CHANDRAKALA HORA MEMORIAL LECTURE, 1975

AQUACULTURE—ITS POTENTIAL AND SCOPE IN INDIA

by S. Z. QASIM, *National Institute of Oceanography*
Dona Paula, Caranzalem P.O., 403301, Goa

(*Delivered 16 May 1975*)

One of the very useful ways of generating extra food resources is through coastal aquaculture or sea farming. The procedure involves the introduction of certain principles of animal husbandry to gain control over the animals and their environment. Practically in all the littoral countries of the world, mariculture has been given a high priority for research and development. The organisms which are being cultured come under the major groups of fishes, crustaceans, molluscs and seaweeds.

Among the fishes, the culture of milkfish is at present very rewarding. It is being practised throughout the Indo-Pacific regions. Maximum yield of milkfish (1000–2500 kg/ha) is obtained in Taiwan using multiple stockings. Similarly, mullet culture is of considerable importance for several countries including India. *Tilapia* culture has also been tried in many countries with little success. The culture of eels, on the other hand, seems to have good possibilities in India because eels form an item for export. Several other fishes, which are tolerant to large changes in salinity, are also suitable for cultivation in estuaries and backwaters.

Crustaceans form another important group for cultivation. Shrimp culture is being undertaken in many countries either by natural or controlled stocking. In Japan, the yield of cultured shrimps is more than 2000 kg/ha. In certain parts of India, even by adopting traditional methods, shrimp culture has proved to be quite profitable. Lobsters form a luxury item of seafood and considerable success in their culture has been obtained in the United States. Lobsters and crabs, being highly carnivorous animals, pose certain problems during their culture. In the Philippines, crabs are cultivated with the milkfish.

So far, maximum success has been achieved in India in the culture of molluscs. Mussel culture on ropes has given spectacular results. Similarly, the culture of clams, edible oysters and window pane oysters can also be undertaken in suitable nets with success. In recent years, the culture of pearl oysters on wooden rafts using sandwich-type frame nets has given excellent results. From the pearl oysters it is now possible to produce cultured pearls on a commercial scale using indigenous technology.

The culture of seaweeds on coir ropes and wooden frames has given promising results and many seaweeds of economic importance can now be cultivated on a fairly large scale. Similarly, the culture of several other organisms such as sponges, holothurians and turtles can also be attempted in India.

For popularizing mariculture, national demonstrations are necessary to indicate the principles involved and the monetary returns the culture of selected species can give.

INTRODUCTION

Aquaculture may be defined as the development of all such techniques by which a certain degree of control is achieved over the aquatic animals and their environment so that these animals no longer remain fugitive but are kept under different degrees

of domestication and are harvested from time to time. Basically, aquaculture involves the introduction of certain principles of animal husbandry to change the process of hunting for aquatic animals to farming. The manipulations required are to reduce natural predation, improve the chances of survival and finally introduce such changes in the environment which can lead to an acceleration of growth from early life to maturity so that the yield is quick and large.

In India, the culture of several fishes and prawns in freshwater environments of Bengal and in brackish waters of Kerala is an age-old practice and from the ways a change-over seems to occur from capture to culture, using empirical methods, it is difficult to ascertain where capture ends and culture begins. However, despite the immense potential which the aquaculture offers for generating extra food resources in countries like India, it is surprising to note that it has been extremely slow in its growth and development. Lack of scientific methods to illustrate the usefulness of aquaculture, and the absence of relevant data to show the monetary returns it can give, have been the main factors for its restricted application. Perhaps the most important factor which has contributed to the slow growth of aquaculture has been the somewhat unrealistic appraisal of the potentialities of biosphere to produce food for the growing population, as it was thought that the food resources of the sea are simply inexhaustible and the desired increase is always possible by intensifying the exploitation of wild stocks. This tacit assumption has at last been disproved all over the world and at present the general thinking of many fishery biologists is that practically all the regions of the sea are very nearly fully exploited or over exploited. Moreover, the most productive regions of the oceans are within the coastal zones and these areas are subjected to ever-increasing human activities and have become extremely vulnerable to destructive forces of pollution and disproportionate modifications in the environment, resulting in progressive decline in their yield.

Today about 5 million tonnes of food is produced by aquaculture in the world from approximately 400,000 hectares of aquatic areas under operation. Of this, nearly 75 per cent comes from the Indo-Pacific region (Pillay 1973). The total fish production of the world for the last few years, stands at about 65–68 million tonnes. This means that only about 7–8 per cent of the total fish yield is contributed by aquaculture. According to FAO, the total area available for aquaculture in the world amounts to several million hectares. In India alone about one million hectares of backwaters, estuaries and shallow water lagoons, creeks, bays and marshy swamps suitable for aquaculture, are found adjoining the coastline (Qasim 1972*a*). And in this communication only the culture of marine and brackish water environments (mariculture), excluding the fresh water resources, will be described. The potential and scope of cultivable species coming under the major groups of fishes, crustaceans, molluscs, seaweeds and miscellaneous organisms in India have been discussed in relation to other countries of the world where aquaculture is being practised.

FISHES

Milkfish

The milkfish *Chanos chanos* is a widely distributed marine fish and occurs almost throughout the tropical regions of the Indian and Pacific Oceans. It grows upto 1.5 m in length and has great tolerance to variations in salinity. It is a non-carnivorous

fish and can be cultivated in coastal, brackish and freshwater areas so easily that at present no other aquatic animal can surpass its adaptability to domestication. The adults are prolific breeders with a fecundity of over 5 million eggs per female, but they attain sexual maturity and spawn only in the sea and not in any type of impounded water. The delicate fry, slender and almost transparent, measuring about 13 mm in length, enter the shallow coastal bays, lagoons and creeks in millions once or twice a year when they can easily be collected for culture. Their growth is very fast and they are relished as a high class table fish. Their food consists of a benthic complex of blue-green algae, diatoms, copepods, foraminiferans, ostracods, algae and detritus. In experimental marine farming in India, 80 mm fingerlings have been reported to grow to 300 mm in one year (Tampi 1960). Along the south-eastern coast of India, spawning of the fish is intensive from February to April/May (Tampi 1957). In Adayar, near Madras, two peak seasons for the occurrence of fry have been reported (Evangeline 1967). In Indonesia, the fish breeds twice a year and in the Philippines and Taiwan only once during the year (Bardach *et al.* 1972).

Milkfish is extensively cultured in Indonesia, Philippines and Taiwan. In India, its culture is being taken up at a moderate level, and in Ceylon, Thailand, Malaysia and Vietnam its culture is becoming more and more popular. In Indonesia, *Chanos* is cultured in brackish water coastal ponds known as 'Thambaks' spread over 120,000 ha with an overall production of 47,000 tonnes of fish at the rate of 250–1000 kg/ha per year. In the Philippines, the area under culture is much larger—about 160,000 ha—with an average production ranging from 200 to 250 kg/ha. About 90,000 tonnes of fish is harvested annually. Taiwan's production rates of milkfish are simply spectacular, ranging between 1000–2500 kg/ha—or at times even greater with an overall production of 20,000 to 30,000 tonnes of fish per year; although the area under cultivation is barely 16,000 ha. The high yield obtained in Taiwan is as a result of improved methods of stocking and harvesting based on the principle of population management—in addition to proper upkeep and maintenance of the ponds. In Indonesia and Philippines, mostly the traditional methods are still followed involving a single stocking with one size group of fingerlings leading to one harvest of all fish at the end of the culture period which may last from about 3 to 9 months. The disadvantage of this method is that there is enough food available in the pond when the fishes are young and their grazing capacity is limited to their total weight. However, as they grow in length, their food requirement increases in proportion to their body weight resulting in short supply of food, which is to be supplemented by artificial feeds. Further, the yield is restricted to a single harvest. In the improved Taiwanese method of culture, there is multiple stocking of different size groups of fish at intervals of few months. This is followed by selective harvesting of the larger fish at frequent intervals. The total weight of the fish stocked initially in the improved method is the same as in the traditional method, but their numbers differ. As the fishes grow and when the older ones are harvested, they are replaced by the younger groups, and thus the total weight of the fish always remains about the same in the pond (Ling 1973). This method aims at striking a balance between the rate of grazing and the rate of natural replenishment of organic productivity in the pond. The total yield from repeated harvests is much greater than that obtained from a single harvest after one long culture period.

The milkfish ponds are somewhat similar in their construction in all the three major milkfish producing countries and they are composite in nature, *i.e.*, they include separate enclosures for receiving fry, rearing them to fingerlings in nurseries, and then stocking them to marketable size. All these enclosures are interconnected by passages provided with sluices. In Taiwan, where the winter is rather severe, an additional sheltered enclosure is provided for overwintering a large number of fingerlings with a limited food supply, which consequently keeps them stunted. These overwintered fishes are stocked during the next favourable season in growing ponds along with the other size groups.

After harvesting, the ponds are drained, predators and pests are destroyed by using tobacco waste or other indigenous material, they are manured and partially filled with water to allow a good growth of a benthic complex known as 'lab-lab' or 'Tai-Ayer' consisting of blue-green algae and microfaunal elements which are essential especially for the fry and fingerlings. To supplement the natural productivity, artificial feeds such as rice bran, oil cakes, etc., are introduced into the ponds. In the Philippines, filamentous red algae *Gracilaria,* because of its fairly rich protein and carbohydrate contents, is also used to feed the milkfish. *Chanos* culture is mostly a monoculture system in all these countries, but the accidental entry of other young fishes and crustaceans contribute, at times, to the extent of 20 per cent non-chanos harvest. *Penaeus* and *Metapenaeus* spp., Mysids, some crabs, *Therapon, Megalops, Lates,* etc., constitute this additional crop.

In India, the fry collection centres are located along the south-eastern and south-western coasts (Tamil Nadu, Kerala and Andhra Pradesh). Fry and fingerlings are reported to occur in other coastal areas also. *Chanos* culture is carried out mostly in fresh waters of India. The collection of fry, their acclimatization to lower salinity conditions, rearing them to fingerlings in nurseries, transporting them in suitable containers and finally stocking them in freshwater ponds, tanks and lakes are being practised economically in a routine manner on a moderate scale by the Directorates of Fisheries of the respective states. Raising *Chanos* in brackish water is at present restricted because of the high initial cost involved in the construction of ponds with an adequate water supply system.

Mullets

Like the milkfish, the grey mullets are non-carnivorous and highly cultivable fishes. They are more widely distributed than *Chanos.* Their distribution extends up to the coasts of Atlantic and the Mediterranean. They are abundant all along the backwaters and estuaries. The eggs and larvae are pelagic. The fry feeds on blue-green and green algae, diatoms, etc. The adults are benthic and feed on detritus, diatoms, algae and small crustaceans. They are able to tolerate a salinity range from 0 to 38 $^{o}/_{oo}$ and temperatures from 3° to 35°C. Most species grow to about 50 cm in length. *Mugil tade,* however, grows upto 70 cm in length. *Rhinomugil corsula* is essentially a freshwater species but is known to thrive well in brackish waters also. Grey mullets are cultured in Israel, Italy and other Mediterranean countries and in many parts of the Indo-Pacific region, including India, Pakistan and Bangla Desh.

The cultivable grey mullets in India are : *Mugil macrolepis, M. parsia, M. tade, M. cephalus, M. dussumeri, M. troschelli, M. cunnesius* and *Rhinomugil corsula.*

They are cultured largely in West Bengal and Kerala and to some extent in Tamil Nadu and other littoral states. Fry are abundant in creeks, lagoons and estuaries soon after the monsoon and they are collected by dragnets and dipnets of various kinds. Nursery practices are little resorted to, and stocking of the fry and fingerlings is usually done directly into the ponds. Often, the sluices are kept open for the entry of fry and fingerlings with the incoming tides into the brackish water ponds. In most cases, the fishes survive entirely on the natural productivity of the ponds, but additional food such as rice bran is also used. The fish is harvested annually, but sometimes they are allowed to remain in the ponds for longer periods. Growth is good and some species like *M. tade* grow much faster and attain a size of 24 cm in the first year and upto 36 cm in the second year. In brackish water impoundments, mullets are reared along with other species such as *Etroplus suratensis* and *Lates calcarifer.*

Techniques of induced spawning in mullets have advanced considerably. *M. cephalus* in Taiwan, Israel and India, *M. capito* in Israel and *M. macrolepis* and *M. troschelli* in India have been successfully bred with pituitary and synahorin injections administered intramuscularly or into the coelomic cavity of the ripe females (Bardach *et al.* 1972). With the known techniques well at hand, and with many suitable indigenous species of mullets, and vast cultivable areas available, the scope for mullet farming in India on sound scientific lines appears to be very promising.

Tilapia

The cichlid fish, *Tilapia mossambica,* is originally a native of East Africa. It became well established after it was introduced to Indonesia in early fifties, where it is known as Java Tilapia. It was considered by some fish culturists a very suitable species for large scale cultivation in several Asian countries to meet the protein shortage and nutritional requirement of the masses. It was first brought to India from Bangkok by the Central Marine Fisheries Research Institute for experimental purposes to ascertain the suitability of its introduction into the Indian waters (Panikkar and Tampi 1954) and later on from Ceylon by the Department of Fisheries, Govt. of Tamil Nadu. The fish was stocked in fresh water habitats throughout the State (Sreenivasan 1967). The results so far obtained in India and in many other parts of the world are rather disappointing. There is, however, a need to re-examine the culture of this fish and to reorientate the farming practices at least in limited areas, for unlike many other cultivable fishes, *Tilapia* not only survives but also breeds in almost all types of fresh and saline waters.

It is essentially a freshwater fish but can tolerate high salinities. In brackish water, its growth is as good as in fresh water, or even better, but in salinities of about 30 $^{o}/_{oo}$ its growth rate slows down. Breeding gets inhibited and no reproduction occurs at salinities higher than 40 $^{o}/_{oo}$. The optimum temperature for its survival and growth is from 20° to 35°C. It is an omnivorous fish and feeds on plants and small animals with a strong preference to filamentous algae. The fry feeds on diatoms, blue-green algae and small crustaceans. Growth is known to vary with farm conditions. Chacko and Krishnamoorthy (1954) have found that the fish grows to 22 cm (110 to 140 g) in eight months. Sexual maturity is attained after two months and the fish

breeds continuously at intervals of one or two months, producing 80 to 1000 eggs in each spawning. The males scoop circular depressions, 30–90 cm in diameter, at the bottom of the pond and the females deposit their eggs in these depressions, but soon pick them up after fertilization for oral incubation.

Wherever *Tilapia* culture was attempted, it gave rise to population explosion, resulting in a process called 'runting', *i.e.* its size became smaller but reproduction continued and the harvest of smaller and smaller fishes became commercially valueless. When cultured along with non-predatory fishes, *Tilapia* created a problem of overcrowding, resulting in competition for food and space. Sreenivasan (1967) states that the introduction of *Tilapia* in ponds has adversely affected the carp and *Chanos* culture in Tamil Nadu. In waters where predatory fishes such as *Notopterus, Ophicephalus* and catfishes occur, *Tilapia* grows to a fairly large size because of a natural control of its population increase. Hickling (1970) is of the opinion that since maturity in *Tilapia* gets somewhat delayed in brackish water, the fishes grown in estuarine areas include a greater proportion of marketable fish. Pakrasi *et al.* (1964) state that in the delta region of West Bengal (impounded brackish waters), *Tilapia* and carps together thrive extremely well. Since *Tilapia* is a fast breeder, and since it is now established that it could serve as a forage fish, suitable polyculture systems could be developed both in fresh and saline waters in combination with some carnivorous fishes which would lead to a higher rate of growth of *Tilapia* and thus producing them of acceptable size.

Eels

Eels of the genus *Anguilla* form a luxury item of food and these are cultured very intensively in Japan and several other countries. Taiwan initiated the eel culture soon after the second world war and has made incredible progress. Eels are also cultured in the Italian valli, the Mediterranean lagoons, parts of Israel, United Arab Republic, Soviet Union and West Germany. The fact that during the culture, they require enormous quantities of proteinous food, discouraged many countries, which are in short supply of protein food for human consumption, to undertake the eel culture. But the synthetic feeds, now available in the world market, have proved to be an efficient protein substitute for culturing eels. However, in developing countries it seems difficult to use these on a large scale mainly because of the heavy recurring cost involved. Instead, appropriate farm management practices involving methods of stocking and utilizing trash fish, offal from slaughter houses etc., will help a great deal in raising the eels for domestic markets or for export trade.

Eels attain sexual maturity in the riverine system; but being catadromous fishes they migrate into the sea for spawning. Their larvae (leptocephali) have a prolonged pelagic life and after a partial metamorphosis, they enter the estuaries as 'elvers'. These, while ascending up the rivers, grow into adult eels. Farming of eels, therefore, implies a regular collection of elvers every year and growing them in suitable impounded waters to marketable size. In Japan, the present annual output of eels from farming is about 24,000 tonnes. Of this, 95 per cent is supported by the local species *Anguilla japonica* and the rest by the imported European eel, *Anguilla anguilla*. Elvers, 5–7 cm long, reach the Japanese shores from December to April when they are collected

by special dipnets and kept for a few days in floating baskets before they are transferred to nursery ponds. The nursery ponds are of two types—the smaller ones measure 200 m^2 and the larger ones 600 m^2. At first, the elvers are kept in smaller ponds at the rate of 300,000 elvers per hectare. After three months, they are transferred to larger ponds. They are fed twice a day at the rate of 30 per cent of their body weight on dried sardines, sardine meal, earthworms, etc., and occasionally on silkworm pupae. Food is suspended in trays in shallow waters and is never sprinkled so as to avoid contamination of water. When the young eels grow to 12–15 cm in length, they are sold to private culturists to be stocked in their ponds. Ponds used for eel culture are from 3,000 to 10,000 m^2 in area and are about 50 cm deep. Stocking rates vary and the eels are generally fed at the rate of 10 per cent of their own body weight. The feed consists of chopped fish, fresh or frozen sardines, and artificial food pellets. Silkworm pupae are given for fattening the eels. About 30 per cent eels reach marketable size at the end of first year. They are harvested and the pond is replenished with younger eels. Complete harvesting of the pond is done at the end of the second year. Yield from 6,000 to 10,000 kg/ha is obtained in ponds but in running water impoundments it is much higher and ranges from 26,000 to 46,000 kg/ha. Japan's eel culture industry is so extensive that the supply of elvers from within the country falls considerably short of the total demand by the culturists. The quantities of elvers imported from Taiwan, China, Hongkong, Philippines, France, Italy, Great Britain, Canada, and U.S.A. are appreciably large (about 317,445 kg). The import price varies and largely depends upon the quality of elvers. Smaller elvers fetch a higher rate of about $ 200 a kilogram.

Eel culture in Japan is mostly a monoculture, *i.e.*, only eels are grown in the ponds. Very often, a few striped mullets are introduced to clean up the accumulating debris at the bottom. In Taiwan, it is practised as a polyculture in which young eels are stocked along with the common carp, grass carp, big-head, gold fish and striped mullets. The growing eels are fed with trash fish, offal from the slaughter houses and factory rejects from food processing establishments. Synthetic feeds are also utilized (Bardach *et al.* 1972). Eels are grown to larger sizes than in Japan to meet the export trade. In the polyculture system, the advantage is that some of the species depend upon the natural resources of the pond itself and contribute a fair amount to the overall fish production of the pond.

In India, for the eel culture, two species of *Anguilla* namely *A. bengalensis* and *A. bicolor* are worth mentioning. Abundant elver resources of these species have been reported from the Hooghly River (Pantulu 1956), in the deltaic regions of the Godavari (Rahimulla *et al.* 1944) and at Srivaikundam Anicut in the Tamraparni River (Nair 1973). In the experimental eel culture carried out at the Regional Research Centre of Central Marine Fisheries Research Institute, Mandapam Camp, very promising results were obtained. The young elvers of *A. bicolor* were fed on minced clam meat (*Donax*) during the first three months and subsequently on sliced miscellaneous fishes like *Sardinella* sp., polynemids and sciaenids. The initial average length and weight were 10 cm and 2 g respectively. At the end of one year, the average length and weight became 35 cm and 106 g respectively, thus recording an average monthly increment of 20.8 mm in length and 8.6 g in weight. At the end of the second year, the average length and weight were 42 cm and 160 g with a monthly increase of 6 mm

and 4.5 g respectively. The maximum growth observed at the end of the first year was 50 cm and 202 g and at the end of the second year it was 55.6 cm and 380 g (Nair 1973). It was thus concluded that growth being very fast during the first year and little during the second year, it would be profitable to harvest the fish at the end of the first year itself. The elvers were reared under experimental conditions in rectangular cement tanks 180 cm long, 150 cm wide and 75 cm deep with a water level of 60 cm. Under proper culture conditions using artificial feed, the growth of this species can be expected to be even better. Eel culture has not been initiated in India on a commercial scale. It however holds good prospects in view of the easy availability of the elvers and the extensive water areas well-suited for their cultivation. Apart from meeting our own needs of farming, the elver resources, if adequately surveyed, can be of direct export value to other countries.

Miscellaneous species

In addition to the fishes noted above, there are several other species suitable for culture in estuarine and marine environments. Some of them may not lend themselves to any large scale production, but being highly esteemed as table fishes and appreciably large in size, they could give a fairly high monetary return.

Lates calcarifer (Centropomidae) known as the seabass, cockup or 'bhekti' is one of such fishes. It is essentially a salt water fish but thrives equally well in brackish and fresh waters and grows up to 150 cm in length. It is predaceous and even cannibalistic. It grows from 300 to 500 g in weight in one year. When cultured, juveniles weighing 500 g grow to 3000 g at the end of the first year and to 500 g at the end of the second year (Gopalakrishnan 1973). Sexual maturity takes place after the second year of its life and spawning occurs twice in nearshore waters in June-July and January-March. The fry are collected in appreciable quantities from the river mouths for stocking in impounded waters. They occur along both east and west coasts of India, but their greatest abundance is in West Bengal in the Hooghly-Matlah estuarine system (Ghosh 1973). Practically everywhere, the demand of the fry of this species is greater than the extent to which they are available. In Thailand, juveniles of seabass are reared in enclosures or ponds. They are fed on *Tilapia* either raised in separate tanks by the cultivators themselves or purchased from outside sources (Sribhibhadh 1973).

Elops saurus and *E. machanata* (Elopidae) known as the 'ten-pounders' grow up to 50 cm in length. These are marine fishes and breed in inshore waters. They also have a high tolerance of brackish and fresh water conditions at all stages of their life histories. Hence they are suitable for culture in every type of impounded water, although they are carnivorous. They find an accidental entry in most cultivable waters and contribute in a small way to the total harvest. In Hawaii, *E. hawaiensis* is cultured along with the grey mullets with some success. The 'Tarpon' *Megalops cyprinoides*, which grows upto one metre in length, also thrives well in similar habitats. It has a similar food habit as the ten pounders.

Eleutheronema tetradactylum (Polynemidae) known as the Indian salmon is also a much liked table fish. It grows to a size of 1.8 m and its fingerlings enter into brackish water zones, such as those of the Hooghly estuary. In the Chilka Lake, the

species is known to grow upto 21 cm in the first year and about 36 cm in the second year (Jhingran and Natarajan 1969). Sparid fishes, especially *Sparus sarba* tolerate wide variations in salinity. Its fry measuring 10–15 mm in length occur at the mouth of Chilka Lake during January–February. They are also considered suitable for coastal aquaculture (Jhingran and Natarajan 1973).

Ideally suited for brackish water culture in small ponds of India and requiring very little attention, as it entirely subsists on the natural productivity of ponds, is the cichlid fish *Etroplus suratensis,* popularly known as the pearl spot. It grows to about 45 cm in length. It feeds largely on detritus and filamentous algae, although worms, shrimps, insect larvae, gastropods, etc., also form its food. It breeds in brackish water and lays from 1,300 to 6,000 eggs. The mother fish attaches the eggs to some suitable objects at the bottom and guards them until they are hatched. It grows to 30 cm during the first year, 36 cm in the second year, 41 cm in the third year and 46 cm in the fourth year (Gopalakrishnan 1973).

In recent years, perhaps the most spectacular achievement in aquaculture in Japan has been the culture of the habitually fast-moving schooling fishes like the yellowtails, *Seriola quinquiradiata* growing to a very large size in cages made of synthetic fibre or steel wire netting. The cages are firmly fixed in shallow waters or are suspended from rafts in deeper waters of the inshore regions. This type of culture permits intensive stocking in limited space. The fish are fed daily on expensive feeds yielding high conversion ratios. In Japan, the quantity of cultured yellowtails in 1968 was 30,000 tonnes. Production rates are incredibly high and reach upto 280 tonnes per hectare in farms with rotary cropping system as practised in Taiwan for milkfish farming. (Bardach *et al.* 1972). Yellowtails are so expensive in the Japanese market that they bring in reasonably high profits in spite of the very high cost of production.

CRUSTACEANS

Shrimps

During the last two decades a phenomenal expansion has occurred in the export of shrimps from India to other countries. The increasing demand of shrimps in the world market has necessitated increased production (Qasim 1973). With the exception of a few species of shrimps which occur in deeper waters, the exploitation of natural stocks is largely limited to areas near the coast. In some regions of India, the catch per unit effort has declined so much that much apprehension has been expressed among the shrimp exporters and entrepreneurs regarding the sustainability of the harvest from the natural resources alone (Qasim 1971*a* and 1972*b*). To avoid depletion and to augment shrimp production, the culture of shrimps in India, like in many other countries, is becoming a necessity.

About 21 species of prawns are being cultured in the United States of America, Japan, Taiwan, India, Bangla Desh, Indonesia, Philippines, Vietnam, Thailand, Singapore, Malaysia and Korea either on a pilot or commercial scale. In most countries, shrimp farming largely includes trapping, stocking and harvesting of natural stocks. These traditional methods are still extensively used, although modern techniques developed by Japan have recently been introduced in some countries.

Among the penaeid prawns, *Penaeus japonicus* and *Penaeus orientalis* are used for culture in temperate waters, whereas *Penaeus indicus, Penaeus monodon, Penaeus merguiensis. Metapenaeus dobsoni, Metapenaeus monoceros, Metapenaeus affinis* and *Parapenaeopsis stylifera* are suitable for tropical waters. The palaemonid species, *Macrobrachium rosenbergii* and *Macrobrachium malcolmsonii* are of special interest because of their large size.

Almost all the species of penaeid prawns breed in the sea, but their larval stages enter the estuaries where they grow to adult size fairly quickly and then return to the sea for breeding. *Macrobrachium rosenbergii* is largely a brackish water species, but its juveniles migrate to fresh water where they feed and grow. *M. malcolmsonii* is mainly a fresh water species.

The different culture operations used all over the world can be grouped into the following heads :

(*i*) *Natural stocking*—This is done in brackish water ponds or impoundments adjoining the coastal waters and estuaries which are influenced by the tides. Shrimp larvae enter these ponds along with the incoming tides. The inflow and outflow of water are controlled by sluice gates. The young shrimps largely feed on detritus and grow rapidly in these ponds. Harvesting is done during the full moon and new moon periods.

Natural stocking of shrimps is also done along with the milkfish in Indonesia, Philippines and Taiwan where a composite culture of shrimp and fish is being practised.

In India and Bangla Desh, shrimp culture is made to alternate with the paddy crop in paddy fields and low-lying areas adjoining the estuaries and backwaters. Paddy cultivation in these fields lasts from May to September and for the rest of the year the fields are used for shrimp culture. The main drawback of this method is that young predatory fishes usually enter the ponds along with the shrimp seeds and prey heavily on them.

(*ii*) *Controlled stocking* — In this method, shrimp seeds are collected by professional collectors, using simple hand-nets or tow-nets, from the estuaries, tidal canals and mangroves. The larvae are sorted and those suitable for culture are stocked in brackish water ponds.

In Japan, Korea and Taiwan, shrimp larvae are produced under controlled conditions. They are reared and then stocked. In Thailand, Malaysia, Indonesia, Singapore, India and Bangla Desh, this method is being practised on an experimental basis but the main difficulties faced in this method are to obtain enough gravid females for spawning in captivity and the non-availability of suitable feeds for the larvae during rearing.

The shrimp culture techniques developed and practised in Japan are somewhat sophisticated. These include elaborate control of water conditions, heavy stocking and intensive feeding. *Penaeus japonicus* (kuruma prawn) is extensively used for the culture operations. The gravid females are released in cement tanks (30–50 females in 57 m^3 tanks or 50–100 females in 200 m^3 tanks), provided with a regular temperature and aeration control. The females are separated after spawning and the larvae are fed on diatoms. The post-larvae are reared in running water. They are fed first

on *Artemia* nauplii and then on artificial feeds developed by different culturists. The quantities of food given during the rearing operations are as follows :

0.2 —0.5 g stage — 50 per cent of the total weight
1.0 —2.0 g stage — 25 per cent of the total weight
10.0 g stage — 15 per cent of the total weight

The yield per hectare is over 2,000 kg, while the production cost works out to be more than $ 6.00/kg.

In Taiwan, farm management is carried out using natural food supplemented by artificial feeds. The species cultured are *Penaeus monodon* and *Metapenaeus monoceros*. Several years ago, natural shrimp seed resources were used for stocking but during the last two years, propagation of six species, namely, *Penaeus japonicus, P. monodon, P. semisulcatus, P. teraoi, Metapenaeus monoceros* and *M. joyneri* has been carried out successfully.

In the United States, farming of the species belonging to the genus *Macrobrachium* has been intensively taken up. The larvae are first kept in phytoplankton-rich green water with 10 $^{o}/_{oo}$ salinity. After 12 days, the larvae are transferred to clear water having the same salinity. They are fed on the nauplii of *Artemia salina* and ground fish meat. The post-larval stage is attained in 30 days. The juveniles are then stocked in fresh water ponds and are intensively fed on artificial feeds till they attain a marketable size. The production cost is about $ 6.47/1000 prawns, but experiments are underway to reduce the cost to about $ 2.00/1000 prawns.

In Malaysia, several hundred hectares of embanked mangrove swamps are being utilized for shrimp culture. In these, natural seeds are used. The total yield ranges from 800 to 1,500 kg/ha per year.

In India, shrimp culture is still being practised in a traditional way and most of the natural areas ideally suited for this purpose are remaining unutilized. The methods employed include stocking of natural seeds in low-lying areas and paddy fields of Kerala, Karnataka and Goa, fresh water impoundments of Andhra Pradesh and the marshy swamps of West Bengal. The stocked shrimps grow on natural food (detritus) to adult size. Several authors have described the shrimp culture in paddy fields of Kerala and the possibilities of its further expansion (Panikkar 1952; Menon 1954; George *et al.* 1967). The entire operation lasts for 3–6 months. The average yield of prawns from the paddy field is 250–1,500 kg/ha. George *et al.* (1967) have suggested some methods of improving the yield of prawns from paddy fields. George (1975) also gives the average growth rate of *Metapenaeus dobsoni, M. monoceros, M. affinis* and *Penaeus indicus,* as 0.35, 0.47, 0.38 and 0.49 mm per day respectively, and further states that *Metapenaeus dobsoni* and *Penaeus indicus* are the most suitable species for culture operations.

An interesting account of the farming of *Macrobrachium* species in freshwater and brackish water ponds of Andhra Pradesh has been given by Rajyalakshmi (1960, 1961 and 1968). Kewalramani *et al.* (1971) have indicated that larval stages of *Macrobrachium malcolmsonii* require a certain degree of salinity for their development.

Some interesting observations on the growth rate under experimental conditions have been made by Subrahmanyam (1972) and Verghese *et al.* (1975) on *Penaeus*

monodon and by Suseelan (1975) and Ramamurthy and Manickaraja (1975) on *P. indicus*. Subrahmanyam (1972) recorded an average growth rate of 16 mm/month in *P. monodon*, while in the same species, Verghese *et al.* (1975) gave the growth rate of 150.2 mm in length and 28.03 g in weight within 6 months. Suseelan (1975) recorded a maximum growth rate of 30.55 mm/month in *P. indicus* from the salt pans near Kanyakumari and Ramamurthy and Manickaraja (1975) gave the growth of the same species as 118 mm in 6 months.

Profitability of shrimp culture — Monetary returns from shrimp farming are largely related to the cost of production and the market value of the product. The shrimp food used may be natural or artificial. The yield/unit area in the former case is low but with better methods, using artificial foods, the yield can be increased to 2,500 kg/ha per year and the production cost should not normally exceed Rs. 10/kg. Experiments are underway to reduce the cost even further by increasing the yield and by using cheap artificial food materials. The success of shrimp farming would largely depend upon the total cost of production.

Shrimp culture in India in all respects is a payable proposition and its future appears to be most promising. The cultures of *Penaeus indicus*, *P. monodon* and the giant freshwater prawn, *Macrobrachium rosenbergii* have already shown excellent results.

Lobsters

These form one of the highly valued seafoods. Experimental culture of lobsters is being carried out in Japan, Taiwan, Australia, Korea, United States of America and several other countries. The most important aspect of lobster cultivation involves the production of second generation from the hatchery-reared adults. Until recently, none of the successfully mated females produced fertilized eggs. However, the hatchery biologists, by deepening the water of the tanks containing females, to 45 cm, induced the females to lay the fertilized eggs successfully. The temperature also influences the metabolic rate of lobsters considerably. The hatchery lobster can reach a large size in 2–3 years as compared to 6 years growth in the sea. These studies clearly indicate that lobster culture on a commercial scale is a definite possibility.

The largest lobster hatchery operation today is being carried out by the State of Massachusetts on the Island of Martha's Vineyard, U.S.A. Hughes (1968) has indicated the possibilities of commercial rearing of *Homarus americanus* from eggs to adult. Gravid females were kept in running sea water (salinity 30–31 $^{\circ}/_{\circ\circ}$) in hatching tanks measuring 274 × 91.5 × 30 cm. The phyllosoma larvae on hatching were fed on the nauplii of *Artemia* and the later stages on finely ground beef liver, ground clams and crab viscera. The survival rate was found to be 30–40 per cent. When the lobsters reached the fourth moulting stage, they were released in selected areas along the coast of Massachusetts. Little is known about the fate of the hatchery-reared lobsters after their release.

Ingle and Witham (1969) have suggested some measures for the successful lobster culture. The procedure includes the location of a protected bay from which post-larvae could be obtained, installation of an artificial habitat to attract the post larvae,

removal of the post larvae from the habitat to holding ponds, provision of large quantities of small articles of porous texture to be used as a sanctuary for the juveniles, and finally feeding them on artificial feeds regularly. After the larvae have passed through more vulnerable stages, they are kept in ponds until ready for the market. One of the serious problems during lobster culture is cannibalism. The newly moulted lobsters become extremely vulnerable to the attacks of other lobsters and so far no proper solution of this problem has been found. Keeping all the lobsters well fed has helped the situation but maintaining the freshly moulted lobsters in isolation increases the cost of rearing considerably. Hormones are being tried to control the moulting process in such a way that most of the lobsters shed their exoskeleton at the same time and hence cannibalism could be avoided.

Other members of the family Palinuridae which have been tried for culture are *Panulirus japonicus* and *P. longipes* (in Japan), *P. argus* and *P. inflatus* (in USA), and *P. polyphagus* (in Malaysia). In Japan, the young *P. japonicus* caught in traps are held in ponds or shallow bays and fed on trash fish.

The results obtained in most countries indicate that lobster culture is a very profitable proposition. Unfortunately no organised lobster culture is being practised in India but it is hoped that the cost of raising lobsters in India would be much lower than in most of the countries mentioned above.

George (1967*a* and 1967*b*) has given an account of the Indian spiny lobster *Panulirus homarus* while Mohamad and George (1967) carried out some tagging experiments for studying the migration and growth of this species. Thomas (1972) has related the growth of *P. homarus* in captivity to moulting. The growth per moult was at the rate of 4 to 9 mm carapace length and the annual rate of growth was 30 mm in males and 17 mm in females. The common lobsters found along the coastal waters of India are *Panulirus homarus, P. longipes, P. versicolor, P. penicillatus, P. ornatus, P. polyphagus* and *Thenus orientalis.* Large concentrations of the deep sea lobster, *Puerulus sewelli* are known to occur along the Kerala coast and Gulf of Mannar at depths of 200 to 300 m and these are being exploited. Exploratory trawling off the Kerala coast carried out recently has shown that another species of lobster, *Palinustus mossambicus,* also occurs in fairly good numbers in certain localities.

P. homarus is commercially the most important lobster caught from the Indian coast. This lobster is seen only along the rocky coasts or around coral reefs. It has a prolonged breeding season with a peak in November and December. About 200,000–400,000 eggs are laid at a time. The rate of growth of this species is not properly known, and it seems that at the end of the second year it reaches a length of 200 to 220 mm. After that the annual increase is about 20–30 mm only. All lobsters are known to be carnivorous. Their food includes marine worms, molluscs, smaller crustaceans, etc. They are more or less omnivorous and frequently behave like scavengers. Maximum catches of lobsters are obtained from the coast of south India, especially from Colachel to Kanyakumari.

Crabs

Edible crabs occur in marine, estuarine, brackish water and fresh water environments and all these can be grouped under 3 main families, namely Portunidae

(swimming crabs), Xanthidae (mud crabs) and Caneridae (cancer crabs). The main species supporting the crab fishery of India are *Scylla serrata*, *Portunus pelagicus*, *Portunus sanguinolentus*, *Charybdis* sp. and *Paratelphusa* sp. At present, no crab culture has been attempted in India and exploitation of crabs is entirely based on natural resources. However, considering the number of edible species available, their high nutritive value, a good market price and their relatively short life cycles, it is almost certain that the commercial culture of a few species of crabs will become a reality in not too distant a future.

Scylla serrata forms the mainstay of crab fishery of the Indo-Pacific region. Although it is essentially a salt water species, it is capable of living in fresh water also. Its large size (15–16 cm carpace width) and early maturity, which it attains after about 5 months, make the species very suitable for culture. However, cannibalistic and burrowing habits of this species will have to be controlled to minimize losses and to make the farming profitable. In the Philippines, *S. serrata* is cultivated along with the milkfish as a polyculture.

In the culture ponds, the crabs enter as zoea larvae or juveniles, when the sea water is allowed to get in with the incoming tides through the sluice gates. The crabs feed on naturally occurring food material. Sometimes, supplementary food is also given. Harvesting is done after 6 months. Thus with no proper management, the production of *S. serrata* from brackish water ponds in Taiwan in 1969 was 1,68,102 kg. Similarly, the milkfish ponds in Java produced an average of 200 crabs/ha per year. The annual catch of crabs in India from the natural population is 38,000 tonnes [25,000 tonnes marine and 13,000 tonnes brackish water (Rao *et al.* 1973)].

Experiments on the rearing of larval stages of juveniles of *S. serrata* have been conducted in India, Malaysia, Thailand, Sri Lanka and the Philippines and on the larvae of *Neptunus pelagicus* and *Portunus trituberculatus* in Japan and on *Callinectes sapidus* in the United States. The last two countries have achieved varying degrees of success.

Ong (1964 and 1966) studied the life history of *S. serrata* in Malaysia. The larvae were reared up to the megalopa stage giving phytoplankton culture, *Artemia* nauplii and fish flesh as food. Ong's studies have already been put to use in Sri Lanka, where the Ceylon Fisheries Corporation has achieved encouraging results. Raphael (1973) has recorded the average survival, at the end of the culture period, as 35 per cent in *S. serrata*. The juveniles reared in the laboratory are stocked in ponds to attain the adult size. Varikul *et al.* (1973) carried out stocking of *S. serrata* at the rate of 10,000 animals/ha in brackish water ponds in Thailand. The first experiment in 1962 was of 45 days duration. With the artificial feed, the weight increased from 1070 kg/ha to 1998 kg/ha. The second experiment in 1968 lasted 60 days during which period the increase in weight was from 997 kg/ha to 1289 kg/ha. Arriola (1940) and Pagcatipunam (1973) have made observations on the culture possibilities of *S. serrata* in the Philippines waters. The Japanese biologists kept gravid females of *Portunus trituberculatus* in cement tanks (5 × 13.3 × 1.7 m) with sea water having salinity 33–34 $^{o}/_{oo}$. The zoeae on hatching were fed with the culture of *Chlorella*. Later on, the larvae were fed on *Artemia* nauplii.

Metamorphosis occurred within 25 days after hatching and the survival rate of juvenile was 20 per cent. These were kept in ponds for growth.

In the United States, the most common portunid crab is *Callinectes sapidus.* Like *S. serrata,* this species also occurs in brackish water areas. In 1969, studies were carried out in the Institute of Marine and Atmospheric Sciences, University of Miami on the rearing of *C. sapidus* from eggs to adults of marketable size (9 to 12 cm carapace width). The life history took only 3 to 4 months after hatching. Costlow (1967) has indicated that temperature and salinity are important factors during the culture operation of this species.

From the details noted above, it may be concluded that the culture of crabs has a good potential in India because of the abundance of edible species all along the coastline, their fast growth rate and a short life history. However, a control of cannibalism seems the most important factor to make the culture economical.

MOLLUSCS

Molluscan resources offer the maximum scope for culture, as these give exceptionally high yield. The annual yield of total marine molluscs in the world is about 4 million tonnes out of the total of 68 million tonnes of all types of food obtained from the sea (FAO 1972). Unfortunately, from India reliable figures of molluscan production are not available.

Among the molluscs, bivalves are the most suitable animals for culture because of their sessile habit requiring no caging or impoundment to prevent escape. Moreover, as they essentially feed on phytoplankton and suspended detrital particles by filtering sea water, their yield in terms of sea surface area is high, as the total volume of water available for filtration is large. The important cultivable bivalves of India are mussels, clams, edible oysters, window pane oyster and pearl oysters.

Mussels

Mussels, among all the shellfishes, are the easiest to cultivate. The species used for culture in India is *Mytilus viridis.* Unlike the temperate species, the Indian mussel has several advantages. It has a higher growth rate of about 113 mm in 8 months, matures early in life, approximately at 15.5 mm size, and is almost a continuous breeder (Davis 1970).

At present, the reported annual yield of green and brown mussels of India from natural beds is about 1,200 tonnes (Jones and Alagarswami 1973), but the potential resources are very high and with suitable methods of culture and management the production could be increased considerably.

Mussel culture experiments on ropes hanging from wooden rafts were initiated by the Central Marine Fisheries Research Institute in 1971-72 at various places along the south-west and south-east coasts of India. These have given very promising results (Sundaram 1975). Qasim and Achari (1972), based on preliminary experiments, have reported that the yield of mussel from rope culture at Vizhingam is about 200 tonnes/ha per year. The yield obtained in Spain from rope culture of mussel is 300,000 kg/ha per year (Bardach *et al.* 1972). The results obtained

in India on the yield of mussels are most encouraging and hence mussel culture should be undertaken on a priority basis.

Clams

The commercially important clams are *Meretrix meretrix, M. casta, Paphia malabarica, P. textile, Katelysia marmorata, K. opima, Vellorita cyprinoides cochinensis* and *Gafrarium tumidum.* These are abundant in estuaries, backwaters and bays along both the coasts. Although the existing exploited resources of clams from the natural populations are less than 5,000 tonnes, their potential is very high (Alagarswami and Narasimham 1973).

Most of the species of clams noted above are euryhaline. They are fast growing, and mature early in life. They have prolonged breeding seasons, and are well-suited for cultivation. They can be cultured using cheap methods of transplanting the clam-seeds into specially prepared beds. They can also be grown with the molluscs and detritus feeding fishes as a polyculture.

Durve and Dharma Raja (1965) have shown that the production of *Meretrix casta* transplanted to a bed is 4–5 times greater than under natural conditions. The growth rate of transplanted *M. casta* is accelerated by at least three times (Abraham 1953). Ranade (1964) has estimated the yield of *M. casta* to be more than 5,000 tonnes/year from the Maharashtra coast. Along the Goa coast, the clam landing for 1972–73 was about 600 tonnes, but the total potential appears to be about 3,000 tonnes/year.

The wedge clams, *Donax incarnatus, D. cuneatus, D. faba* and *D. apperitus,* which occur abundantly on the sandy beaches all along the Indian coast, have an excellent scope for combined cultivation. Of the four species, three occur together forming a high population density (158,650 animals/m^2) and a high biomass (30 kg/m^2). These are easily accessible for exploitation (McLusky and Stirling 1973).

The razor clam *Solen kempii,* with an existing estimated potential of 100 tonnes/year, can also be used for cultivation, especially along the Maharashtra and Goa coasts (Rao *et al.* 1962). Another clam is the ribbed ark-shell, *Anadara granosa.* It has an annual yield of about 1,000 tonnes in the Kakinada Bay (Narasimham 1969). This species can also be cultured in beds, like the other clams.

Edible oysters

The edible oysters, belonging to the genus *Crassostrea* are very common in the nearshore regions, estuaries and backwaters of India. Of the eight species recorded from the Indian waters, four, namely, *Crassostrea gryphoides, C. madrasensis, C. discoides* and *C. cucullata* are fairly abundant and these support fisheries of local importance (Alagarswami and Narasimham 1973).

Farming of the oyster, *C. gryphoides* on a small scale was carried out at Kelwa, Navapur and Ussali in Maharashtra (Durve 1959) and of *C. madrasensis* at Ennur and Pulicat Lakes in Tamil Nadu (Alagarswami and Narasimham 1973). The oyster farming at these places included some preliminary work on their upkeep in captivity with promising results.

Along the Goa coast at Ribandar, Curca and Siolim, there used to be a flourishing fishery of *C. gryphoides* some years ago. At present, a seasonal fishery exists

only at Siolim with an annual yield of about 200 tonnes (Anon. 1974). Another 300 tonnes of oysters are reported to be fished from Ratnagiri, Purnagad and Jaithapur along the Maharashtra coast (Alagarswami and Narasimham 1973). Sonapur backwaters (Orissa coast) also support a sizeable oyster fishery with an annual yield of about 500 tonnes (Alagarswami and Narasimham 1973).

With such a rich natural distribution of edible oysters both along the west and the east coasts of India, it is evident that a systematic culture of oysters, when practised, can be extensive and rewarding.

Window pane oyster

The window pane oyster resources are constituted of a single species, *Placenta placenta*. It has a fishery in the Gulf of Kutch (Dwaraka Bay and Rann Bay) and also in the Kakinada Bay. In the Rann Bay, fishing is done for seed pearls in this oyster which are used in pharmaceutical industry, but at Kakinada, where the annual yield is about 4,000 tonnes, the shells are exploited mainly for the preparation of lime. Rao (1963) has indicated that the quality of meat of this oyster is fairly good and hence it offers a promising scope for culture.

Pearl oyster

Pearl oyster resources in India are found in the Gulf of Kutch (Gujarat) and in the Gulf of Mannar (Tamil Nadu). The species which at one time contributed to the pearl fishery at both the places in India is *Pinctada fucata*. In both these areas, because of the indiscriminate destruction of oysters for obtaining natural pearls, the resources became seriously depleted.

In 1971, efforts were made by the Central Marine Fisheries Research Institute to revive the pearl oyster resources of south-east coast by farming them on rafts. For this purpose, a site in a coastal village (Veppalodai), 25 km north of Tuticorin, was selected. The oysters were collected from the natural pearl banks by SCUBA diving and skin diving. They were placed in sandwich-type frame nets and suspended from a raft (for details see Alagarswami and Qasim 1973 and 1974). Each raft contained 900–1500 oysters, and in the first phase of oyster farming, several thousand oysters were raised on four rafts. The survival of oysters on the rafts was about 78 per cent. The mortality was largely caused by fouling organisms whose settlement over the oysters cemented their valves.

When sufficient numbers of oysters were thus available, experiments were conducted on the development of cultured pearls from the oysters. The oysters were brought to the pearl culture laboratory where they were conditioned in standing sea water and then narcotized. A minor surgery was performed on each oyster to implant a nucleus in its tissues (see Alagarswami 1974; Alagarswami and Qasim 1973). The oysters generally accepted the nuclei, and 3 months after the operation, free spherical cultured pearls were produced for the first time in India.

In the first series of experiments, the nuclei used were imported from Japan, but subsequently efforts were made to produce the nuclei (spherical beads) indigenously from the conch shell (sacred chank, *Xancus pyrum*). The details of the equipment and the method of making beads have been described by Velu, Alagarswami and

Qasim (1973). In the next series of experiments, the indigenously made beads were used as nuclei and the quality of cultured pearls obtained using these beads, was similar to that of the Japanese beads. Recently, pearl oyster spats were also found at Vizhingam, near Trivandrum (Kerala Coast). Investigations undertaken at Vizhingam showed that nylon ropes with free suspended filaments or baskets are most suitable for collecting spats. The collected spats were reared to adult size in about 6 months and free cultured pearls were produced within about 55 days. Here, in addition to imported Japanese beads and conch shell beads, plastic beads were also successfully used as nuclei for producing pearls (Nair 1975).

From the technology of oyster farming and pearl culture, developed entirely from indigenous efforts, it has now become possible to produce cultured pearls on a commercial scale in India.

SEAWEEDS

Although the seaweed resources of India are large (164 genera and 389 species, Srinivasan 1960), at present there is no proper method of their harvesting. The concerned industries employ untrained labour, who remove the seaweeds the way they like. Very often, a particular area is completely denudated resulting in considerable damage of resources. Proper demonstrations are required at the state level for cropping of the seaweeds. There is also a need for some regulation regarding how much seaweeds and of what size should be collected from a particular area.

Table I gives an estimate of the annual yield of seaweeds in certain parts of India for which data are available. As can be seen from the table, the approximate annual yield from the Indian coastline is of the order of 30,000 tonnes. This estimate does not include the rich seaweed resources of Lakshadweep, Andaman and Nicobar Islands and of many other parts where no survey has been done.

TABLE I

Annual yield of seaweed at some places along the Indian coastline

Locality	Total dry weight (tonnes)	Author
Mandapam	329.24	Rao (1973)
Kanyakumari-Colachel	4.55	Koshy and John (1948)
Point Calimere	66.00	Chacko and Pillai (1958)
Tamil Nadu Coast	7.10	Thivy (1960)
Krusadai Island to Hare Island	1,011.72	Rao (1967)
Gulf of Kutch	18,825.50	Chauhan and Krishnamurthy (1968)
Gulf of Kutch	10,000.00	Desai (1967)
Adatra (near Okha)	60.00	Rao *et al.* (1964)
Pamban	1,014.00	Varma and Rao (1962)
Gulf of Mannar	300.00	Desai (1967)

The growing demand of seaweeds by the industries is at present not adequately met from the natural resources, because for a proper functioning of the industries, a continuous supply of dry seaweeds is to be maintained. Restrictions on the export of seaweeds from India to other countries have somewhat helped the situation but the problem has not yet been solved.

The only satisfactory approach, therefore, is to generate extra resources of seaweed by aquaculture. A few attempts towards this direction by Krishnamurthy (1967) and Subbaramaiah and Krishnamurthy (1967) and Rao (1970, 1973 and 1974) have shown very good results. The culture of seaweeds has been done on coir ropes and on wooden frames woven with coir ropes. Fragments of seaweeds are inserted through the twine of ropes throughout its length and in between the meshes. The ropes and frames are then kept in the sea below the surface of water. Within a short time, the seaweeds grow and they are periodically pruned. The yield of seaweed thus obtained is incredibly high, as pruning is done at short intervals. The same rope and frame can be used for a long time.

In India, seaweeds are mainly used for the extraction of agar-agar, alginin and alginate, etc. The edible seaweeds are seldom consumed as food.

Other Organisms

In addition to the groups of organisms mentioned above, there is scope for the culture of some sponges, holothurians and turtles in the coastal waters of India.

Although the introduction of synthetic products has decreased the use of natural sponges, they still find a place in a number of household uses. Moreover, painters, bricklayers, decorators, lithographers and jewellers also use them in fairly large quantities. Marine sponges are abundant in certain regions of India and about 305 species have been recorded from the Indian coast. Of these, a species *Spongia officinalis* var. *ceylonensis* appears to have commercial possibilities because of its softness, absorbent power, elasticity combined with its size and shape. It is widely distributed in the shallow areas of Gulf of Mannar, Palk Bay and Lakshadweep. To increase the quantity of this species so that it could readily be obtained throughout the year, its culture in selected areas of the Gulf of Mannar or other suitable places is advisable. The culture may also help in improving its quality (Thomas 1973). Sponges can be cultured by attaching small sponge-cuttings on to stones or cement discs and placing them at the bottom in shallow areas. In the Mediterranean and in certain parts of the United States, sponge culture is being undertaken commercially (Jacob 1973; Bensam *et al.* 1974).

Beche-de-mer or the cured holothurian is considered a delicacy in some south-east Asian countries. The total production of this holothurian is about 30,000 kg annually and practically all of it is exported to south-east Asia and to other parts of the world.

Holothuria scabra is the only edible species found in India. It grows to about 30 cm in length and 0.5 kg in weight. It is collected by divers or by trawling from February to September in the Gulf of Kutch and along the south-east coast. It is more abundant in the Palk Bay than in the Gulf of Mannar. In the coral reefs and lagoons of Lakshadweep and in the Andamans, large sized holothurians such

as *Thelenota ananas, Holothuria marmorata* and *Actinopyga mauritiana* are found and these seem to be well-suited for making *beche-de-mer*. Transplantation of these larger and commercially important species from Lakshadweep and Andamans to other parts of India would be useful for the production of *beche-de-mer* in India. Artificial breeding of the important species can enhance the production of holothurians further (James 1973).

Turtles are caught in several coastal regions of India, but except for the Gulf of Mannar and Palk Bay, these animals are of little economic importance elsewhere. The species of commercial importance is the green turtle, *Chelonia mydas*. A regular fishery for the green turtle is found in the Gulf of Mannar and it is estimated that on an average about 3000 to 4000 turtles are caught every year between Pamban and Kanyakumari. In the Palk Bay, about 1000 turtles are landed annually between Rameswaram and Mimisal (Jones and Fernando 1973).

Turtle farming is getting popular in several countries, and by adopting suitable techniques, many of the atolls of Lakshadweep can easily be converted into turtle farms.

Conclusion

The present author during the last five years has repeatedly indicated that culture of marine and estuarine organisms is an obvious answer to the problem of protein shortage in the country. However, sea farming, contrary to our expectations, has been put to very restricted use in India. Coastal waters, estuaries and backwaters, where aquaculture could be undertaken, are largely under the control of the Government, except for a small percentage which is privately owned. Investments on sea farming, even on a modest scale, have not been forthcoming either from the public or private sectors. This is simply because of the lack of incentive offered by the Central and State Governments to sea farming. Demonstrations at the national level are required by the Research Institutes to indicate the economics of production of selected species in relation to their existing demand within the country and abroad (export potential).

The ultimate objectives of aquaculture are efficient resource utilization and resource management and there seems little reason why the principles of animal husbandry should not be applied profitably to a wide variety of aquatic species in diversified areas and environments. Certainly it seems far more challenging than either agriculture or poultry farming.

References

Abraham, K. C. (1953). Observations on the biology of *Meretrix casta* (Chemnitz). *J. zool. Soc. India.*, **5**, 163-190.

Alagarswami, K. (1974). Development of cultured pearls in India. *Curr. Sci.*, **43**, 205–207.

Alagarswami, K., and Narasimham, K. A. (1973). Clam, cockle and oyster resources of the Indian coasts. *Proc. Symposium on Living Resources of the Seas Around India., Spl. Publ.* Central Marine Fisheries Research Institute, 648–658.

Alagarswami, K., and Qasim, S. Z. (1973). Pearl culture—its potential and implications in India. *Indian J. Fish.*, **20**, 533–550.

Alagarswami, K., and Qasim, S. Z. (1974). What are pearls and how are these produced? *Seafood Export J.*, **6**(1), 1–10.

Anonymous (1974). *Status of Fishing Industry in Goa, Daman and Diu,* 1972 *and* 1973. Directorate of Fisheries, Panaji, Goa : 1–15.

Arriola, F. J. (1940). A preliminary study of the life-history of *Scylla serrata,* Forskal. *Philipp. J. Sci.,* **73**, 437–456.

Bardach, E. J., Ryther, J. H. and McLarney, W. O. (1972). *Aquaculture,* 868 pp. Wiley-Inter Science, John Wiley & Sons, London.

Bensam, P., Ramdoss, K., and Sundaram, N. (1974). Methods of mariculture. *Seafood Export J.,* **6**(11), 23–31.

Chacko, P. I., and Krishnamoorthy, B. (1954). Observations on *Tilapia mossambica* Peters in Madras. *J. Bombay nat. Hist. Soc.,* **52**, 349–353.

Chacko, P. I., and Pillai, M. (1958). Studies on utilization of seaweed resources of Madras State. *Contrib. Mar. Fish. Biol. St. Krusadai Isl.,* No. 6, **1**, 12.

Chauhan, V. D., and Krishnamurthy, V. (1968). An estimate of algin bearing seaweeds in the Gulf of Kutch. *Curr. Sci.,* **37**, 648.

Costlow, J. D. (1967). The effect of salinity and temperature on survival and metamorphosis of megalops of the blue crab *Callinectes sapidus. Helgolander wiss Meeresunters.,* **15**, 84–87.

Davies, G. (1970). Mussels as a world food resource. *Proc. Symp. Mollusca.* Mar. Biol. Ass. India, Pt. III : 873–883.

Desai, B. N. (1967). Seaweed resources and extraction of alginate and agar. *Proc. Seminar Sea Salt and Plants,* CSMCRI, Bhavnagar, 343–351.

Durve, V. S. (1959). *A study on oysters.* Ph.D. Thesis, University of Bombay, 1–189.

Durve, V. S., and Dharma Raja, S. K. (1965). A study of the dimensional relationship in the clam, *Meretrix casta* (Chemnitz) collected from two localities. *J. mar. biol. Ass. India,* **7**, 69–78.

Evangeline, G. (1967). *Chanos* culture at the brackish water fish farm, Adayar. *Madras J. Fish.,* **3**, 68–115.

FAO (1972). Year book of Fishery Statistics, Vol. **34**, 1–560.

George, M. J. (1967*a*). The Indian spiny lobster. *C.M.F.R.I. 20th Anniversary Souvenir,* 82–86.

————(1967*b*). Observations on the biology and fishery of the spiny lobster, *Panulirus homarus. Proc. Symp. Crustacea,* Mar. Biol. Ass. India, 4, 1308–1316.

————(1973). The lobster fishery resources of India. *Proc. Symposium on Living Resources of the Seas around India., Spl. Publ.,* Central Marine Fisheries Research Institute, 570–580.

————(1975). Observations on the growth in certain penaeid prawns in prawn culture experiments in paddy fields. *Proc. Symp. Est. Biol.,* Cochin, p. 76. (Abstr.).

————, Mohamad, K. H., and Pillay, N. N. (1967). Observations on the paddy-field prawn filtration of Kerala, India, *FAO Fish. Rep.,* **2**, 427–442.

Ghosh, A. (1973). Observations on the larvae and juveniles of the 'Bhekti', *Lates calcarifer* (Bloch) from the Hooghly-Matlah estuarine system. *Indian J. Fish.,* **20**, 372–379.

Gopalakrishnan, V. (1973). Taxonomy and biology of tropical fin-fish for coastal aquaculture in the Indo-Pacific Region. *Coastal Aquaculture in the Indo-Pacific Region,* Ed. T.V.R. Pillay, I.P.F.C., FAO, 120–149.

Hickling, C. F. (1970). Estuarine Fish Farming. In *: Adv. mar. biol.* Vol. **8**, pp. 119–213. F. S. Russell and C. M. Yonge (eds.). Academic Press, London and New York.

Hughes, J. T. (1968). Grow your own lobster commercially. *Ocean Industry,* **3**, 46–49.

Ingle, R. M., and Witham, R. (1969). Biological considerations in spiny lobster culture. *Proc. Gulf. Caribb. Fish. Inst.,* 21st Annu. Sess. (Nov. 1968), 158–162.

James, D. B. (1973). The *Beche-de-Mer* resources of India. *Proc. Symposium on Living Resources of the Seas around India, Spl. Publ.,* Central Marine Fisheries Research Institute, 706–711.

Jacob, P. G. (1973). Sponges—A group of commercially important animals. *Seafood Export. J.,* **5**(4), 23–26.

Jhingran, V. G., and Natarajan, A. V. (1969). A study of the fisheries and fish populations of the Chilka Lake during the period 1957–65. *J. Inland Fish. Soc. India,* **1**, 49–126.

Jhingran, V. G., and Natarajan, A. V. (1973). Role of Chilka Lake Fisheries in the development of coastal aquaculture in eastern India. *Coastal Aquaculture in the Indo-Pacific Region* (Ed. T. V. R. Pillay). I.P.F.C., FAO, 109–115.

Jones, S. (1970). The molluscan fishery resources of India. *Proc. Symp. Mollusca*, Mar. Biol. Ass. India, Pt. III, 906–918.

Jones, S., and Alagarswami, K. (1973). Mussel fishery resources of India. *Proc. Symposium on Living Resources of the Seas around India, Spl. Publ.*, Central Marine Fisheries Research Institute, 641–647.

Jones, S., and Fernando, A. B. (1973). Present status of the turtle fishery in the Gulf of Mannar and the Palk Bay. *Proc. Symposium on Living Resources of the Seas around India, Spl. Publ.*, Central Marine Fisheries Research Institute, 712–715.

Kewalramani, H. G., Sankolli, N. K., and Shenoy, S. S. (1971). On the larval life history of *Macrobrachium malcolmsonii* in captivity. *J. Indian Fish. Ass.*, **1**, 1–25.

Koshy, T. K., and John, C. C. (1948). Survey of *Gracilaria* resources of Travancore. *Dept. Res. Univ. Travancore Rep.* for Sept. 1939–45, 33–55.

Krishnamurthy, V. (1967). Field unit for Marine algal studies at Mandapam camp. *Salt. Res. Industry*, **4**, 139–140.

Krishnamurthy, V. (1969). Seaweed resources of India and their utilization. Presidential Address to the Seaweed Research and Utilization Association of India, Mandapam, pp. 1–6.

Ling, S. W., (1973). A review of the status and problems of coastal aquaculture in the Indo-Pacific Region. *Coastal Aquaculture in the Indo-Pacific Region*, Ed. T. V. R. Pillay, I.P.F.C., FAO. 2–25.

Mohamad, K. H., and George, M. J. (1967). Results of the tagging experiments on the Indian spiny lobster *Panulirus homarus*—movement and growth. Australian/New Zealand meeting on Decapod crustacea, Sydney, October, 24–28, 1967 and *Indian J. Fish.*, **15**, 15–26 (1971).

McLusky, D. S., and Stirling, A. (1973). *Report on I. B. P. Sponsored visit to India.* Univ. of Stirling (U.K.), 1–13.

Menon, M. K. (1954). On the paddy field prawn fishery of Travancore-Cochin and an experiment on prawn culture. *Proc. Indo-Pacific Fish. Coun.* V meeting : 1–5.

Nair, R. V. (1973). On the export potential of elvers and cultured eels from India. *Indian J. Fish.*, **20**, 610–616.

Nair, R. V. (1975). Recent trends in mariculture in India. *Seafood Export J.*, 7(1), 19–36.

Narasimham, K. A. (1969). Studies on some aspects of biology and fishery of the cockle, *Anadara granosa* (Linnaeus) from Kakinada Bay. *Proc. Symp. Mollusca*, Mar. Biol. Ass. India, Pt. II, 407–417.

Ong, K. S. (1964). The early developmental stages of *Scylla serrata* Forskal (Crustacea : Portunidae), reared in the laboratory. *Proc. Indo-Pacific. Fish. Coun.*, **11**, 135–146.

Ong, K. S. (1966). Observations on the post-larval life history of *Scylla serrata* Forskal, reared in the laboratory. *Malaysian Agric. J.*, **45**, 429–443.

Pagcatipunam, R. (1973). Observations on the culture of Alimango, *Scylla serrata* Forskal at Canarine Norte (Philippines). *Coastal Aquaculture in the Indo-Pacific Region* (Ed. T. V. R. Pillay). I.P.F.C., FAO, 362–365.

Pakrasi, B. B., Das, P. R., and Thakurta, S. C. (1964). Culture of brackish water fishes in impoundments in West Bengal, India, *Occ. Pap. Indo-Pacific. Fish. Counc.*, **66**/8, 13 pp.

Panikkar, N. K. (1952). Possibilities of further expansion of fish and prawn culture practices in India. *Curr. Sci.*, **21**, 29–33.

Panikkar, N. K., and Tampi, P. R. S. (1954). On the mouth breeding cichlid *Tilapia mossambica* Peters. *Indian J. Fish.*, **1**, 217–230.

Pantulu, V. R. (1956). Studies on the biology of the Indian fresh water eel *Anguilla bengalensis* Gray. *Proc. natn. Inst. Sci. India.*, **22**, 259–280.

Pillay, T. V. R. (1973). In : *Coastal Aquaculture in the Indo-Pacific Region*, 497 pp. (Ed. T. V. R. Pillay). I.P.F.C., FAO.

Qasim, S. Z. (1972*a*). Ocean harvest. *Indian Fmg.*, **22**(6), 104–111.

Qasim, S. Z. (1972*b*). Are there enough shrimps in the sea? *Seafood Export J.*, **4**(1), 5–17.

Qasim, S. Z. (1973). Can there be famine in the sea? *Seafood Export J.*, **5**(1), 1–10.

Qasim, S. Z., and Achari, G. P. K. (1972). Mussel culture—its potential and implications. *Seminar on Mariculture and Mechanized Fishing*, p. 13 (Abstr.). Dept. of Fisheries, Govt. of Tamil Nadu.

Rahimulla, M., Mohamood, S., and Kabir, S. A. (1944). A note on the breeding habits of the common eel, *Anguilla bengalensis* Gray and Hardy. *Proc. Indian Acad. Sci.*, **B19**, 16–18.

Rajyalakshmi, T. (1960). Observations on the embryonic and larval development of some estuarine palaemonid prawns. *Proc. natn. Inst. Sci. India*, **B26**, 395–408.

Rajyalakshmi, T. (1961). Studies on maturation and breeding in some estuarine palaemonid prawns., *Proc. natn. Inst. Sci. India.*, **B27**, 179–188.

Rajyalakshmi, T. (1968). Try prawn in tanks and inland waters. *Indian Fmg.*, **18**(11), 37–43.

Ramamurthy, S., and Manickaraja, M. (1975). An experiment on the culture of *Penaeus indicus* (Milne Edw.) in the estuarine pond at Mangalore. *Proc. Symp. Est. Biol.*, Cochin p. 77. (Abstr.).

Ranade, M. R. (1964). *Studies on the biology, ecology and physiology of marine clams.* Ph.D. Thesis, Univ. of Bombay. pp. 1–266.

Rao, Srinivasa, Iyengar, E. R. R., and Thivy, F. (1964). Survey of algin bearing seaweeds at Adatra Reef, Okha. *Curr. Sci.*, **33**, 464–465.

Rao, M. Umamaheswara (1967). Seaweed resources of India. *C.M.F.R.I. 20th Anniversary Souvenir*, 125–129.

Rao, M. Umamaheswara (1970). The economic seaweeds of India. *Bull. cent. mar. Fish. Res. Inst.*, **20**, 1–68.

Rao, M. Umamaheswara (1973). The seaweed potentials of the Seas around India. *Proc. Symposium on Living Resources of the Seas around India, Spl. Publ.*, Central Marine Fisheries Research Institute, 687–692.

Rao, M. Umamaheswara (1974). On the cultivation of *Gracilaria edulis* in the nearshore areas around Mandapam. *Curr. Sci.*, **43**, 660–661.

Rao, P. Vedavyasa, Thomas, M. M., and Rao, G. Sudhakara (1973). The crab fishery resources of India. *Proc. Symposium on Living Resources of the Seas around India, Spl., Publ.* Central Marine Fisheries Research Institute, 581–591.

Rao, K. V. (1963). Edible molluscan shell-fish of India. *Indian Fish. Bull.*, **10**, 23–24.

Rao, K. V., Narasimham, K. A., and Alagarswami, K. (1962). A preliminary account of the biology and fishery of the razor shell, *Solen kempii* Preston, from Ratnagiri in Maharashtra State. *Indian J. Fish.*, **9**, 542–579.

Raphael, Y. I. (1973). A preliminary report on the brackish water pond culture of *Scylla serrata* (Forskal) in Ceylon (Abstr.) *Coastal Aquaculture in the Indo-Pacific Region* (Ed. T. V. R. Pillay). I.P.F.C., FAO. 395.

Sreenivasan, A. (1967). *Tilapia mossambica*: Its ecology and status in Madras State, India. *Madras J. Fish.*, **3**, 33–43.

Sribhibhadh, A. (1973). Status and problems of coastal aquaculture in Thailand. *Coastal Aquaculture in the Indo-Pacific Region* (Ed. T. V. R. Pillay), I.P.F.C., FAO, 74–83.

Srinivasan, K. S. (1960). Distribution pattern of marine algae in Indian Seas. *Proc. Symposium Algology*, I.C.A.R., New Delhi, pp. 219.

Subbaramaiah, K., and Krishnamurthy, V. (1967). Laboratory culture of seaweeds. *Proc. Seminar Sea salt and plants*, CSMCRI, Bhavnagar, 321–326.

Subrahmanyam, M. (1972). Experimental studies on growth in *Penaeus monodon* Fabricius. *Seafood Export J.*, **5** (6), 13–19.

Sundaram, K. (1975). Observations on the biology and culture of the green mussel, *Mytilus viridis* Linnaeus (Bivalvia : Mytilidae) in the Ennore estuary. *Proc. Symp. Est. Biol.*, Cochin 4.05, p. 26. (Abstr.).

Suseelan, C. (1975). The prawn culture practices in salt pan reservoirs at Manakkudy near Cape Comorin. *Proc. Symp. Est. Biol.*, Cochin, p. 66, (Abstr.).

Tampi, P. R. S. (1957). Some observations on the reproduction of the milkfish *Chanos chanos* (Forskal). *Proc. Indian Acad. Sci.*, **B46**, 254–273.

————(1960). Utilization of saline mud flats for fish culture. An experiment in marine fish farming. *Indian J. Fish.*, **7**, 137–146.

Thivy, F. (1960). Seaweed utilization in India. *Proc. Symposium Algology*, I.C.A.R., New Delhi, pp. 345–365.

Thomas, M. M. (1972). Growth of the spiny lobster, *Panulirus homarus* (Linnaeus) in captivity. *Indian J. Fish.*, **19**, 125–129.

Thomas, P. A. (1973). The sponge resources of India. *Proc. Symposium on Living Resources of the Seas around India, Spl. Publ.*, Central Marine Fisheries Research Institute, 693–699.

Varikul, V., Phumiphol, S., and Hongpromyart, M. (1973). Preliminary experiments in pond rearing and some biological studies of *Scylla serrata* (Forskal). *Coastal Aquaculture in the Indo-Pacific Region* (Ed. T. V. R. Pillay). I. P. F. C., F. A. O., 366–374.

Varma, R. P., and Rao, K. Krishna (1962). Algal resources of Pamban Area. *Indian J. Fish.*, **9**, 205–211.

Velu, M., Alagarswami, K., and Qasim, S. Z. (1973). Technique of producing spherical shell beads as nuclei for cultured pearls. *Indian J. Fish.*, **20**, 672–676.

Verghese, P. U., Ghosh, A. H., and Das, P. M. (1975). On growth, survival and production of jumbo tiger prawn, *Penaeus monodon* Fabricius in backwater ponds, West Bengal (Kakdwip). *Proc. Symp. Est. Biol.*, Cochin, p. 26. (Abstr.).