Sustaining Crop and Animal Productivity —
The Challenge of the Decade
Editor : D.L. Deb
Associated Publishing Co., New Delhi, 1995, pp. 345-363.

TECHNOLOGY FOR IMPROVING MARINE FISHERY PRODUCTION

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India is the largest country in the Indian ocean region and is blessed with a long coast line and vast living resources in the seas. The need for increasing the protein-rich seafood production to cater to the needs of the rapidly increasing population has been and continues to be a serious concern for the government. Besides, the fact that the per capita fish consumption in India is around 3.5 kg is also a cause for serious concern in the context of reducing protein malnutrition and improving the health of the people of the country. The availability of resources in the vast seas around the country and the increasing demands for increasing production for domestic consumption as well as for export have lead the organisations concerned with research and development of marine fisheries, develop appropriate technologies. Several technologies were developed by the Research Institutes, for increasing production through capture as well as culture and several innovations were made in the fisheries development by the concerned agencies. The present paper deals with the technologies of marine capture and culture fisheries as applicable to Indian situation.

CAPTURE FISHERIES

Of the total fish production of 3.84 million tonnes in 1990-91 in India, 60% is contributed by the marine capture fisheries. The fishing is carried out up to about 50m depth but the availability of an area of 20,17,900 sq. km. in the Exclusive Economic Zone of the seas around the country offers scope for increasing production of the hitherto unexploited or underexploited stocks.

Marine Fishing in India: The fishing in the Indian seas restricted as it was, to the use of artisanal gear and craft in the nearshore waters during forties, has improved vastly later by introducing and popularising mechanised vessels with trawl nets. By seventies, purse seines were introduced along west coast (first in Goa and later in Karnataka and Kerala). This development has resulted in increase in the area of fishing and increase in the production of demersal resources along entire Indian coast and pelagic resources along west coast. With the increasing demand for fish and with improved technologies, the indigenous crafts are motorised to reach the fishing grounds quickly and to operate drift/gill nets and hooks and lines for catching pelagic fish and sharks.

Andhra Pradesh has the maximum number of nonmotorised artisanal craft which forms 34% of total non motorised craft in the country followed by Tamil Nadu (21.8%), Kerala (12.0%), Maharashtra (8.2%), Karnataka (7.2%), Orissa (6.3%), Gujarat (4.0%), West Bengal (2.5%), Pondicherry (2.0%), Goa (1.2%), Andaman and Nicobar Island (0.6%) and Lakshadweep Islands (0.3%).

Among the states using motorised traditional craft Kerala ranks first with an estimated 7000 units forming 45.3% of these units in the country followed by Maharashtra (30.7%), Tamil Nadu (9.1%), Gujarat (7.5%), Goa (3.0%) and others. Thus motorised traditional craft operation along east coast is very poor.

In the operation of mechanised boats in the country, Maharashtra stands first with about 5500 units forming 24.3% of total mechanised craft in the country followed by Kerala (14.6%), Karnataka (13.8%), Gujarat (12.1%), Tamil Nadu (11.0%), West Bengal (6.9%), Goa (6.8%), Andhra Pradesh (4.4%), Orissa (2.9%), Pondicherry (1.5%), Lakshadweep (1.3%) and Andaman group of islands (0.4%).

Coast wise, the non-motorised indigenous craft, motorised indegenous craft and mechanised boats form respectively 32.8%, 88.0% and 72.9% in the country's total along west coast and 67.2%, 12% and 27.1% along east coast. Thus, motorised crafts and mechanised fishing effort is very poor along east coast. Not only this; the operation of purse seines, mechanised gillnets, and ring seines (a smaller version of purse seine) with motorised craft is not popular along east coast.

All these gears are operating in the inner continental shelf up to about 50 m depth and during 1992 an estimated 2.28 million tonnes of marine fish are landed from the seas around India. Maximum catches are obtained from off Kerala which contributes 24.0% of total catch followed by Maharashtra, Tamil Nadu, Gujarat, Karnataka, Andhra Pradesh, Goa, Orissa, West Bengal, Pondicherry, Andaman group of islands and Lakshadweep islands.

Prawns (both penaeid and non penaeid together) form the most dominant component in the marine landings in India, followed by oil sardine, other clupeoids, mackerels, carangids, sciaenids, Bomaby duck, perches (predominantly threadfin breams), ribbonfish, anchovies, catfish etc.

Potential yield in the 0-50 m depth zone: The potential yield in the presently fished grounds (0-50 m depth) is estimated as 2.21 million tonnes (Anon, 1991). Of this, the maximum quantity is available off Kerala coast with an estimated 5,71,317 tonnes forming 25.8% of the total country's potential. Next in importance is Tamil Nadu (3,59,677 t; 16.3%) followed by Maharashtra (3,56,043 t; 16.1%), Gujarat (2,93,929 t; 13.3%), Karnataka (2,70,146 t; 12.2%), Andhra Pradesh (1,41,563 t; 6.4%) and others.

In West Bengal, Orissa and Andhra Pradesh, the present yield is 93% of the estimated potential and off Maharashtra and Gujarat the same is around 90%. Therefore, there does not seem to be much scope to increase production from the present level from the present fishing grounds in these states. In the remaining states/Union territories the present yield is 70-75% of the potential and there appears to be some scope to increase production from the presently fished areas in these states. Though the present yield in the country is around 80% of the potential yield in the 0-50 depth range and there is not much scope to increase production from this zone, it appears that certain groups like lesser sardines, lizardfish, carangids, silverbellies, oil sardine and mackerel offer scope to increase production by about 10-15% by suitably increasing/diversifying the effort.

In this connection, it may be mentioned that detailed studies on the population dynamics of dominant species (Alagaraja *et al* 1986, Devaraj and Gulati 1988, Karthikeyan *et al* 1989, Kasim 1987, Kasim and Hamsa 1989, Kasim *et al* 1989, Lalitha Devi 1986, 1987, Murty 1983, 1985, 1986 a, 1986 b, 1987, 1988, 1989, 1990, 1991 Narasimham 1983, 1987, 1988; Sudarasan *et al* 1990, Venkatraman *et al* 1982, Yohanan 1983) have shown that the present yields are only slightly less than or have crossed the MSY levels in the present fishing grounds and that in cases where the current yields have not reached MSY levels, their catch rates will drastically fall if effort is increased. Moreover, in the case of most of the trawl-caught species it has been observed that the cod end mesh sizes of trawl nets are small (15-20 mm) and smaller than those which give MSY and the yield of these species can be increased if the cod end mesh sizes are increased by about 40%. It is thus only a matter of sound management of the resources and there is no scope for any substantial increase in production from the presently fished areas by increasing effort.

Potential yield beyond 50 m depth in the EEZ: It is clear from the above that the logical step to increase the much needed marine fish production is to introduce and intensify the effort in the presently under/unexploited grounds. Based on researches on primary and secondary production and surveys by experimental and exploratory fishing, it has been estimated that the potential yield of the resources as detailed below in the EEZ beyond 50 m depth is around 1.7 million tonnes and this region is virtually unexploited.

A. Pelagic fish resources: The potential yield of pelagic fish resources in depths beyond 50 m is estimated as 7,42,000 tonnes of which 4,01,000 tonnes is available in the 50-100 m depth zone and the rest from 100-200 m depth zone. The south west coast is the richest region having about 33% of the total estimated potential; of this, two thirds is available in the 50-100m and the rest in the 100-200 m depth zones. The north west coast is the second richest region supporting over 25% of the total potential and over 85% of this is available in 50-100 m zone. The south east coast supports a potential yield of 61000 tonnes of which 52% is available in the 50-100 m and the rest in 100-200 m depth. The sea beyond 50 m depth along north east coast is less productive for pelagic fish supporting only a potential of 46000 t with more or less equal quantities in the 50-100 and 100-200 m depth zones. The seas around Andaman and Lakshadweep islands support a potential resource of 139000 t, and 63000 t, respectively.

The major components of the above potential are carangids (304000 t), coastal tunas (242000 t) ribbonfish (216000 t), elasmobranchs (mainly pelagic sharks) (103000 t) and mackerel (62000 t) all of which have considerable value for export as well as local consumption.

Rich grounds of carangids (horsemackerels, scads, trevallys) are located in the depth range 50-125 m along south west coast, off Gujarat and north east coasts. In the ribbonfish, nearly 75% of the potential in the 50-200 m depth is concentrated along south west and north west coasts. Greater portion of the potential of mackerel is available along north east coast. Compared to the very poor landings of around 30,000 t of coastal tunas, a rich potential of these fishes, of around 100,000 tonnes, and 50,000 tonnes is available around Andaman and Lakshadweep islands respectively in addition to about 50,000 tonnes off the coast of mainland immediately beyond 50 m.

In the oceanic waters in the depths beyond 200 m to the EEZ limit, oceanic tunas and bill fish support a potential of 2,13,200 tonnes of which over 85% can contribute to surface fishery and the rest subsurface fishery. Pelagic sharks and other fishes account for an estimated potential of 32,800 tonnes.

B. Demersal fish resources: The potential yield of demersal resources in the 50-200 depth zone is estimated at 6,25,100 tonnes of which 4,23,800 tonnes can be taken from 50-100 m depth region and the rest (201300 t) from 100-200 m depth zone. The north west coast is the richest in regard to the quantity of demersal fish available (3,78,600 t) in the 50-200 m depth zone (as against the south west coast for pelagic fishes), followed by north east coast (117400 t), south west coast (92300 t) and south east coast (36800 t). The depths beyond 50 m along south east coast are least productive for demersal fish (as against north east coast for pelagics).

In the depths beyond 200 m, the potential of demersal fishes is estimated at 28,300 t and south west coast is the most productive region (in this depth range) supporting over 70% of the potential demersal resources along Indian coast in the depths beyond 200m.

The major constituents of demersal resources in the 50-200 m depth are perches, catfish, bulls eye, croakers, lizard fish and others. Among perches which support a potential of 125000 tonnes, threadfin breams (*Nemipterus* spp.) account for nearly 90%. The bulk of the potential is available along north west coast followed by south west coast, Wadgebank and north east coast. South east coast is least productive in respect of this resource. In the case of cat fish which provides a potential of 63000 tonnes, north west coast is most productive supporting over 65% of total potential followed by south west coast and north east coast. Bull's eye (*Priacanthus* spp.) is another important demersal resource in the 50-200 m depth zone having a potential of 55000 tonnes; the major portion (46%) comes from north west coast followed by south west coast (33%), north east coast (13%) and the rest from wadgebank, Gulf of Mannar and south east coast. Croakers and lizard fish have potentials of 22000 t and 20900 t, respectively with the largest quantities being available along north west coast. Deep sea prawns and lobsters constitute a potential of 8600 tonnes in the depth range 50-300 m with maximum quantities of 7600 tonnes being available off south west coast of India.

Deep sea fishing: Fish being a protein-rich food item there is urgent need to make this item available to all fish-loving people in the country and to boost the exports of marine products. This can be achieved by extending fishing into deeper areas in the sea because an estimated 16,80,000 tonnes of fish is available in the seas beyond 50 m depth zone in the EEZ of India which is virtually unexploited and there is continuous poaching in our EEZ by foreign vessels.

The yield from the presently fished areas (0-50 m depth) has almost reached its potential and there is little scope for increasing production by increasing effort in this zone.

Strategies for development of deep sea fishing: Most of the major pelagic and demersal fin and shellfish resources constituting to the potential beyond 50 m, depth as identified above are conventional species and offer scope for exploitation without any hesitation. In fact majority of them such as carangids, coastal tunas, ribbonfish, threadfin breams and catfish are presently exploited in large quantities from the 0-50 m depth zone and are valued for export also. However, certain resources (as for example myctophids, stomiatids, chlorophthalmids, polymixids, neoscopelids, bortulids, stromateids etc. for which potential yield estimates are not available) which are known to be abundant in deeper waters constitute non- conventional resources and may not command lucrative price presently. However with appropriate value added product development it should be possible to realise economic returns from these resources also. Therefore the strategy for the non conventional species should be towards product development and better utilization.

A large quantity (2,40,000 t) of oceanic tunas is estimated to be available in deep sea beyond 200 m and proper deployment of effort can harvest these resources which already enjoy an established international market.

In view of the high costs involved in deep sea fishing, the economic viability of this venture is always under doubt and it becomes difficult to attract entrepreneurs into this. However, the fact that there is regular poaching in the country's EEZ by foreign vessels, is an indication that fishing in deep sea is not an unprofitable venture. It is, however, essential to demonstrate the economic viability of this by fishing with commercial gear (different trawls, purse seiners, gill nets, long lines, squidjiggs) in the depths of 50-200 m and then by processing and marketing the same.

In the context of increased costs in the enterprise, knowledge on the availability of fish concentrations at particular localities in the sea assumes significance in the sense that the vessels are assured of steady returns for their voyages. The vessels of Govt. of India conducting exploratory fishing can send radio messages to the shore as well as to the vessels in the sea on the areas of concentrations of fish so that the vessels can reach the spot on time and exploit the resources. Further, the information on potential fishing zones (PFZs) being issued by NRSA is also useful in this direction. Thus the efficient transmission of radio messages and capability of locating potential fishing zones become very important.

Seasonal variations in the abundance of fish is a well-known phenomenon. This affects the returns of the vessels if they are not fully equipped to catch resources by adopting different catching methods. Multipurpose vessels are therefore necessary so that they can operate trawl of different types, purse seines, gillnets, long lines (particularly tuna long lining), traps or lobster pots depending upon the availability of different types of fish and shellfish. These vessels need not idle at the harbour or they need not return without any catch. Adequate processing and preserving facilities have also to be provided in each vessel so that the different types of the catch can be suitably processed and preserved immediately after hauling.

The most important requirement for deep sea fishing is the availability of trained manpower. The human resources development therefore becomes an integral part of planning deep sea fishing. Trained skippers, fishing masters, technicians and other crew are necessary for running the vessel, operating different gears and for processing the fish. Adequate incentives have to be provided for the crew and other vessel staff so that the trained staff will remain in the profession which is often hazardous. Retention of trained staff on the vessel, is as important (perhaps more important than) as recruitment of trained persons.

Suitable infrastructure facilities such as fishing harbours, gear fabricating units, cold storages and processing plants have to be developed before the deep sea fishing is encouraged in a bigway. There is a general feeling that the facilities at the fishing harbours are currently inadequate. Further, adequate care has to be taken for maintaining hygenic conditions at the fishing harbours.

The most important aspect of development of deep sea fishing is the provision of adequate financing. Though loans and subsidies are liberally available through different financing agencies, suitable policies have to be developed to attract financing from NRIs and such other foreign agencies.

The present export market is largely shrimp-oriented whereas the bulk of the resources in the deep sea are finfish. There is therefore an urgent need for a detailed market survey to enable the export of finfish. Though small quantities of finfish are exported occasionally, there is tremendous scope to improve the export of this item so that the deep sea fishing will stand on a strong footing and help improve the much needed foreign exchange reserves.

RESOURCE MANAGEMENT

Fish being a renewable resource, scientific management assumes greater importance in the context of ensuring sustainable returns. Management should be understood as an essential tool for the sound, sustained development of the fisheries and not as a constraint upon exploitation. There is need to formulate management decisions on the basis of results of research on biological, environmental, and socioeconomic aspects of fisheries.

There is adequate information on the distribution of different species contributing to the fishery in the 0-50 m depth but similar information on deep sea resources is rather scanty. The exploratory and experimental fishing surveys have therefore to be intensified in this depth zone.

Though fisheries resources are renewable, they are subject to overexploitation and depletion and therefore effective management measures such as number and size of vessels to be introduced, the type and mesh size of the gear, closed seasons and areas etc have to be introduced right from the beginning of the fishery instead of waiting till the effects of overexploitation are realised.

The requirement of reliable data on various aspects of the fishery need not be stressed. This is an essential part of fishery management system. However, it does not seem to be appreciated by the industry. It is therefore necessary to make it mandatory on the part of all mechanised boats operating in the inshore waters as well as in the deep sea to make available the log sheets (duly filled in) to a central agency to enable storing the data, studying and interpreting the same. Suitably designed log sheets have to be given to all vessels. Similarly the data of exploratory and experimental fishing vessels have also to be sent to the central agency. To make the industry realise the importance of reliable data on exploited resources suitable programmes have to be developed to impress on them the possible effects of exploitation on fisheries resources and need for remedial measures.

Reliable and timely data on various aspects of the exploited resources are essential for monitoring of fishery management and development. Though considerable expertise is available in the country now, in the context of extending operations into the deep sea, the requirement of greater coverage for data becomes imminent. Therefore adequate care has to be taken to increase and improve the capability to collect data on a sound statistical base.

The capability of stock assessment of exploited marine fisheries has to be enhanced by giving suitable training programmes in the country and outside. Only this capability can determine allowable catches of a particular resource and hence help ensure sustained yield.

CURRENT STATUS OF COASTAL AQUACULTURE

Coastal aquaculture comprises both brackishwater culture and mariculture. It is either land-based or sea-based and the latter is popularly known as seafarming or mariculture. Alagarswami (1990) reviewed the status of coastal aquaculture in India.

Traditional system of land-based aquaculture in brackishwater ponds is in vogue in the country for the production of finfish such as milkfish (*Chanos chanos*), grey mullets (*Mugil* sp., *Liza* sp.), seabass (*Lates calcarifer*), pearl spot (*Etroplus suratensis*) and penaeid prawns (*Penaeus monodon, P. indicus, Metapenaeus monoceros, M. dobsoni* etc.) The traditional system had been developed by utilising the low-lying saline lands, which are not suitable to raise agricultural crops, for the cultivation of fish and shellfish. Also wherever feasible the practice of raising paddy and fishery crops by rotation came into existence. In this system, the near freshwater conditions prevailing during the monsoon months are used for paddy cultivation and the medium to high saline periods for fish and prawn cultivation. This culture practice is popularly called as "trapping-cum-holding' system wherein the tidal water carrying juveniles of prawns and fishes is periodically let into the ponds/impoundments during high tide and the trapped populations are allowed to grow for short durations, feeding upon the naturally available food. They are harvested around full moon and new moon periods when the tides are favourable. The traditional system of culture is practised in about 8000 ha in seasonal (*pokkali*) and perennial (*varshakattu*) fields in Kerala (George, 1974), in the *bheries* in West Bengal in 32,930 ha (Saha *et al.*, 1986), in the Khar lands in Karnataka in about 2,500 ha, in the Khazan lands of Goa in 6,500 ha and in about 900 ha in Orissa (Mohanty, 1988). The yield, comprising both finfish and prawns, is highly variable at 350 to 1089 kg/ha/year. In the last couple of years the existing traditional system of farming is being replaced with extensive and semi-intensive culture for prawns and increasingly additional land is brought under aquaculture.

Although several technologies have been developed, seafarming on commercial line is yet to take off in the country.

FINFISH CULTURE

James (1984) reviewed the status of marine finfish culture in India. Considerable experimental work has been done but viable technologies, particularly controlled seed production for several species are yet to be developed.

A. **Milkfish**: The milkfish does not mature and breed in confined waters. In India hatchery technology is yet to be developed though some success was recently achieved in the Philippines and Taiwan in artificial breeding and seed production. The seed (2.7 cm in length) are collected from the wild and stocked in earthen ponds. The desired water salinity is 10-35 ppt. Organic manures and inorganic fertilizers are used to enhance the production of algal food in the pond. The production ranges from 250 to 500 kg/ha/year in single batch stocking and 300 to 1900 kg/ha/year when multiple batches are stocked (Bensam 1993a). Milkfish are also cultured in pen enclosure in the Philippines.

B. **Grey mullets:** Among the cultured grey mullets, *Mugil cephalus* is most important followed by *Liza macrolepis* and *L. subviridis*. In Hawai, Israel and Taiwan success has been achieved in artificially inducing breeding of *M. cephalus* by injecting mullet pituitory extract, human chorionic gonadotropin and the synthetic harmone, Synahorin. In India induced breeding of *L. macrolepis* has been achieved (Alikunhi *et al.*, 1971, James *et al.*, 1983) although hatchery technology is yet to be developed. Culture in earthen ponds is similar to that of milkfish culture and the experiments in India have shown the production at about 2.2t/ha for *L. tade* and *L. parsia* (Bensam, 1993 a).

C. **Pearl spot:** In Kerala and Karnataka this fish is much in demand. It breeds in confined waters and is usually cultured in brackishwater ponds along with milkfish and grey mullets.

D. **Seabass:** This is a high value table fish and is traditionally cultured in brackishwater ponds in India, Indonesia, Philippines, Taiwan etc. Hatchery technology has been developed in the Philippines, Singapore, Taiwan and Thailand. Experimental studies on seabass culture in brackishwater ponds in India showed a production potential of 1.7 to 3.35 t/ha/year (Anon, 1985). Intensive commercial culture of seabass is carried out in Singapore in floating net cages and a production cage of 5 x 5 x 3 yields 600 kg/6-7 months. A raft unit of 32 such cages covering 0.5 ha yields 19.2 t per harvest and the annual production is 38.4 t (Anon, 1986). In India technologies for controlled seed production and net cage culture are yet to be developed.

E. **Groupers:** The groupers, *Epinephalus tauvina* and *E. malabaricus* are cultured in earthen and concrete ponds in Taiwan and in floating or fixed net cages in Hongkong, Malaysia, Singapore, Taiwan and Thailand. The methods followed in cage culture are similar to those practised in seabass culture. Some experimental work has been done on cage culture of the groupers in India (James *et al.*, 1984, Bensam, 1993 b).

CRUSTACEAN CULTURE

A. **Prawn culture:** In recent times prawn culture assumed great significance and rapid changes have taken place from the age old "traping-cum-holding" practice to highly advanced scientific farming. Big business houses and first generation entrepreneurs have ventured into prawn culture. The tiger prawn, *Penaeus monodon* and the white prawn, *P. indicus* are currently cultured in India. *P. semisulcatus, P. merguiensis, P. japonicus, P. canaliculatus* and *P. latisulcatus* have the potential for farming. The hatchery technology for the seed production of *P. indicus* and *P. semisulcatus* has been developed in India (Silas *et al.*, 1985, Maheswarudu *et al.*, 1990) and successfully transferred to end users (Muthu and Pillai, 1991). Recently various aspects of prawn culture in India were dealt by (Pillai *et al.*, 1993).

In the traditional prawn farming, practised in West Bengal, Kerala, Karnataka, Goa and Maharashtra, the young ones of prawns enter the pond along with desired ones in variable quantity and production is low at 200-700 kg/ha/season.

Extensive farming is an improvement over the traditional system. With selective stocking of fast growing species at 50,000 to 1 lakh seed/ha, supplementary feeding and water management, production varies from 1-1.5/ t/ha/crop.

In the semi-intensive farming, stocking density is high at 1-3 lakhs/ ha, 20-50% of the pond water is replaced daily and provided with good aeration. Supplementary feeds are given and the production varies from 4-5 t/ha/4-5 months.

Intensive farming requires high stocking density of 3-10 lakhs/ha in similar, usually concrete ponds, up to 300% daily water exchange, vigorous aeration and high energy feed. The production is over 10 t/ ha/crop.

Super-intensive farming is still in experimental stage and calls for greater environment control and high energy feeds. The stocked prawns are more vulnerable to diseases than in other farming systems and disease control measures are yet to be developed.

In the world, India ranks 5th among the countries producing shrimp through aquaculture. The annual production of prawns by aquaculture in brackishwaters is estimated at 45,000 t from 70,000 ha while the cultivable area is estimated at 1.2 million hactares (Pillai *et al.*, 1993). While semi-intensive system of culture is fast picking up, intensive and super-intensive types of culture are not practised in the country.

B. **Crab culture:** The mud crab *Scylla serrata* and *S. tranquebaric* are suitable for culture. Crab culture is practised either in brackishwater ponds and pens or in cages erected in open coastal waters. Two type of culture namely growing the juveniles to market for 2-10 months and short duration (20-30 days) 'fattening' are practised (Srinivasagam and Kathirvel, 1992). In India success has been achieved in the laboratory-scale production of seed of *S. serrata* and the technology is yet to be upgraded for mass production.

The juvenile crabs (20-85 mm carapace width) are reared in earthern ponds provided with a fence and the production varies from 600 kg/ ha in monoculture to 690 kg/ha in polyculture experiments. Experimental work on crab rearing in cages in India showed good growth of 45-97 g/month and 85-90% survival in 6 months. However commercial cultivation is yet to take off.

'Fattening' is essentially a holding operation in cages, pens or ponds during which immature crabs are reared until their gonads develop. The post-moult "water" crabs are also held for short periods until they gain weight. With the export of live crabs picking-up, the practice of "fattening" has spread to India from other southeast Asian countries.

C. **Lobster culture:** The spiny lobsters *Panulirus polyphagus, P. homarus* and *P. ornatus* are suitable for culture. The studies conducted at CMFRI indicate the feasibility of *P. homarus* culture. Fish farmers in Gujarat collect the juveniles of *P. polyphagus* from wild and grow them in intertidal 'pits' (30 x 15 x 1.25 m) covered with monofilament net. The juveniles of 30-35 g initial weight grow to 100 -125 g in 10-13 weeks (Suseelan *et al.*, 1993). Lobster culture with puerulii as seed is risk-prone and gives lower profits.

MOLLUSCAN CULTURE

The molluscs like oysters, mussels and clams are cultured in open waters bodies. They are efficient converters of primary production into nutritious food suitable for human consumption and give high production per unit area. Several viable seafarming technologies have been developed mainly due to the R & D efforts of the Central Marine Fisheries Research Institute for the production of mussels, edible oysters, saltwater pearls and clams. These technologies are yet to be commercialised except for an attempt to produce culture pearls.

A. **Mussel culture:** The green mussel *Perna viridis* and the brown mussel *P. indica* are cultivable. CMFRI has developed the technology of mussel culture by the raft method for both the species. *P. viridis* gives a production of 4.4 kg to 12.3 kg/m rope/5 months in the open sea, off Calicut (Kuriakose, 1980). The size of the rafts varied from 5 x 5 m to 8 x 8 m. In the sheltered Vizhinjam bay, cultivation of the brown mussel from smaller rafts of 5 x 4 m and 6 x 6 m gave a production of 10-15 kg/m rope/7 months. In the open sea off Vizhinjam, the production is 15 kg/m rope/5 months (Appukuttan *et al.*, 1980). At CMFRI, success has been achieved in the laboratory-scale production of seed of both the species of mussels.

   Experimental culture of green mussel at Goa, Ratnagiri and Madras gave comparable results. It is estimated that about 12000 seeded ropes can be cultured in one hactare and the seeded rope length depends upon the depth where the raft is moored. High production rate of 250 t shell-on wt/ha/6 months is projected in the raft culture of green mussel in 5 m depth.

B. **Edible oyster culture:** The technology for the culture of the edible oyster, *Crassostrea madrasensis* has been developed by CMFRI at Tuticorin. In the rack and tray method, high production of 120 t shell-on/ha/year has been obtained. In the ren method the production is 70-80 t/ha/year and in the stake method 10-15 t/ha/year (Nayar *et al.*, 1988; Rao *et al.*, 1993). Also the technology for large scale seed production has been developed (Nayar *et al.*, 1987). Currently a pilot projects on oyster culture is being operated by CMFRI at Tuticorin in collaboration with National Bank for Agriculture and Rural Development to create awareness and to demonstrate the technoeconomic viability by scaling up the operations.

Recent studies at CMFRI showed that Kakinada bay, Pulicat lake, Ashtamudi lake, Munambam, Dharmadham, Korapuzha estuary and Karwar bay are suitable for developing oyster culture and a seasonal crop of 6-8 months can be raised.

C. **Pearl culture:** The technology for the production of cultured pearls in the pearls oyster, *Pinctada fucata* has been developed successfully for the first time in India at CMFRI (Alagarswami and Qasim, 1973). Also hatchery technology for the production of seed of *P. fucata* and *P. margaritifera* have been developed (Alagarswami *et al.*, 1983, Alagarswami *et al.*, 1989). In the past two decades, as a result of concerted efforts at CMFRI, various aspects of the technologies such as breeding, seed production, mother oyster farming and production of cultured pearls have been standardised by scaling-up the operations. Recently in the raft method of pearl culture in the open Valinokkam bay waters, a single raft of 5 m x 5 m size holding 9414 implanted pearl oysters yielded 1849 pearls with a success rate of 19.64% pearl production. Double and triple nucleus implantation in pearl oyster gives proportionately higher pearl yield. The size of the cultured pearls varies from 2-7 mm. A group of fishermen at Valinokkam are actively associated in all activities of pearl culture in the CMFRI's pearl farm and have developed the necessary skills to take up pearl culture on their own. Based on the technology developed by CMFRI Tamil Nadu Pearls Ltd. and Tamil Nadu Fisheries Development Corporation have ventured into commercial production of cultured pearls and marketed over 15 kg of pearls so far.

D. **Clam culture**: Clam culture is low intensive both for capital and labours. CMFRI has developed the on-bottom farming technology for the production of the blood clam, *Anadara granosa* in the Kakinada bay (Narasimham, 1983). A high production rate of about 40 t shell-on/ha/6 months is indicated; also hatchery technology for seed production of *Meretrix meretrix*, *A. granosa* and *Paphia malabarica* has been developed by CFMRI (Muthiah *et al.*, 1992 and Narasimham *et al.*, 1988).

SEAWEED CULTURE

Phytochemicals such as agar, carrageenan and algin are extracted from seaweeds. Seaweed culture in India still remains in experimental stage. Chennubhotla *et al.*, (1987) and Kaliaperumal (1993) dealt on seaweed culture in India. *Gracilaria edulis* culture on coir rope in the shallow waters at Mandapam by the vegetative propagation method gives a production of 2 to 3 kg/m^2/45-60 days and there is 3 to 6 fold net increase in the weight of seeded material. The lagoon waters of Minicoy indicate still higher production. Also techniques for the culture of *Acanthophora spicifera, Gelidiella acerosa* and *Hypnea musciformis* have been developed, giving yields comparable to those obtained in *G. edulis* culture.

CULTURE OF OTHER ORGANISMS

A. Sea cucumber culture: The sea cucumbers are processed into a high value product known as *beche-de-mer* priced at about Rs.700/kg and the entire production in the country, obtained by the harvest of wild stocks, is exported. Acute shortage of sea cucumbers by the industry forced the government to impose a ban in 1982 on the export of *beche-de-mer* below 7.5 cm in size. Success has been achieved in the artificial breeding and seed production of *Holothuria scabra.* Pen culture of baby sea cucumbers in coastal waters offers considerable potential for augmenting the production of *beche-de-mer* (James, 1993).

B. Culture of live food organisms: The success reported in the seed production of prawns, crabs, bivalve molluscs and sea cucumbers in the country is essentially due to the development of technology for the large scale culture of live food organisms such as microalgae, *Brachionus plicatilis, Artemia* etc. The work on live food organisms has been reviewed by Kulasekharapandian and Radhakrishnan (1989) and Gopinathan (1993).

SEA RANCHING OF HATCHERY SEED

Though sea ranching of hatchery seed in suitable coastal waters does not strictly come under the definition of aquaculture, a measure of husbandry is bestowed in the early part of the life history of the candidate species. It is a practice widely followed in the Japan and several European countries to increase the productivity of coastal fisheries. In India, CMFRI has initiated this work in 1985 for pearl oyster and till this date over one million seed have been ranched in the pearl oyster beds in the Gulf of Mannar; also the prawn seed (*P. semisulcatus*) numbering 2.77 million have been ranched in the Gulf of Mannar during 1989-93. While difficulties were experienced in the above two cases in monitoring/studying the effect of ranched seed on natural stocks, in the case of the clam seed (*P. malabarica*), 7 to 17% of the ranched stock has been harvested after 4-5 months and a production of 12-25 t/ha/5 months is indicated in coastal areas, earlier free of clam population.

COASTAL AQUACULTURE NEEDS MAJOR THRUST TO INCREASED PRODUCTION

The world aquaculture production in 1990 was estimated at 15.32 million t by F.A.O and India ranked second with 1.01 million t. However, a break-up of the Indian production shows that freshwater fish culture is the most significant component and accounted for 97.1% and the ramaining 2.9% by coastal aquaculture. This is in contrast to a high 51.85% contributed by coastal aquaculture in the global scenario.

Coastal aquaculture has high potential and can play a significant role in augmenting the fish production. The rich diversity of cultivable species, vast tracts of derelict coastal areas suitable for farming, tropical climatic conditions resulting in fast growth of the species and high production rates, the availability of strong research base, several indigenously developed low-cost production-oriented technologies, sizeable number of trained manpower, a vast reservoir of unemployed and underemployed labour in the rural areas and the insatiable demand in the overseas markets for some of the aquaculture products are great assets for the development of coastal aquaculture in the country. Judicious utilisation of these assets in a planned manner will put the country firmly on the road towards realising the potential of blue revolution.

The thrust areas requiring R & D efforts for developing coastal aquaculture are given below. At present about 70,000 ha of land is under brackishwater farming against the estimated 1.2 million ha and steps are needed to bring it under culture. For seafarming, suitable enactment of legislature, confining lease-hold right on open water bodies to prospective entrepreneurs is needed.

Alagarswami (1990) suggested that India should aim for semi-intensive prawn culture which gives a production up to 5t/ha/crop instead of high-tech intensive farming since the latter system was found to be not sustainable as it is prone to quick outbreak of diseases and is associated with environment degradation. The strategy should be to bring the existing traditional and extensive farming practices under the fold of semi-intensive culture. In prawn culture, up to 60% of the operating cost is accounted by the feed and feeds giving high conversion are imported. Development of suitable feeds should receive priority attention.

It is common knowledge that the results of research, particularly in seafarming, are yet to find their way for commercial application. Under this category come the culture of edible oyster, mussels, clams, pearl, seaweed and sea cucumber. There is need to organise pilot-scale demonstration projects to create awareness and generate adequate techno-economic viability information. As some of these aquaculture products are not conventionally eaten, the demonstration projects should be integrated with product development, both for domestic consumption and overseas markets. Marketing of the products should also be linked with the demonstration project so that economic data for various components of the integrated project becomes available for the entrepreneurs to exercise choice.

The country is lagging behind in finfish culture when compared to the progress made in Thailand, Philippines and Singapore. Technology development for breeding and seed production of *M. cephalus*, *C. chanos*, *L. calcarifer* and *Epinephalus* sp. should receive priority. Also cage and pen culture of finfish has vast potential and the sporadic efforts made in the country gave meagre information. In yellow tail and European seabass culture, aquaculture engineering played a significant role in cage design to withstand rough sea conditions and feeding is by automatic release systems. As the pressure on the land for the development of land-based aquaculture builds up, the country will be left with no option except for going in for seafarming. By and large seafarming is environment friendly when compared to land-based aquaculture, such as semi-intensive prawn farming. National effort is required for the development of seafarming of finfish and shellfish in the country.

Basic and applied research on fish and shellfish nutrition, diseases, physiology, endocrinology and genetics needs to be strengthened. In aquaculture, biotechnology is sought to control disease, eliminate waste products and enhance growth of cultured organisms. It is suggested that high priority should be given to biotechnology research related to coastal aquaculture.

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