadly pathogens through these injuries and there are instances of high mortality due to infection by pathogenic bacteria.

Fattening in land-based holding systems

Lobsters can be successfully held and fattened in land-based holding systems provided suitable environment is provided. Critical environmental parameters include the concentration of dissolved oxygen, ammonia, nitrite and carbondioxide. Nitrate concentration, pH, salinity and alkalinity levels within the system are also important. In flow through systems, the main limiting factor is dissolved oxygen. The requirement of oxygen will be high during molting and soon after feeding. Both the process normally takes place during night and optimum levels of oxygen shall be maintained during night to avoid oxygen depletion and mortality. Oxygen related stress would adversely affect growth significantly. Unlike shrimps, lobsters are oxygen conformers and may not show any sign of low oxygen conditions, as they are capable of adjusting the metabolism even at very low levels of oxygen. Sufficient water needs to be pumped through or the water needs to be aerated to ensure lobsters are supplied with sufficient oxygen. Sudden salinity fluctuation during rains is a serious situation and in such circumstances salinity, alkalinity and pH should be adjusted in a reservoir, before the water is pumped in. though lobsters can tolerate gradual changes in salinity to a limited range, sudden dilution can lead to stress,

susceptibility to disease and mortality. Tolerance limits for various water quality parameters is given in Table. 1.

Indoor tanks

Two main systems are currently being used for fattening lobsters: flow-through and recirculating. In flow through systems, the water that is pumped into a tank is used only once. Water flow is to be decided based on the stocking density and feeding intensity. The incoming water is to be free of sediments and should have water quality parameters required for lobster farming. The water should be regularly monitored to avoid wide fluctuations in environmental parameters. In recirculating systems, the majority of the water is re-used after each pass through the tanks, first being treated to remove waste products before being returned to the tanks. Even though initial set up costs may be higher, there is an increasing interest in the use of recirculating systems. In recirculating systems also the main limiting factor is dissolved oxygen: however, the unionized ammonia concentration becomes increasingly important, and is probably the next important limiting factor. Ammonia should be removed from the system at a rate equal to the rate of production to maintain safe concentration. All recirculating systems remove waste solids, oxidize ammonia and nitrite, remove carbon dioxide, and aerate the water before returning it to the fattening system. Solid wastes can be removed by mechanical filtration, ammonia and nitrite by biological filtration and carbon dioxide by the provision of an air/water interface. The safe level of ammonia for holding lobsters is $<2 \text{ mgL}^{-1}$. The flow rate calculations must be adjusted according to the species held, size of the animals, the rate of feeding and the holding temperature. The required estimated flow rate in a tank holding 10000 kg of 500 g fed *J. edwardsii* lobsters at 13% C is 4500 L h^{-1} . The water management schedule and monitoring frequency of environmental parameters is shown in Table 3.



Tank design

Raceways, rectangular, square or circular tanks can be used. The most preferred are individual raceway tanks. Circular or square tanks made of brick and cement or concrete are also good. Square tanks will save space when compared to circular and are also less expensive as they could be connected serially. These tanks will be difficult to clean and feed the lobsters. Raceways are easier to maintain and with proper slope, the wastes can be easily removed through the outlet pipe fixed at the end of the tank. For complete removal of water, the standpipe can be lifted. Square and circular tanks will have a central drainage system or a self-cleaning two way waste removal system by which both suspended and settled wastes can be automatically flushed out of the tank. The wastes can be concentrated towards the centre of the tank by creating a vortex by the incoming water. This tank design is used in flow through systems. For recirculating system the wastewater flowing out of the tank is recirculated after removing the waste products and will be a continuous process. Since lobsters grow fast in subdued light, tank covers have to be provided to avoid bright sunlight.

Stocking density

Undersized lobsters procured from secondary holding centres transported to the fattening facility may be kept under quarantine for 48 hours to relieve the lobsters from stress. The quarantine facility should be away from grow out tanks. Healthy lobsters may be stocked at 1.0-1.25 kg/m² after segregating into different size groups. The difference in weight between the lower and upper size should not be more than 20 g. Hideouts provided in the tank will help them to congregate around the shelter during day and prevent them from continuously moving in the tank spending lots of energy. Lobsters feed on variety of natural and artificial feed making them suitable for farming. The natural feed includes mussels, clam, squid, trash fish, and smaller crabs and shrimp meat. Artificial includes shrimp pellets that are

suitable for juveniles and subadults. Lobsters feed actively after dusk; feeding during night will reduce feed spoilage and waste.

In Florida, *Panulirus argus* weighing 300-400 g held in captivity molted every 50-60 days and attained an average increase in bodyweight of 40% and is reported to obtain 60% return on investment. Table 2 shows percent postmolt weight increase and intermolt period (days) of spiny lobsters held in recirculating seawater systems at a constant temperature of 29 °C with 12:12 light:dark cycle (Lellis and Russel, 1990). Juveniles of *P. ornatus* stocked at 43/m² showed good artificial feed acceptance (>75%), biomass production (4.7 kg/m²) and good growth rate (SGR 1.56%). It is estimated that a weight increase of 1 kg is possible in less than 18 months. Juveniles of *P. homarus* in South Africa have attained 60 mm CL in 18 months. In India puerulii of *P. homarus* have been reared to 250 g in 18 months at Kovalam Field Laboratory of CMFRI. *P. homarus* weighing 80 g stocked in self cleaning indoor system at Calicut attained 330 g in 12 months with an FCR ranging from 3.5 to 4.0 on feeding with an exclusive diet of green mussel. The minimum exportable weight of 200 g was obtained in 130 days (Radhakrishnan, 2004). Another study in indoor grow out system at Tuticorin showed 172.7 g weight increase in juvenile *P. homarus* in 150 days. In Taiwan, wild caught animals stocked at 2g mean weight reach 330 g in 16 months in small 200 m² ponds. A fourty growth study on *P. polyphagus* conducted at Northern Territory University showed lobster juveniles grew substantially to 148.5 g in nine months.

Growth enhancement of juvenile lobsters by eyestalk ablation has been demonstrated in *P. Homarus*, *P. ornatus* and *P. versicolor*. The ablated *P. homarus* gained a weight gain of three to seven times more than the normal. In *P. ornatus*, 100 g lobsters attained 1.5 kg in 8 months. However, food consumption and mortality is higher in ablated lobsters when compared to normal.

Lobster culture in intertidal pits

Fattening of *P. polyphagus* was carried out in intertidal pits along the Bhavnagar coast of Gujarat during early 1990s



(Sarvaiya, 1991). The pits are dug in the limestone intertidal areas and are of varying dimensions. No standardized stocking or feeding regimes were followed. 3000 numbers of lobsters weighing 30-50 g were stocked at a stocking density of 20 lobsters/sq.m in a pit of 21 m x 7 m x 1 m. the pits were covered with nylon nets to prevent lobsters from escaping during high tide. Lobsters were fed with trash fish, small crabs, marine worms and clams @ 10% bodyweight and also on compounded feeds. Juvenile lobsters, which were procured at Rs. 20/kg attained 100-125 g in 90 days, which were sold at Rs.250/kg during 1991. The harvest of live lobsters packed in bamboo baskets are sold to exporters. The highly profitable practice was discontinued due to intensive poaching and non-availability of enough quantity of seed lobsters.

Lobster culture in cages

In Philippines lobster culture was practiced in floating cages made of nylon material. *P. ornatus* weighing 100-300 g stocked at 8/m² attained 800-1.3 kg in 6-15 months. Survival for larger sizes has been more than 90% whereas in smaller juveniles of 30-80 g, survival was less than 50%. Trash fish is the main feed, which is procured at US\$ 0.13-0.22 per kg. Selling price of live lobster was US \$ 21-31/kg; hence a wet FCR of more than 10 can still be profitable.

In Vietnam, mariculture of lobsters in floating, fixed and submerged cages were practiced in protected bays or lagoons that have a good tidal flow. *P. ornatus* is the main species and *P. homarus*, *P. Versicolor*, *P. longipes* and *P. simpsoni* were also cultured. Floating cage is made of nylon net material with a frame and buoy and located at a depth of 10-20 m. Wooden fixed cage is normally 20-40 sq.m and even large cages of 200-400 sq.m are also used. The off-bottom cage is typically about 0.5 m above the seabed. This kind of cage is suitable for sheltered bays. Submerged cage is made of iron framework with a diameter of 15-16 m. The height is 1.0-1.5 m. the cage has a cover and a

feeding pipe and is used for nursery rearing. Seed lobsters of about 25-30 mm TL are stocked (100- to 200 per cage) and grown to a size of about 50 g (10-12 cm TL). Lobsters are fed exclusively with either whole finfish or chopped fish or shellfish. Finfish comprised about 70% of the diet and the preferred fish is lizardfish. Feeding trash fish results in water quality problems. The total nitrogen content in the seawater exceeded the standard level for aquaculture of 0.4 mg/L. Increase in cage farming and using fresh trash fish and shellfish has led to disease problems in some areas. Some common diseases are black gill disease, shell necrosis and red body. Treatment protocols followed are treatment with 100 ppm formalin for 3-5 minutes. Red tail disease has been reported in spiny lobsters, which is similar to the *gaffkemia* in *Homarus americanus*. The symptoms are lethargy, reddish colour of underside of the abdomen, spread eagle posture during late stages, poor food consumption and mortality. The bacteria enter into the body through the injury in the abdomen and multiply in the haemolymph. Isolation of the affected individuals and oral administration of oxytetracycline through feed are protocols for treatment. Antibiotic administration is possible only during the early stages of infection. The disease is highly contagious and spreads through water.

The estimated total annual production of farmed rock lobster was about 1500 metric tones a year with a farm gate value of US\$26./75/kg. The average profit margin was 50%. Therefore lobster culture is a profitable industry provided adequate seeds could be collected without disturbing the wild fishery. Suitable artificial diets are to be formulated and feeding regimes established in order to succeed lobster farming in a commercial scale. Disease protection measures should be prioritized. Cage designs should be studied for improved lobster husbandry.

Preliminary experiments in cage culture of lobsters were attempted in India by NIOT, Chennai. Floating and fixed net



cages were positioned in protected areas. Fishermen fattened juvenile lobsters caught from the wild stocked in cages. However, the feasibility of large-scale farming is doubtful, as sufficient seeds may not be available for stocking when more number of people are involved. This may also result in high fishing pressure on wild fisheries and negative impact on natural lobster fisheries.

Future prospects

All marine lobsters are highly considered as fine table food and thus are in high demand. Most wild fisheries are overexploited, with many stocks having already collapsed or catch rates closely regulated to sustain the wild fishery. For these reasons, lobsters fetch high prices. The highest price is paid for live product, chilled or frozen products bring much lower prices. Aquaculture offers the only prospects by which lobster supplies can realistically and sustainably be increased. Considerable export potential exists for live product to Southeast Asian markets. Packing and transport conditions for live shipment of lobsters are well developed and would not be a problem. Development of a successful export market would require both continuity of supply and a reasonable volume of production. However, the greatest concern is whether aquaculture production would be sustainable if recruiting seed was taken in large quantities for aquaculture. Attempts in 1970s and in late 1990s to establish large-scale intensive aquaculture of spiny lobsters in the Philippines collapsed within a few years of establishment when seed supplies became insufficient to support the venture. In India the resource is limited to certain pockets along the coast and lobster landing is drastically declining in all the centres due to indiscriminate fishing. Therefore, before contemplating aquaculture, research is warranted to better determine the stock structures of spiny lobsters and to estimate recruitment patterns and survival rates. Such research would enable responsible fishery management policies to be put in place to ensure sustainability of the wild fishery stocks. Low intensity aquaculture of spiny

lobsters for value enhancement and export strictly adhering to the legal procedures could be a profitable industry in some specific locations along the coast.

Table 1: Tolerance limits for various water quality parameters for the culturable species of lobsters

Parameter	Tolerance limits
Temperature	12 to 31°C (25-30°C)
DO (% saturation)	Minimum 70% Preferably above 80%
Salinity (ppt)	30-38
Ammonia (mg L-1)	< 2
Nitrite (mg L-1)	< 5
Nitrate (mg L-1)	100
PH	7.8 to 8.4
Hardness (ppm)	100-200

Table 2: Postmolt weight increase (%) and intermolt period (days) of spiny lobster (*Panulirus argus*) held in recirculating system at a constant temperature of 29 °C with 12:12 light:dark cycle (Lellis, 1990)

Initial weight (g)	Weight increase (%)	Intermolt time (days)
100-200	52.3	40
201-300	45.9	47
301-400	39.9	53
401-500	35.7	65
501-600	30.1	74
601-700	27.8	83
701-800	23.8	84
801-900	25.0	79
901-1000	21.8	91
>1000	24.4	112

Table 3: Monitoring schedules for different environmental parameters

Parameters	Schedule	Equipment
Temperature	Daily at 1000 hrs and 1600 hrs	Thermometer glass/digital
Salinity	Weekly and before adding new water	Salinity refractometer
pH	Weekly or during water change	pH meter
Oxygen	Weekly: (every 2-3 hrs 0 when new water is added)	Oxygen probe
Ammonia, nitrite, nitrate, alkalinity and hardness	Weekly	Measuring kits



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