HAND BOOK ON AQUAFARMING

SEA WEED
SEA URCHIN
SEA CUCUMBER

THE MARINE PRODUCTS EXPORT DEVELOPMENT AUTHORITY
(Ministry of Commerce, Government of India)
MPEDA House, Panampilly Avenue
P.B. No. 1663, Kochi - 682 015, India
Phone: 311979 Fax: 91-484-313361 Telex: (0885) 6288/6648

CONTENTS

PART I

SEA WEED CULTURE

N. Kaliaperumal
Central Marine Fisheries Research Institute
P.B.No. 2704, Kochi - 682 031
Kerala, India.

SEAWEED CULTURE

Introduction

Seaweeds or marine algae are the primitive type of plants and they grow abundantly in the shallow waters of sea, estuaries and backwaters. They flourish wherever rocky, coral or suitable substrata are available for their attachment. They belong to four groups namely green, brown, red and blue-green algae based on the pigmentation, morphological and anatomical characters. Seaweeds are one of the commercially important marine living and renewable resources of our country. They contain more than 60 trace elements, minerals, protein, iodine, bromine, vitamins and several bioactive substances.

Seaweed uses

The phytochemicals namely agar, carrageenan (agaroid) and algin are manufactured only from seaweeds. The red algae such as *Gelidiella, Gelidium, Pterocladia* and *Gracilaria* yield agar. Some other red algae *viz Hypnea, Eucheuma, Chondrus* and *Gigartina* are the major sources for production of carrageenan. The algin can be obtained from brown algae like *Sargassum, Turbinaria, Hormophysa, Cystoseira, Laminaria, Undaria, Macrocystis* and *Ascophyllum*. These phycocolloids are used as gelling, stabilizing and thickening agents in food confectionery, pharmaceutical, dairy, textile, paper, paint, varnish industries etc. Apart from these biochemicals, other chemical products such as mannitol, iodine, laminarin and fucoidin are also obtained from marine algae. Many protein rich seaweeds such as *Ulva, Enteromorpha, Caulerpa, Codium, Monostroma* (green algae); *Sargassum, Hydroclathrus, Laminaria, Undaria* and *Macrocystis* (brown algae); *Porphyra, Gracilaria, Eucheuma, Laurencia* and Acanthophora (red algae) are used as human food in countries like Japan, China, Korea, Malaysia, Philippines and other southeast Asian countries in the form of soup, salad, curry etc. Jelly, jam, Chocolate, pickle and wafer can also be prepared from certain seaweeds. The food value of seaweeds depends on the minerals, trace elements, protein and vitamins present in them. They also control goitre disease.

Marine algae are also utilised in different parts of the world as animal feed and fertilizer for various land crops. In India, freshly collected and cast ashore seaweeds and seagrasses are used as manure for coconut plantation either directly or in the form of compost especially in the coastal areas of Tamil Nadu and Kerala. Seaweed manure has been found superior to the conventional organic (farm yard) manure. The high amount of water soluble potash, other minerals and trace elements present in seaweeds are readily absorbed by plants and they control deficiency diseases. The carbohydrates and other organic matter present in seaweeds alter the nature of soil and improve its moisture retaining capacity. The liquid seaweed fertilizer obtained from seaweed extract can be used as foliar spray for inducing faster growth and yield in leafy and fleshy vegetables, fruits, orchards and horticultural plants. The trace elements and growth hormones (cytokinin) present in the liquid seaweed fertilizer act as growth promoters and increase the yield by 20 to 30%. It gives successful results on potatoes, Cauliflower, cabbage, brinjal, Lady'sfinger, chillies, grapes etc. In India, seaweeds are now used mostly as raw material for the production of agar and sodium alginate. They are also consumed in the form of agar jelly and porridge.

Seaweed distribution and resources in India

More than 10,000 species of marine algae have been reported from all over the world. It has been estimated that the seaweed resources of the world comprise about 1460 million tonnes (wet weight) of brown algae and 261 million tonnes (wet weight) of red algae. The total annual seaweed production is about 1721×10^4 tonnes (wet weight). The major sources of seaweeds are in the northeast, western central and southeast Atlantic and the eastern central and northwest Pacific regions. India with a long coastline of 6100 km, has a vast resource of seaweeds along her open coasts and estuarine areas. The luxuriant growth of several species of green, brown and red algae occur along the southeast coast of Tamil Nadu from Rameswaram to Kanyakumari, Gujarat coast, Lakshadweep and Andaman-Nicobar Islands. Fairly rich seaweed beds are present in the vicinity of

Bombay, Karwar, Ratnagiri, Goa, Varkala, Vizhinjam, Visakhapatnam and in coastal lakes like Pulicat and Chilka.

About 700 species of marine algae have been recorded from different parts of Indian coast including Lakshadweep and Andaman Nicobar Islands. Of these, nearly 60 species are commercially important seaweeds. From the seaweed resources survey carried out in the intertidal and shallow water areas of east and west coast and also Lakshadweep so far by the Central Marine Fisheries Research Institute (CMFRI) and other research organisations such as Central Salt & Marine Chemicals Research Institute (CSMCRI) and National Institute of Oceanography (NIO), it is estimated that the total standing crop of all seaweeds in Indian waters is more than one lakh tons (wet weight) consisting of 6000 tons (wet weight) of agar yielding seaweeds, 16000 tons (wet weight) of algin yielding seaweeds and the remaining quantity of edible and other seaweeds. The CMFRI and CSMCRI have jointly surveyed the seaweed resources in the deep waters (5 to 22 m depths) of Tamil Nadu coast from Dhanushkodi to Kanyakumari during 1986-1991. A total number of 100 algal species occurred in the deep waters and the total estimated standing crop from 1863 sq. km area was 75,372.5 tons (wet weight). The quantitative analysis of economically important seaweed encountered in this survey reveals the feasibility of commercial exploitation of *Gracilaria, Sargassum and Hypnea* from deep waters and their utilization for the production of agar, sodium alginate and carrageenan by the Indian seaweed industries.

The CMFRI has also conducted seaweed resources survey in 63 estuaries and backwaters from Madras to Athankarai in Tamil Nadu and Pondicherry during 1988-89. The agarophytes *Gracilaria arcuata, Gracilaria verrucosa* and carrageenophyte *Hypnea valentiae* occur in harvestable quantities in some of these estuaries and they could be exploited for commercial utilization.

Seaweed industries and commercial exploitation of seaweeds in India

There are a number of agar and algin producing seaweed industries situated at different places in the maritime states of Tamil Nadu, Andhra Pradesh, Kerala, Karnataka and Gujarat. Now the red algae *Gelidiella acerosa, Gracilaria edulis, G. crassa, G. foliifera and G. verrucosa* are used for extraction of agar and species of *Sargassum* and *Turbinaria* for sodium alginate. All the seaweed industries depend on the raw materials being exploited from the natural seaweed beds occurring in the southeast coast of Tamil Nadu (from Rameswaram to Kanyakumari and Gulf of Mannar islands). The commercial harvesting of seaweeds from these areas is going on since 1966. The data collected by the CMFRI on the seaweed landings of Tamil Nadu from 1978 onwards show that the quantity of agar yielding seaweeds landed annually varied from 248 to 1289 tons (dry weight) and algin yielding seaweeds from 651 to 5537 tons (dry weight) during the years 1978 -90.

Since 1980 many agar and algin extracting industries are coming up in India. As the demand for raw material of agar yielding seaweeds is more and their natural resources along Tamil Nadu coast are less, there is paucity in supply of raw materials to agar industries. This can be overcome by exploiting the agar yielding seaweeds from other localities along the east and west coast including Lakshadweep and Andaman - Nicobar Islands and also by cultivating them on large scale. The quantity of algin yielding seaweeds *Sargassum* and *Turbinaria* available in Tamil Nadu and other parts of Indian coast including Lakshadweep and Andaman-Nicobar is quite adequate to meet the raw material requirement of algin industries as only about 50% of standing crop is harvested from Tamil Nadu coast.

Seaweed Culture

Seaweeds are cultivated for supply of raw material to the seaweed industries and for their use as human food. There are several advantages in the cultivation of seaweeds. In addition to a continuous supply of alga, crops of single species could be maintained continuously. By adopting scientific breeding and other modern techniques of crop improvement, the yield and quality of the seaweed could also be improved. Further, if seaweed culture is carried out on large scale, natural seaweed beds could be conserved purely for obtaining seed materials.

There are two methods for cultivation of seaweeds; one by means of vegetative propagation using fragments from mother plants and the other by different kinds of spores such as zoospores, monospores, tetraspores and carpospores. In the vegetative propagation method, the fragments are inserted in the twists of ropes, tied to nylon twine or polypropylene straw and cultured in the nearshore areas of the sea. The fragments are also cultured by broadcasting them in outdoor ponds and tanks. The fragment culture method is a simple one and gives quick results. In the culture of seaweeds from spores, the spores are first collected on nets, bamboo splits, polypropylene straw and other suitable substrata; reared to germlings or young plants in the hatchery/nursery and then transplanted to the desired sites where they grow to harvestable size plants. In this method the spores take more period for their development to harvestable size plants when compared with the growth of fragments in the vegetative method.

Seaweed cultivation in foreign countries

The seaweed culture in abroad at present is almost entirely confined to the Orient, reaching its peak of sophistication in Japan and China. The seaweeds under commercial scale cultivation in the Indo-Pacific region are *Porphyra* and *Eucheuma* (red algae); *Undaria* and *Laminaria* (brown algae); *Caulerpa, Enteromorpha* and *Monostroma* (green algae). The important seaweeds for which commercial scale cultivation has been developed are *Gracilaria, Hypnea, Chondrus* and *Gigartina* (red algae) and *Macrocystis* (brown algae). The Japanese and Korean *Porphyra* industry, the Chinese *Laminaria* industry and the Philippine *Eucheuma* industry are now mainly based on the cultured seaweeds. The techniques adopted for cultivation of different species of seaweeds on commercial scale are given below.

Porphyra

Many species of *Porphyra* are cultivated on very large scale in countries like Japan, Korea and Taiwan. The plants are induced to produce monospores in nursery tanks by various thermal and chemical treatments. The monospores get attached to synthetic fibre net by passing the nets through the tanks containing spores. The nets are stored in 20 to 24°C for several months with the monospores remaining viable. This preparation of seedlings is done during winter from December to March. Then these nets with seedlings are hung horizontally on floating racks which are made of bamboo and set in shallow coastal areas where the water is clear and well protected from storm and heavy wave action. Within 15 to 20 days after setting the nets, the seaweed grow to 10 to 15 cm in length and the first harvest is made. The remaining plants continue to grow and harvest is repeated 3 to 4 times before the net is replaced.

Eucheuma

This red alga is cultured on commercial scale in Philippine waters. The seedlings of *Eucheuma* weighing 100 to 150 gm are tied at one end of thin plastic strip (polypropylene straw) and the other end is tied to the nylon monolines installed 0.5 to 1.5 m above the bottom of the sea using mangrove wooden poles. Once the plants reach a weight of 1200 to 1500 gm, they are harvested by pruning to 500 gm and the process continues.

Undaria

This brown alga is commercially cultivated on large scale in Japan and Korea by adopting the artificial spore collection technique developed in 1960. Twine frames made of synthetic fibre yarn of 2-3 mm diameter are used for zoospore collection and culture of germlings. The zoospore from mature plants of *Undaria* are released in concrete or plastic tanks filled with seawater and they are collected on twine frames. The seedlings which develop on twine frames and then the frames are transferred and suspended in the sea from a raft to raise the germlings into healthy young plants until they grow to 2-3 cm in length. During autumn (September-November) when the water temperature in the sea falls below 20°C, seedling twines are attached to 10-20 mm diameter synthetic fibre rope at suitable intervals. Sometimes the twine is cut into short pieces of 5-6 cm length and inserted in twists of the ropes. The harvest is made when the plants grow more than 50-60 cm in length by hauling the rope to a boat and cutting the plants with sickle.

Laminaria

Many species of brown algae is commercially cultured on large scale in China and Japan of which *Laminaria japonica* is the common one. The basic technique involved in artificial propagation of *Laminaria* consists of collecting zoospores from mature plants in late autumn and lodging them on short ladders made of bamboo split and hung from floating rafts in the sea. Young plants appear on the ladders in January and they reach harvestable size of more than 3 m in length in 4 to 5 months. The harvest of fully grown plants is made from boats.

Caulerpa

This edible green alga is commercially cultivated in ponds connected to the sea through feeder canal in Philippines since 1970. The chopped fresh pieces of mature *Caulerpa lentillifera* are planted in the ponds (7000 kg/ha of pond) and the water level of the ponds is maintained to a minimum depth of 50 cm by adjusting flow of seawater by the sluice of the feeder canal. Fertilizers like NPK are used to enhance the growth of *Caulerpa* and fertilizing is done once in a month. The harvesting of the crop is made in about 2 to 3 months from a small flat bottom boat using a scoop net.

Enteromorpha and *Monostroma*

These edible green algae are cultured on commercial scale in Japan similar to *Porphyra* on the nets suspended horizontally at intertidal level near river mouths. They are cultured along with *Porphyra*. *Monostroma* is cultured separately also.

Gracilaria

This agar yielding red alga is cultured successfully at Taiwan in shallow coastal flats and ponds since 1962. The species most commonly cultured is *Gracilaria verrucosa* . *Gracilaria gigas* is also cultured in some areas. Each plant is cut into pieces and they are planted uniformly on the bottom of the ponds usually in April. 3000 to 5000 kg of fragmented plants are planted in a pond of one hectare size. They are usually fixed on bamboo sticks planted on the bottom or covered with old fishing nets to prevent them drifting to one side or one corner of the ponds. Either organic or inorganic fertilizer is used to accelerate the growth. The harvest is made by hand or by using scoop nets in 10 days from June to December.

In Malaysia *Gracilaria cylindrica* and other species of *Gracilaria* are cultured by spore collection technique. Spore setting is done in the hatchery on nylon or linearly stressed polyethylene raffia which are wound on PVC frames. These spore bearing lines are transferred to the culture site in the shore area and their ends are attached to stakes. The spores grow and reach harvestable size plants after four months. The first harvest is done after 4 months of outplanting and subsequent harvests are also made.

Hypnea, Chondrus and *Gigartina*

These are carrageenan yielding red algae. *Hypnea musciformis* is cultured in outdoor plywood tanks at Summerland key and Florida. A continuous flow of seawater is supplied to the tanks and it is agitated with continuous flow of compressed air pumped through a sparger located along the deep end of culture tanks. The culture tanks are enriched with sodium nitrate, ammonium nitrate or ammonium sulphate as source of nitrogen and trisodium phosphate as phosphate source. In Philippines *Hypnea* is cultivated in protected areas of the sea by suspending the plants. Similar to *Hypnea, Chondrus crispus* and *Gigartina* spp. are propagated in detached form in agitated ponds or tanks.

Macrocystis

In the United States, seedlings of *Macrocystis* are cultured on plastic rings and the rings are set on rocky substratum of the sea using underwater epoxy cement. Recently methods for mass culture of *Macrocystis* germlings and their disposal in the sea have been developed. The germlings attached to polyethylene film substrate or glass fibre cloth substrate are cultured in a refrigerated room in long trays through which chilled, filtered and sterilized seawater is passed. Then the germlings are scraped from the substrates, suspended in seawater and dispersed on rocky bottom by pouring them down through a hose. Some times dispersal is done with the help of divers.

Seaweed culture in India

In India only experimental scale cultivation of a number of agar, carrageenan, algin and edible seaweeds such as *Gracilaria, Gelidiella, Hypnea, Cystoseira, Hormophysa, Caulerpa, Ulva* and *Acanthophora* is attempted since 1964 by the CMFRI, CSMCRI and other research organisations at different field environments using various culture techniques. These experiments reveal that *Gelidiella acerosa* can be successfully cultivated on coral stones and *Gracilaria edulis, Hypnea musciformis* and *Acanthophora spicifera* on long line coir ropes and coir rope nets. The methods of cultivation and yields for these four species are given below.

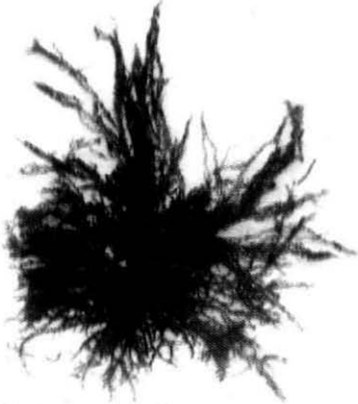
Gracilaria edulis

Cultivation of *Gracilaria edulis* was carried out by the CMFRI in the nearshore areas of Gulf of Mannar and Palk bay at Mandapam. These experiments revealed that *G. edulis* can be successfully cultivated on commercial scale in the open shore environments during November to March in Gulf of Mannar and during June to September in Palk Bay side of Mandapam area. The seaweed was cultivated on coir rope nets, HDPE rope nets and nylon monolines. The fragments of the plants were directly inserted in the twists of coir rope nets, tied at mesh intersections of HDPE rope nets with nylon twine and hung on nylon monolines using plastic strips (Polyethylene straw). In these experiments a maximum yield of 14 fold increase and an average yield of 3 fold increase over the quantity of seed material introduced were obtained after 80 days and 60 days respectively.

In this method one kg of seed material would yield on an average 3 kg/m^2 of net after 60 days. In one hectare area of nets (1000 nets) 30 tons of fresh *G. edulis* could be obtained in one harvest. Six harvests could be made in a year.

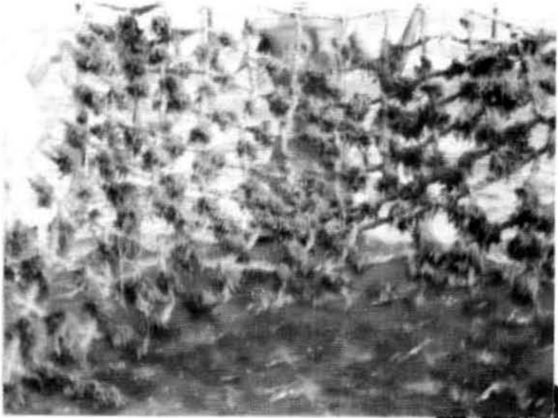
For cultivation in one hectare, 1000 nets of 5 x 2 m size, 2000 casuarina poles of 1.5m height and 10,000 kg of fresh seed material (for initial introduction) are required. The cost of 2000 casuarina poles is Rs. 16,000 and cost of 1000 coir rope nets is Rs. 40,000. The seed material will be collected for the initial introduction from the natural beds and from the cultured crop for subsequent seeding. Wages for fabrication, seeding,

Turbeneria ornata



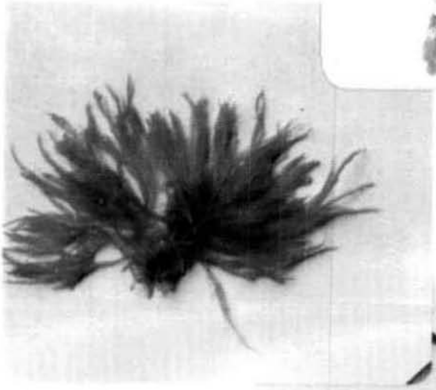
Hypnea musciformis

Ulva lactuca

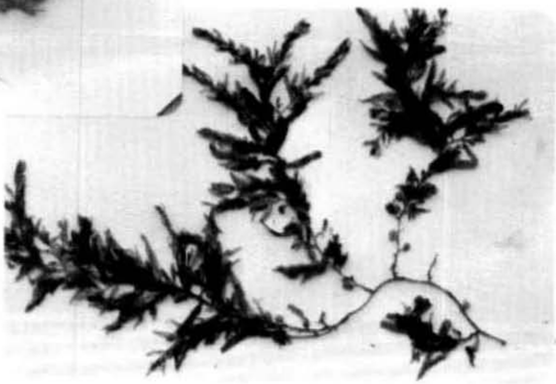


Gracilaria edulis

Sargassum ilicifolium



G. arcuata



S. tenerrimum

harvesting and maintenance of the seaweed farm for 4 persons at the rate of Rs. 15 per day for 360 days works out to Rs. 21,600. The total expenditure for one year would be Rs. 78,000 including miscellaneous expenditure of Rs. 400.

The estimated cost is arrived at on the assumption that a minimum of four harvests could be made in a year. A total of 120 tons (wet weight) of crop could be obtained from four harvests in a year when the yield is 3 kg / m2. If the seaweed is dried (75% moisture) and marketed at a rate of Rs. 3000 per ton, the net profit would be Rs. 12,000 for one year. The profit will be high when agar is produced from the cultured seaweed and then marketed.

Attempt was also made by the CMFRI to cultivate this species on long line coir ropes and nets in the lagoon of Minicoy Island of Lakshadweep by vegetative propagation method. Very encouraging results indicating high potential of more than 8 fold increase in yield was obtained after 60 days growth. The pre-monsoon (March to June) and post monsoon (October to February) seasons are found suitable for successful farming of this agar yielding seaweed on commercial scale.

G. edulis was cultivated by the CSMCRI in a sandy lagoon at Krusadai Island near Mandapam on long line ropes. Fragments of 2.5 to 3.0 cm length removed from the apices of healthy plants were inserted in the twists of ropes. These seeded ropes were tied to bamboo poles planted to the sea bottom and adjusted at a level of one foot above the bottom. The plants attained a length of 35-40 cm in about 5 months. Three harvests were made at the end of 5,8 and 10 months after planting and the total harvest during one year was about 3.5 kg from one meter length of rope.

Recently *G. edulis* culture by spore shedding method was carried out by the CMFRI at Mandapam. The tetraspores and carpospores were liberated from mature plants on circular cement blocks and cultured to germlings in the laboratory. Then the cement blocks with germlings were transferred to the sea and tied to coir ropes. Young plants appeared on the cement blocks after one month and they grew to harvestable size within another 4 or 5 months.

Gelidiella acerosa

This agarophyte was cultured by the CMFRI by tieing small fragments of the plants along with their substratum (coral piece) to coir ropes interwoven on G.I. pipe frames. The frames were tied in submerged condition to poles fixed in the inshore waters. The plants reached harvestable size after 75 days and the yield was one fold increase over the quantity of seed material used. The fragments of the seaweed were tied at the mesh intersections of HDPE rope nets and introduced at 4 m depth in floating condition with the help of plastic buoys and anchors. Two fold increase in yield was obtained after 60 days growth. The fragments of this red alga were also tied to nylon twines at regular intervals. The seeded twines were wound on the nails fixed to small coral stones, which were kept in iron cages and cultured at 2 m depth in the sea. The plants reached harvestable size after 5 months with more than 3 fold increase in yield.

Experimental field cultivation of *G. acerosa* was also done by the CSMCRI in the nearshore area at Ervadi using coral stones as the substratum. An annual yield of 33 fold increase over the seed material was recorded in these experiments and the economics is available with CSMCRI.

Hypnea musciformis

This carrageenan yielding red alga was cultivated by the CSMCRI in the lagoon of Krusadai island. Vegetative fragments of *H. musciformis* were used as seed material and cultured in long line ropes. Four fold increase in biomass was obtained after 25 days growth.

Acanthophora spicifera

This edible and carrageenan yielding red alga was cultivated by the CMFRI in the nearshore area of hare Island near Mandapam at 1 m depth following vegetative propagation method. Vegetative fragments tied with polypropylene straw were fastened to nylon monolines. The plants reached harvestable size in 25 days and the yield was 2.6 fold increase over the weight of seed material introduced. This plant was also cultured successfully in pond at Mandapam. The pond was connected to the sea through a feeder canal and hence there was regular inflow and outflow of seawater depending on the high tide and low tide respectively. The fragments of the plants were tied at the mesh intersections of HDPE rope nets with nylon twine and the seeded nets were tied in submerged condition to the palmyra poles erected in the pond. The seedlings grew to harvestable size after 45 days yielding 3.6 fold increase over the quantity of seed material in the latest harvest. The remnants of the plants on the nets were allowed to grow for another one month and the second harvest was made which yielded more than 2 fold.

Post harvest technology of seaweeds

The harvested seaweeds are brought to the shore and dried on the beach. The dried seaweeds are weighed, packed in gunny bags and despatched to seaweed industries. The percentage of moisture content and purity decide the price for seaweeds. The rate for dried *Gelidiella acerosa* ranges from Rs. 7000 to 9000 for *Gracilaria* from Rs. 2500 to 3000 and for *Sargassum* and *Turbinaria* from Rs. 1200 to 1500. The agar fetches a price of Rs. 220 to 400 per kg and sodium alginate Rs. 80 to 100 per kg depending on the grade and their qualities. The process for extraction of agar, carrageenan and algin are outlined below.

Agar

The seaweeds are cleaned to remove other unwanted algae and foreign matters and washed thoroughly before extraction of phytochemicals. For the extraction of agar, the washed seaweeds are leached in soft water and boiled in fresh water by passing steam. The agar gel is collected in trays, cut into pieces after it is cooled at room temperature and kept in cold storage for 1 or 2 days. The trays containing frozen agar are removed from the cold storage, thawed to remove suspended impurities and then dried in the sun. The dried agar strips are bleached with sodium hypochlorite or chlorine water and sun dried again. Agar is marketed as strips or as powder.

Carrageenan

The cleaned dry seaweed in stainless steel is heated under milk alkaline condition on a boiling water bath. The heated seaweed sample was blended to a paste and heated further. Filter aid is added to the mixture, stirred and filtered hot under pressure. Sodium chloride solution is added to the filtrate. The mixture is poured with rapid stirring into twice its volume of isopropanol. The carrageenan precipated is strained through fine cloth, washed twice with isopropanol, shredded, dried overnight in a oven, weighed and ground to powder.

Algin

For extraction of alginate, the algae is maceraed with ten times the weight of sodium carbonate and the extract is acidified to obtain alginic acid. It is mixed with either sodium or calcium salts to make sodium or calcium alginate. In another method, the seaweeds are first treated with acid or calcium chloride to reduce the salt content. Sodium alginate in crude form extracted by digestion with sodium carbonate is treated with Calcium chloride solution to form calcium alginate and then acidified before converting to sodium alginate.

Seaweed harvest calender

As now the demand for raw material from agar manufacturing industries is more, the agarophytes *Gelidiella acerosa* and *Gracilaria edulis* are being over exploited from Tamil Nadu coast. Because of the extensive and unresctricted commercial harvest of these seaweeds throughout the year, there is depletion in the stock of these red algae from the natural seaweed beds in Mandapam area during recent years. In order to conserve the natural stock of the commercially important agar and algin yielding seaweeds in Tamil Nadu coast and also to get consistant crop every year, the harvest calender (Table 1) should be followed for commercial exploitation of these seaweeds. This will ensure the regeneration and regrowth of seaweeds by vegetative and reproductive growth to harvestable size plants for the next harvesting season. A single harvest in a year is recommended for some years for *Gelidiella acerosa* and *Gracilaria* spp. However, in areas where there are rich growth of these algae, harvesting may be made twice in a year as given in Table 1.

Table 1. Calender for commercial harvest of economically important seaweeds from Tamil Nadu coast

Sl. No.	Seaweed	Period of occurence	Suitable period for harvest
Agarophytes			
1.	*Gelidiella acerosa*	Throughout the year	January to March & July to September
2.	*Gracilaria edulis*	-do-	January to March & August to September
3.	*Gracilaria crassa*	- do-	- do -
4.	*Gracilaria foliifera*	- do -	- do -
5.	*Gracilaria corticata var. corticata*	- do -	June to August & November to December
6.	*Gracilaria verrucosa*	March to November	May to August
Alginophytes			
7.	*Sargassum wightii*	Throughout the year	October to December
8.	*Sargassum myriocustum*	- do -	May to August
9.	*Sargassum ilicifolium*	- do -	July to September

Contd...

Sl. No.	Seaweed	Period of occurence	Suitable period for harvest
10.	*Turbinaria conoides*	Throughout the year	October to December
11.	*Turbinaria ornata*	- do -	October to December
12.	*Turbinaria decurrens*	- do -	December to January
Carrageenophytes			
13.	*Hypnea musciformis*	- do -	December to March
14.	*Hypnea valentiae*	- do -	January to March

Transfer of Technology on seaweed culture and Training in seaweed culture and utilization

The culture technology developed for *Gracilaria edulis* by the CMFRI was transferred to the local fishermen of Mandapam and nearby fishing villages under the Lab-to-Land programme of the Institute. The CMFRI is also organising short term training course every year on seaweed culture and utilization to the interested seaweed utilisers, private entrepreneurs and Govt. officials.

Prospects

The bays and creeks present in the open shore along the east and west coast, lagoons of coral reefs in the southeast coast of Tamil Nadu, Andaman-Nicobar Islands and atolls of Lakshadweep have immense potential for cultivation of seaweeds where commercial culture could be undertaken by the seaweed utilisers and private entrepreneurs by availing the financial assistance from banks and other funding agencies connected with rural development programmes. Seaweed cultivation on large scale could not only augment supply of raw material to the seaweed industries, but also provide employment to the coastal population which will help in improving their economic status and thus help in rural upliftment. The edible seaweeds such as *Porphyra, Caulerpa, Ulva, Enteromorpha and Acanthophora* can also be cultivated and used for human consumption in our country.

The untapped algal species like *Gracilaria verrucosa, Hypnea, Cystoseira, Hormophysa, Ulva, Enteromorpha* and *Caulerpa* could be exploited from their natural beds and used for extraction of agar, carrageenan, sodium alginate. In India at present only agar and sodium alginate are produced from seaweeds. The other phytochemicals particularly carrageenan can be produced by utilising the huge resource of *Hypnea* spp occurring in our waters. The edible seaweed products like jelly, jam, pickle, wafer etc can also be prepared and marketed.

The brown algae *Laminaria* and *Macrocystis* are used for production of methanol in some developed countries. The species of *Sargassum* and *Turbinaria* available in large quantities at different parts of Indian coast could be used for this purpose. The huge quantity of cast ashore seaweeds from our coastline may be utilised as a source of energy for producing methanol, hydrogen and biogas and as fodder, manure and for liquid seaweed fertilizer. The seaweeds may also be used for extraction of bioactive agents and producing many important pharmaceutical products.

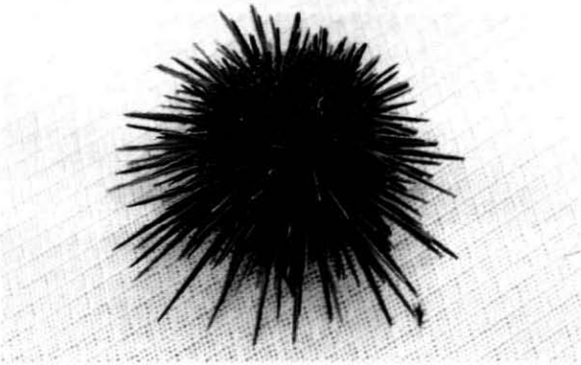
There is very good demand for certain seaweeds in foreign countries such as Japan which are now under exploited or unexploited in our country. Hence they may be exploited and exported to earn foreign exchange to the nation. At present some quantities of agar and sodium alginate are also exported. The seaweed industries in India could not produce the required quantity of agar and sodium alginate (particularly agar) either for local consumption or for export due to paucity of raw material. Hence importing of raw material from other countries could also be attempted so that production of these phyto chemicals could be increased to meet the local requirement of our country and to boost the export of these value added marine products.

PART II

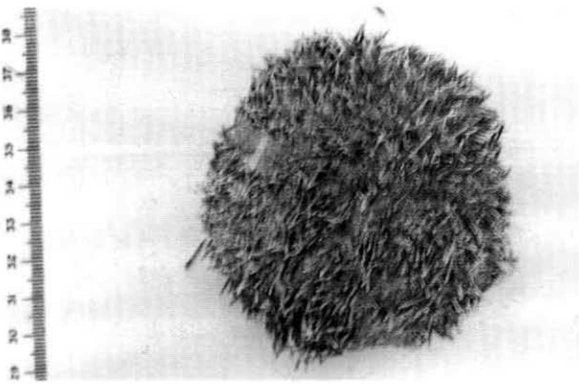
SEA URCHIN CULTURE

D.B. James
Central Marine Fisheries Research Institute
P.B.No. 2704, Kochi - 682 031
Kerala, India.

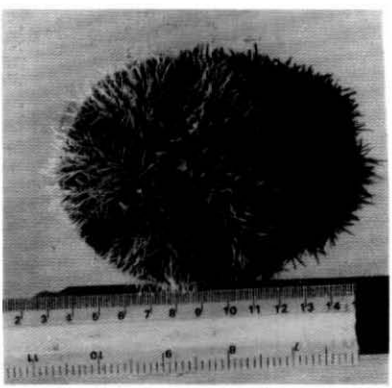
Stohopneustes variolaris



Toxopneustes piliolus



Tripneustes gratilla



SEA URCHIN CULTURE

1.1. Introduction

Ripe Sea urchin eggs are considered as a delicacy by the Japanese and one kilogram of the same costs 200 U.S. Dollars. According to the FAO's annual statistics for 1984 approximately 54,000 tonnes of sea urchin eggs were harvested. Although it has excellent export potential very little information is published on the subject. James (1989) summerised all the information available on the industry. Although there are more than 50 species of sea urchins from the shallow waters of India there is no export of the eggs from this country. On the mainland of India and in the Andaman and Nicobar Islands and also in the Lakshadweep valuable species of sea urchins exist whose eggs can be exported profitably. There is an ever increasing demand for this product in the global markets. It is gratifying to note that in recent years the local export companies are evincing keen interest in this product and some of the Japanese have also come for on spot study of our resources.

1.2. Resources, Cultivable species, Biology and Exploitation

The eggs of sea urchins like *Pseudocentrus depressus* and *Hemicentrotus pulcherrins* are said to be very tasty and valuable. Another sea urchin *Acanthocidaris crassispina* which is used for sea urchin industry in Hong Kong is said to be moderately good. However the above species are not available in the seas around India. In the world 14 species belonging to 10 genera are found to be edible. In India the eggs of four species can be tried on experimental basis. A field key is given below to identify the species based only on the colour and external appearance.

Field key to the Indian species

1. Black in colour with long spines .... *Stomopneustes variolaris*

1'. Spines small, colour not entirely black 2

2. Looks more like a flower under water, hand becomes numb on handling due to toxins ....*Toxopneustes pileolus*

2'. Does not look like a flower under water, no danger in handling in live condition 3

3. Spines white and short .... *Tripneustes gratilla*

4. Spines somewhat long and banded ....*Temnopleusrus toreumaticus*

Stomopneustes variolaris

This species is characteristic of rocky shores. It is abundant in Visakhapatnam, Muttom near Cape Comorin and also at Karwar where the shore is rocky. It is somewhat gregareous and bores into rock for protection against wave action. At Visakhapatnam a resource of 1224 metric tonnes of live material is estimated in 30 kilometer coastline at an average of 8.5 numbers per sq.m. It is found in good numbers in Andamans around Port Blair and also found in the Gulf of Mannar and Lakshadweep. The concentration of this sea urchin is more in the crevices of rocks and sheltered areas than in open rocky coasts. The diameter of the shell is 100 mm. and therefore the quantity of eggs is considerable.

Toxopneustes pileolus

This species is more valuable than the previous species for the eggs. In some of the Islands of Lakshadweep this species is abundant in the lagoons. This species is collected from the Islands of Chetlat, Kiltan, Kadamat, Amini and Kalpeni. It is likely to occur in all the Islands of Lakshadweep. This species occurs in good abundance in the lagoon of Amini Island. At some places 3-5 numbers are distributed per sq. m. It grows to a large size and each specimen weighs 200-300 g. Ripe eggs in large specimens weigh nearly 200 g. It is also known from the Gulf of Mannar and the Andaman and Nicobar Islands.

Temnopleurus toreumaticus

This species is distributed in the Gulf of Mannar, Palk Bay and the Lakshadweep. Large quantities of this species are caught in the fishing trawlers from the Palk Bay. The shell has a diameter of 40 mm. A few years back this species was purchased in good quantities for its eggs.

1.2.1. Exploitation

In India practically there is no exploitation for sea urchins since they are not locally consumed, and the potential for export has not been tapped.

However, the fisherman near Cape Comorin collect *Stomopneustes variolaris* for the shell which is used as curios. They remove the spines and clean the shell which becomes white in colour. This can be used as ash trays also. Some of them eat the ripe eggs in raw condition.

The timing of harvest of the eggs is very important and the quality and quantity depends on the right time of harvest. When the eggs reach maximum weight it should be harvested. Males and females can be separated based on the colour and consistency of the eggs. However it is not possible to tell the stage of development without opening the shell. So proper records regarding the ripening of the egg should be maintained. An interesting phenomenon is observed regarding the release of eggs. When the first sea urchin releases the eggs this induces the other sea urchins to release their eggs whether the egg is ripe or not.

The method of harvesting sea urchins vary with locality and size of operation. Sea urchins are collected by divers using snorkel and SCUBA equipment.

1.3. Farming Methods

1.3.1. Natural seed resources and collection methods

Seed of sea urchins is often encountered in the algal collections since sea urchins are vegetarians and they feed on algae. Seed of *Stomopneustes variolaris, Salmacis virgulata* and *Temnopleurus toreumaticus* are often collected with algae. Seed of *Stomopneustes variolaris* is collected during the month of October and the diameter of the shell varied from 11-16 mm. Seed of *Salmacis virgulata* is collected in July. Sometimes large quantities of seed of *Temnopleurus toreumaticus* is collected in the drag net and also trawl nets. The best way to collect seed of sea urchins is to use drag net and *Thallu Vallai* over algal beds. Also smaller trawl nets can be operated on algal beds for shorter durations to collect the seed.

1.3.2. Hatchery technology for seed production

Inducing the sea urchins is relatively simple. Larvae can be produced by stripping the gonads. A piece of shell with ripe gonad induces them to release the eggs. The larvae can be fed on mixed culture of diatoms. Sea weeds are given when the shell diameter is 3 mm. since the yield after feeding on seaweeds is extremely good.

1.3.3. Nursery rearing

Favourable results can be obtained by piling up rocks in suitable site or by building a beach in a small area and releasing the sea urchins in these areas. They can be fed by putting seaweed in a net and fixing it securely so that it will not be washed away by waves. Such suitable areas have to be first located for nursery rearing.

1.3.4. Grow-out systems

Raft type culture is done for sea urchins. A suitable location for this type of culture must have strong flow of sea water. The area should be easily accessible. The raft can be built in the usual way. It's size should be large enough to withstand damage but not so large as to cause interference with the flow of sea water inside the raft. The sea urchins will be placed in a basket. The mesh should be of standard size. The basket should be set at a depth of approximately 4 m. in areas of 7-10 m. depth. Sea urchins feed during nights. Seaweeds should be put in the baskets for feeding. They should be fed once in ten days. If the seaweed discolours or wither it has to be changed. The daily ration for sea urchins should be about 3% of their total weight.

Seed of *Salmacis virgulata* was reared in Aquarium tanks at Mandapam. The diameter of the shell increased to 27 mm in 84 days. Growth in natural environment is expected to be faster.

1.4. Post Harvest Technology

1.4.1. Utilization

The sea urchin eggs should be processed very quickly after it is collected within four to five hours. Eggs are taken by breaking the shell with a knife, proceeding carefully so as not to damage the delicate eggs. The eggs are separated from the shell by tweezers. It is reported that the Japanese have mechanised the removal process but in any case it must be done carefully since the appearance of eggs is very important for the Japanese market. After removing, the eggs are placed on a draining surface and washed in ice water before it is graded and packed fresh or processed. The eggs are graded by colour, bright orange ones are more desirable. When the colour tends to be red it indicates a high fat content which in turn shortens the shelf life. Temperature is an important factor in handling and processing the eggs intended for the fresh market. The eggs must be kept from losing water and the outer bag of egg is kept intact all the while maintaining good flavour. Some chemical treatment are also possible.

Air freight is a must for fresh sea urchin eggs which has to be transported to long distances. Spacing is important as the delicate product must be kept from jostling and allowed to drain while being kept moist and cold. Live sea urchins can be refrigerated and air lifted. This method is used by Canadian harvesters shipping to France. Sea urchins can be kept in cold running sea water without food for two weeks without decreasing the quality and quantity of the eggs.

Sea urchin eggs should be frozen before shipment. After thawing the eggs softens resulting in undesirable odours and bitter taste if preventive measurers are not taken.

Several other ways of processing and preserving the eggs are also employed. It may also be salted. This is often the method chosen for low quality and it is not intended for the fresh market. The eggs are sometimes steamed and then frozen and used as an alternative for the fresh eggs. It can also be preserved in alcohol but this changes the product considerably making it unsuitable for fresh market.

The egg is eaten raw with a drop or two of lemon juice or with soy sauce. In Japan the sea urchin egg is known as *Uni* and the fermented egg is eaten with rice. Raw *Uni* is eaten by keeping in the middle of *Sushi* which is cooked rice, wrapped in dried seaweed.

1.4.2 Marketing

In the past, limited areas of the world valued sea urchin egg and obtained their supply locally. Now the demand exceeds supply in some places and new market for under utilised resource of the sea has been recognised.

Japan and Korea are the largest consumers of the sea urchin eggs. Japan also harvests and processes more eggs than any other country but the demand is so strong that they must import supplies. Because of their commanding position in the market Japan is able to set standard of quality and price.

A number of countries export sea urchin eggs and these include the United States, Canada, North and South Korea, the Philippines, Chilie, Mexico, Australia and New Zealand. The shelf life of the egg is only three hours and therefore it has to be air lifted. This means that all the steps from harvest to market must be accomplished in this brief time. Less valuable forms of eggs may be shipped frozen or preserved in other ways and these can be sometimes shipped by surface. In 1988 fresh sea urchin egg is sold at the rate of 10 US $ for 50 g in retail outlets in Japan. This works out to 200 US $ per kg. Sea urchin imports by Japan during 1985-1987 is given below in Table II.

Table II. Sea urchin imports by Japan during 1985-1987 in metric tonnes

Country	1985	1986	1987
Korea RP	1991	1158	1110
Korea DPR	258	239	252
PR China	145	225	194
Taiwan PC	55	61	18
Hong Kong	26	57	44
Phillippines	37	79	65
Canada	148	176	190
USA	888	1243	1564
Mexico	19	98	125
Chilie	183	263	122
Australia	-	3	138
Turkey	-	0004	-
Total	2857	3601	3697

1.5. Prospects

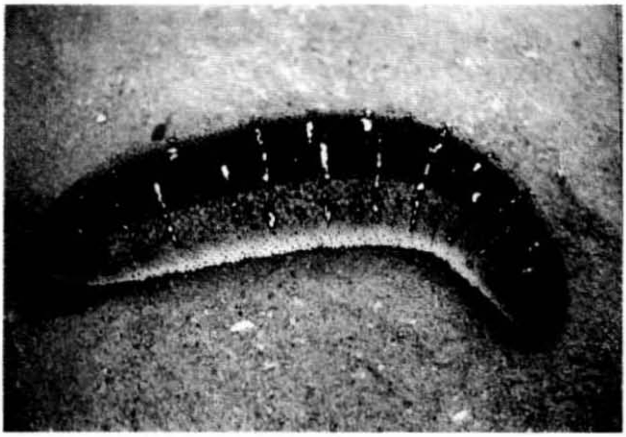
There are excellent prospects for the export of sea urchin eggs from India. James (1990) summarised all information regarding resources, harvesting, recovery, handling, processing of eggs, utilization, mariculture potential, export and marketing of sea urchins in a popular article. As stated earlier there are about 50 species of sea urchin in the sea around India and atleast half a dozen of them have good market potential. There is no internal market for this product in this country. The whole product has to be exported and the unit value is also very high being 200 US $per kg. Some time back the eggs of smaller species *Temnoplerus toreumaticus* was collected on trial basis. Eggs of larger species like *Stomopneustes variolaris* and *Tripneustes gratilla* also can be tried. Culturing some of the species can be tried in the Gulf of Mannar and Palk Bay, Andaman and Nicobar Islands and also be Lakshadweep. India should do well to tap this potential resource for export to earn the much needed foreign exchange for the country.

PART III

SEA CUCUMBER CULTURE

D.B. James
Central Marine Fisheries Research Institute
P.B.No. 2704, Kochi - 682 031
Kerala, India.

Holothuria scabra



Actinopyga echinites

Thelenota ananas

SEA CUCUMBER CULTURE

1.1. Introduction

According to the FAO's annual statistics for 1984 the world echinoderm harvest in 1983 amounted to approximately 80,000 tonnes. In 1989 India exported 51.5 tonnes of *Beche-de-mer* valued at Rs.1.23 crores. There is a growing demand for the *Beche-de-mer* from India. Some of the companies in Singapore are interested to import 10 tonnes every month.

The echinoderms or spiny skinned animals such as the sea cucumbers and sea urchins have good commercial value. The most popular product is processed sea cucumber or *Beche-de-mer,* a Chinese delicacy .

1.2 Resources, cultivable species, biology and exploitation

There are about 650 varieties of sea cucumber known from various parts of the world. In the Seas around India, nearly 200 are known of which 75 are known from the shallow waters within 20 metres depth. Of these about a dozen species are of commercial value. In India at present six species are used in processing. For processing a sea cucumber should be large in size and the body should be thick and hard. Sea cucumbers with white sticky threads inside the body and also those which have soft and thin skins are not preferred.

A field key is given below to distinguish the various species in the field without resorting to internal examination of the animals.

Field key to the genera of sea cucumbers used in processing

1. Surrounding the anus five white 'teeth' are present .... *Actinopyga*

   1'. No teeth surrounding and anus 2

2. Ejects white sticky threads on collection ....*Bohadschia*
2'. No such white sticky threads in the body..............3
3. Body becomes gelatinous and disintegrates on exposure to air ....*Thelenota* and *Stichopus*
3'. Body does not disintegrate on exposure to air ....*Holothuria*

Genus *Actinopyga*

Species belonging to this genus can be easily identified in the field due to the presence of five white 'teeth' around anus. They grow to a medium size of 350 mm length. The body walls are thick and species are of moderate commercial value. Surprisingly members of this species are unknown from the Gulf of Mannar till 1989. At present two species are extensively processed though a third one is also known from the Gulf of Mannar. Species can be differentiated in the field based on colour.

Field key to the species of *Actinopyga*

1. Uniformly black in colour all over the body...........*A. miliaria*
1' Body not uniformly black 2
2. Colour uniformly brown all over the body ....*A. echnites*
2'. Colour not uniformly brown 3
3. Colour brick red on the upper side and white on the lower side ....*A. mauritiana*
4. Colour dark brown with ashy-white circular area around the anus ....*A. lecanora*

Genus *Thelenota*

It is a massive form reaching a length of 700 mm. and the live weight varies from 3 to 6 kg. Shape is distinct and characteristic with numerous pointed papillae arranged in groups on the upper side.

Genus *Stichopus*

Members belonging to this genus are usually four sided with some projections all over the body. Some species grow to a length of 900 mm.

Field key to the species of *Stichopus*

Colour is green and body is four sided ....*S. chloronotus*

Colour is yellowish and body is massive, loaf-shaped arched on the upper side and flat on the lower side .... *S. variegatus*

Genus *Holothuria*

Most of the common and most valuable species belong to this genus. The body is long and tubular. Some of them lie on the open, some bury in the sand, some live among the coral crevices. They occur in various colours. By far this genus is the most important in sea cucumbers since most valuable species come under this genus.

Field key to the species of *Holothuria*

1. Body is loaf-shaped with side projections in the living conditions under waters ....*H. nobilis*

1' Body tubular in shape 2

2. Colour completely black all over .... *H. atra*

2'. Colour not black 3

3. Black on the upper side with white or light yellow bands across the body; lower side white in colour with black dots ....*H. scabra*

3'. Light brown in colour with spiny projects all over the body ....*H. spinifera.*

1.2 Biology

The biology of the most important species *Holothuria scabra* is given below:

Holothuria scabra is known to reach a maximum length of 400 mm. It breeds twice in a year in the Gulf of Mannar. The first spawning season is during March to May and the second one is during November - December. Size at first maturity for females is estimated at 213mm and for males at 210mm. The fecundity is estimated at ten lakhs. The longivity is estimated as ten years. At the end of first, second, third, fourth and fifth years it reaches a length of 136 mm, 225 mm, 284 mm, 322 mm and 348 mm. respectively. In 18 months this species reaches sexual maturity. (B.K. Baskar, Personal communication).

1.2 Exploitation

The easiest method to collect them is to pick them with hand during low tide. This method is applicable for only those species which are found near the shore.

Sea cucumbers are usually collected by skin diving in shallow waters of 2 to 10 metres depth. Divers go in country boats with sails in the morning at 6 A.M. and return in the afternoon. In each boat four to six persons go for diving. Even small boys are employed in diving. The divers take net bags in which the live holothurians are put and brought to the shore. Since 1985 the divers are using aluminium plates for the feet as improvised flippers. These give them greater mobility under water. They can cover greater distances under water with ease and collect more material. Most of the material used for processing is collected in this way only.

Since sea cucumbers are bottom dwelling animals they enter into trawl nets during trawling. They are collected as bycatch.

During the last 17 years another net locally known as *Tallu valai* has been introduced in the Gulf of Mannar and Palk Bay. It is a type of trawl net without otter boards. The net is operated over sea grass beds and on muddy bottoms within four metres depth. The net is dragged by sail boat with one to three sails. In this net the sand fish *Holothuria scabra* is collected along with juvenile prawns and fishes.

1.3 Farming methods

1.3.1 Natural seed resources and collection methods

During February 1978, a natural bed of seed of *Holothuria scabra* was located at South Point near Port Blair (Andamans). The seed ranged in length from 65-160 mm. They were found in the intertidal region and could be collected easily during the low tide. A natural bed of seed of *H. scabra* was located in Kuntikalgut near Pamban. The seed can be collected during low tide by hand picking.

1.3.2. Hatchery Technology for seed production

Here the hatchery technology for seed production of *Holothuria scabra* is described in detail. The Central Marine Fisheries Research Institute has achieved a breakthrough in inducing the sea cucumber *H. scabra* to spawn in the hatchery and produce seed for the first time.

Collection of brood stock material

Brood stock collection is an important aspect in any culture practice. The brood stock is collected from the wild from the commercial catches meant for processing. Only large and healthy specimens alone were selected for this purpose. Those which were injured during the capture were rejected. They were stocked in one tonne tanks with sand brought from the natural beds. The sand is arranged in six inch thickness to enable the sea cucumbers to bury in the sand.

Maintenance of the brood stock

The success of the hatchery depends on the healthy condition of the animals maintained. The water in the tanks is changed every day and the sand is changed every fortnight. If the water is not changed regularly the sea cucumbers will throw out all the internal organs including the gonads and such specimens do not serve any useful purpose for the hatchery experiments. Fresh algae from the sea is brought and this is ground to fine paste in a mixie and put in the water atleast twice in a week. The sea cucumbers live on the organic matter present in the mud. The algal paste settles down to the bottom and this is consumed by the animals along with the mud. If proper food is not provided the animals become shrunken and gonad is reabsorbed. It is desirable to keep 20-30 adults in one tonne tank.

Collection timing

Collection timing is very important for the success of the hatchery management. Although *H. Scabra* spawns round the year, two spawning peaks one in March-May and the other in October-December were noticed.

It is desirable to collect the brood stock material during the spawning season so that the chances of spawning are more since most of the specimens will be ripe and ready to release the eggs. A small rise in temperature is enough to stimulate them to shed the eggs. Another aspect is that there is no known method to ripen the specimens. Therefore it is desirable to conduct these experiments during the breeding season of the animals.

Brood stock management

It is always good to keep the water in the brood stock tank in fresh condition. The whole water is daily changed. Aeration has to be provided for the tanks to keep the animals in healthy condition. Excreta and dirt in the tank should be removed immediately. The behaviour of the individual breeders should be constantly watched.

Spawning

The main aim of artificial breeding is to successfully obtain quality seeds. Details of natural spawning and induced spawning are given below.

Natural spawning

When the eggs are fully ripe, the male and female breeders release the eggs and sperms naturally without any inducement. At first the male releases the sperms, which induce the female to release the eggs in about two hours time. The eggs are generally released around 3 P.M.

Induced spawning

Stimulation by heat only give results in case of *H. scabra.* First the temperature of the water of brood stock tank is noted and this is raised to 5°C by adding hot sea water. The ripe specimens are so sensitive to temperature changes that a rise of even 3°C is enough to trigger them to release the eggs. When the water in the brood stock tanks is changed by sea water from the sump or when the specimens collected from the wild are introduced to sea water from the sump, if ripe specimens are available they immediately react and release the eggs.

Spawning behaviour

In sea cucumbers the sexes are separate and it is not possible to distinguish the sexes externally. Only microscopical examination of the gonads will indicate whether they are males or females. At the time of spawning also it is possible to differentiate the sexes since the behaviour of males and females is different. In all cases the males only first spawn and this is followed by the females. In case of *H. scabra* the males first lift the anterior end and exhibit swaying movements. After exhibiting such movements for sometime the males start releasing the sperms from the gonopore situated at the upper side near the head region. The male when once it starts releasing the sperms it keeps on going this way for about two hours. In the meanwhile if there is a ripe female in the sample it starts reacting to the sperms released in the water. The females start ascending at the corner of a tank and head region becomes bulged due to pressure created inside the body. The head region every time comes out of water a little and again gets into water. After a few attempts like this the female releases the eggs in a single spurt and lies at the bottom of the tank. The eggs are ejected out in a powerful jet reaching to a height of about three feet. The egg mass released is light yellow mucus-like substance. The powerful jet helps in the dispersal of the eggs over a wide area.

Fertilization

It is important to ensure a high survival rate in the artificial breeding by obtaining high quality eggs. Therefore it is necessary to handle the eggs carefully as soon as they are released. The union of male and female elements take place outside in the water. After the eggs and sperms are released the breeders are removed from the tank. The eggs are washed several time in order to remove the excess sperms which might pollute the water in the tank resulting in reduced fertilization and a large number of deformed embryos.

Early development

The female usually releases about one million eggs. About 75 million eggs can be stocked in 750 litres of water. After fertilization the eggs undergo division and transform into three types of larvae. The first and second type of larvae are produced in 24 hours. On the tenth day the third type of larvae is formed. By thirteenth day some of them transform into miniature sea cucumbers and attach to the sides of the tank. The body is tubular with five tentacles at the head region. It has one foot at the rear end. This serves to anchor the animal to the bottom. As days advance more and more feet develop all over the body. They have a habit of moving to the edge of the tank and remain just below the surface of water. Soon they settle down to the bottom of the tank.

Rearing of larvae

Rearing tanks and other tanks used in breeding, especially the new tanks, must be scrubbed clean and filled with water for 20 days, during which period the water is changed repeatedly in order to lower the pH to less than 8.5. Before the tanks are used, they are scrubbed and filled with water containing 40 ppm bleaching powder and then washed clean with filtered sea water before the larvae are released.

Rearing density

Strict control of rearing density of the larvae, i.e. the number of larvae per ml of water is first calculated. At present there are two methods to rear the larvae, still water rearing and flowing water rearing. Second stage larvae concentrate during their early and middle stages at the surface of water. If the density of the larvae is more they will form as a ball and sink resulting in death. Therefore rearing density should be controlled to ensure better survival rate. The desirable density of larvae is 300-700 per litre. In one tonne tank having 750 litres of water 3,75,000 larvae can be stocked.

Selection and counting of the larvae

After fertilized eggs are removed to rearing tanks, they develop into the second stage larvae in 30 hours. The bottom of the rearing tank should be cleaned thoroughly. Healthy larvae occupy the surface layer of water, while deformed ones and dead embryos generally stay in the lower layer of the water column or at the bottom of the tank. All the dead individuals, deformed larvae and sediment should be siphoned out in order to clean the tanks. After the tanks are cleaned, the water in the tanks should be gently stirred so that the larvae can be uniformly distributed. A sample is then taken for counting the larvae. Samples are taken separately from the two ends and the middle of the tank in a 250 ml beaker. The sample is uniformly stirred and one ml sample is taken in a pipette and put in a plankton counting chamber. The number of larvae are counted in each ml. Like this two more samples have to be taken in a pipette and the average of three counts is taken as an indication of the density of the larvae. The result of the count would show whether the density is desirable or not. The period of second stage larval development can be divided into three stages, viz., early, middle and late stages. As they develop from one stage to the next, the bottom of the tanks must be cleaned completely once, or the larvae moved to another tank. Normally the larvae are taken out after every three days so that the tanks can be cleaned thoroughly to avoid infestation of other organisms. On other days the water level is reduced to more than half by keeping the seive inside the tank. The sediment must be removed to keep the water fresh. An upto date information on the survival rate at each developing stage is necessary.

Water management

In the course of rearing, the larvae eject faeces and consume dissolved oxygen constantly. Some of the larvae die in course of time. These and the left over food produce harmful substances like Hydrogen Sulphide and Nitrogen wastes. In addition bacteria produce rapidly with rise of temperature. Poor water quality directly affects the normal development of larvae. Therefore proper water management and sanitation is essential. Regular cleaning of tanks and changing of water are essential. The dirt and deformed larvae at the tank bottom are siphoned out every day. While water is changed by keeping the seive inside the tank, the mesh size of the seive must be smaller than the larvae. Normally 80 seive is used since the larvae and even the eggs are more in size than the seive. While the water is being changed with help of a seive someone should constantly stir the water lightly all round the tank. This will prevent the loss of larvae during water change, since siphoning would normally force the larvae to stick to the sieve causing mechanical injury to the larvae. The sediments at the bottom of the tank should be siphoned out completely every three or four days.

Larval feeding and feeding rates

Suitable and high quality microalgae and correct feeding rates are the key to successful rearing. As the larvae progress in development, the elementary canal is well formed and the larvae must be given diet immediately. The feeding mechanism of the larvae consists of conveying the suspended bits of organisms and unicellular algae into the alimentary canal through the mouth parts by the swaying of the hairlike structures round the mouth. The effectiveness of various microalgae were tried. The results showed better growth rate when fed with the microalgae *Isochrysis galbana*. The mortality rate is also less. After four to five days the larvae are also fed with mixed culture. This chiefly consisted of the phytoplankton *Chaetoceros* sp.

The larvae require different quantities of diet during different developmental stages. Unicellular algae are fed twice in a day, but the quantity given each time depends on the particular stage of larvae. In general 20,000-30,000 per ml in the rearing tank water is maintained. The microalgae *Isochrysis galbana* cultured usually has a concentration of 80,000 cells per ml. When the bloom is good it reaches one million mark. The quality of diet given should be increased or decreased depending on the quantity of food in the stomach of the larvae. This can be visually checked every day before feeding them. Unicellular algae during the peak period of their reproduction are most preferred diet for the larvae.

Environmental Factors

Monitoring of the environmental factors is of paramount importance since the larvae and the seed are sensitive to the environmental changes and easily succumb when conditions are adverse.

Temperature

The ideal temperature for rearing of the larvae was found to be 27-29°C. The temperature of the water should be noted twice in a day, both in the morning and also during the afternoon.

Dissolved oxygen

Dissolved oxygen level varies with water temperature. The higher the temperature, the lower the dissolved oxygen level. The normal range for dissolved oxygen is 5-6 ml/litre. Always aeration is given to the larval tanks throughout the day to see that the oxygen level does not go down much. For one tonne tank generally two aerators are provided one at either end.

pH

Under normal conditions, the rearing sea water is generally alkaline with pH of 7.5-8.6. Tests have shown that the larvae of *H. scabra* adopt to a fairly wide range of pH. However when pH rises over 9.0 and drops below 6.0 the moving ability of the larvae weakens and growth stops. Therefore the pH of the water must be between 6.0 and 9.0.

Salinity

Salinity of normal sea water is 35‰. If the salinity is low all the larvae will die. The lethal critical salinity is 12.9‰. The optimum salinity for larval development ranges from 26.2 to 32.7‰. In this range the higher the salinity, the quicker is the development. Too high or too low salinity adversely affect the normal development of the larvae, resulting in large number of deformed larvae causing death. Salinity estimation is, therefore an important routine work throughout the entire rearing period. A salinity refractometer is now commonly used for quick salinity estimation. If the specific gravity of the water is found out the measured value can be converted into salinity value.

Ammoniacal Nitrogen

The ammoniacal nitrogen of sea water is very low. The sources in the breeding tanks are mainly the metabolites of larvae, the unconsumed diet and decomposing organisms. Too much accumulation of nitrogen can be harmful for the larvae. The larvae can develop normally with an ammoniacal nitrogen content of 70-430 mg per cubic metre of water. When its content is over 500 mg per cubic metre of water it will have harmful effect on the development and growth of larvae.

1.3.3. Nursery Rearing

The larvae after going through three states settle on hard surface when food is sufficient and also when proper substratum is available for them to settle. If these two conditions are not satisfied they continue to swim in the tank for a long time. Therefore correct feed is given for the larvae and often settlers are provided for them to settle.

Types of settling bases

Two types of settling bases are tried for the larvae. In the first type polythene sheets are taken and kept in a tank outside the hatchery where there is good sunlight. Into these tanks filtered sea water is circulated continuously for four or five days. Benthic diatoms and other algae settle on the plates. These plates are taken inside the hatchery and suspended in the tanks which have advanced larvae about to settle down. The hard surface and the food induces them to settle the larvae on the plates. One disadvantage with settlers of this type is that the benthic larvae which settles on the plates comes off completely after four or five days. In other type of settler the polythene sheets are kept in a tank having sea water. To this some algal extract filtered through 40 μ is poured. Usually Sargassum alga is used to make the extract and this is put in the tanks with small quantity of sea water. The algal extract will stick to the plates. The water is changed daily and fresh extract is put in small quantities. After four or five days the polythene sheet is covered with fine coat of algal extract and this serves as a good settling base for the larvae. If food is not provided on the settler the larvae after settling will die. The settling bases should not have any toxicity and should be easily available and also should be inexpensive.

Diet for the seed

After settling down the seed have only weak moving ability. Fresh sea weeds are collected and first cut into small bits and then put in a mixie and ground into fine paste. This is filtered by using 40 μ seive initially. After one month 80μ seive is used since the seed will be in a position to take bigger food particles. This filtered extract is daily given to the seed both in the morning and also in the evening. The seed is found to feed actively on the algal extract and grow well due to high protein content.

Density for the seed

When the larvae develop into seed, they begin to crawl. Most of them stay on the settling bases. After 15 days of settlement, they can be seen with naked eye. The number of seed should be estimated. A random sampling is made with a frame of 400 sq.cm. The samples should be collected from different portions of the tank. The sampling area of each tank must be over 5% of its total area.

In order to achieve increased survival rate, it is necessary to control appropriately the settling bases at the optimum level. Too many of seed in limited area and insufficient diet will be adverse to the growth and survival. Hence, after they are counted, their density should be adjusted to an optimum of 200-500 individuals per one square metre.

Predators and their control

Predation

Copepods and ciliates are the main predators on the second stage larvae since their movements are sluggish. They attack the larvae at the sides and injure the body. Finally the larvae die due to the injuries caused.

They also harm the seed by reproducing fast in the rearing tanks and competing for food with the seed. Algal extracts given for the seed is found in the alimentary canals of the copepods. They also wound the body surface of the seed with their mouth parts and tear the skin of the seed. Infested seed assumes a ball shape and they die gradually. The second stage of larvae is the most vulnerable for the attack of the predators because of their sluggish movements and due to their extended life in that stage for several days.

Predator control

Control trials on copepods with different chemicals at different concentrations have been conducted. Chemicals containing organo-phosphorus can be tried. Copepods can be killed with 2 ppm dipterx in two hours with no harmful effects on the seed. However it is necessary to give careful attention to the preparation of dipterx solution of appropriate concentration. The solution should be evenly sprinkled into the tank and the water of the tank must be changed completely after two hours. This is very important otherwise it will affect the seed.

1.3.5. Grow-out systems

After the seed is grown for a month or two in the nursery it has to be transferred to the sea for further growth. By the end of two months most of the seed will reach 20 mm in length. There is vast difference in the growth of the seed belonging to the same brood. Therefore some culling is necessary. Fast growing seed is separated and transferred to the grow-out systems. The seed can be grown under three different conditions depending on the number of seed on hand.

In the first method rectangular iron cages of the size 3 x 2 feet are taken and they are closely woven with 2 mm. nylone rope into 900 sq. mm. net work. Fine velon screen is taken and stitched as lining for the rectangular ox type cages. The mesh for the velon screen should be very small other wise the sand placed inside the box will escape. Along with fine sand, algal powder is also kept as food for the seed. Four casurina poles are driven into the sea bottom at a depth of one metre and the boxes and securely tied to the poles and kept at the bottom. After introducing the juveniles into the box cage the lid is properly closed and stitched in order to prevent the seed from escaping into the sea. These boxes are removed every month to clean the cages from the fouling organisms and also to take the length and weight of individual sea cucumbers. All the sides of the rectangular box cages are thoroughly scrubbed with brush to remove the fouling organisms. This operation not only helps to remove the fouling organisms but also allows free flow of sea water into the box. Since space is limited large number of seed cannot be grown by this method. Due to limited area the growth is also found to be somewhat slow.

In the second method an old one tonne tank is fixed at the bottom of the sea at a depth of one and half metres. Four casurina poles are driven at the four corners of the tank and the tank is securely tied to the poles. Before fixing the tank at the bottom of the sea it is first filled with fine sand to one fourth from the natural habitat. This should be free from predators such as crabs and other unwanted organisms. Fresh algae from the sea is collected and dried. Then the dried algae is made into powder and this is mixed with the fine sand kept in the tank. The algal powder helps in the better growth of the seed. The tank is covered by a velon screen and placed at the bottom of the sea. The specimens are examined and average length and average weight of the specimens is taken. The growth of the specimens reared in the tank was found to be better and faster due to more space and good circulation of water.

In the third method pens are erected in shallow water in sheltered bays. The pens can be made of bamboo screens or palmyrah rafters. When seed is in large number pens of 25 sq.m. are erected to grow the sea cucumbers. The pens have to be periodically examined to see that they are not damaged by crabs and other wood boring organisms. If the damaged portions are not detected and repaired then sea cucumbers will escape into sea.

1.4. Post harvest technology

It is a cottage industry needing very little investment and mainly based in rural areas along the beaches. The processing is simple. This mainly involves in removing the internal parts, boiling in sea water for an hour or so and then putting it out for sun drying. Sand fish which is then most expensive from India is buried for 10-12 hours after boiling them thoroughly cleaned and boiled once again and dried. Chinese settled all over the world use *Beche-de-mer*. Chinese settled in U.S.A. and Germany and other countries pay a premium and purchase expensive *Beche-de-mer*. At present our processing is crude, unscientific and also unhygienic. Expensive *Beche-de-mer* comes from countries like Korea. India will do well to learn the correct processing methods to get more foreign exchange for the country. To increase the value *Beche-de-mer* is packed in polythene covers so that the material will not be spoiled due to the moisture in the atmosphere since this substance absorbs moisture. They are then packed in attractive cartons to catch better market.

1.4.1. Marketing

There is no internal market for the *Beche-de-mer* in India. So the whole product is exported. Hong Kong and Singapore are the world markets for *Beche-de-mer*. Hong Kong is the foremost country in the world by importing 5000 to 6000 tonnes of *Beche-de-mer* every year. India chiefly exports to Singapore. From Singapore our material is re-exported to Hong Kong and Chinese ports. It is not just physical movements at Singapore for our material since it is re-processed to some extent to add to the value of the product.

Government of India put a ban on the export of *Beche-de-mer* which is less than three inches in length as a measure of conservation in 1982. While conservation and management are essential for any resource the only answer to this problem is large scale farming of the sea cucumbers.

1.5. Prospects

With the breakthrough achieved by the Central Marine Fisheries Research Institute in 1988 in inducing sea cucumbers to shed their eggs and to produce seed there are excellent possibilities for culture of the sea cucumbers in selected area. The seed so produced can also be used for sea ranching programme to enrich the natural populations which are depleted due to overfishing. The prospects for the culture of sea cucumbers in India are excellent. Juvenile sea cucumbers can be grown in enclosed bays to marketable size by using simple methods. There is no need to construct farms with bunds at great cost since the sea cucumbers move not much from the area where they are introduced. Suitable sites have to be located in natural beds which are sheltered. The question of feeding with artificial diet does not arise since they subsist on the organic matter present in the mud or sand. Several economically important species are available in the Seas around India. There are about a dozen economically important species distributed in the Gulf of Mannar and Palk bay, the Andaman and Nicobar Islands and in the Islands of Lakshadweep. Some of the species distributed in the Andaman and Nicobar Islands and also at the Lakshadweep are more valuable than those found in the Gulf of Mannar and Palk Bay. Therefore in order to diversify the industry both in space and species first the juveniles of commercially important species should be collected and grown in the Andaman and Nicobar Islands and also at the Lakshadweep.

So far seed of *H. scabra* alone is produced in a limited manner. The

FOREWORD

Seaweed is identified as the medical food of the 21st century because of its unique life-supporting properties such as vitamins, minerals and trace elements. India's rich untapped seaweed resources can open a new chapter in health-food production of our country through farming. In order to make a beginning in this direction the Marine Products Export Development Authority is trying to project the importance of seaweed in 'INDAQUA', the First Aquaculture Show in India. The pioneering work done by CMFRI in this field and the effort taken by Dr. N.Kaliaperumal and his fellow scientists to compile this volume deserves special appreciation.

Similarly India's rich resources of sea cucumber and sea urchins are totally untapped for aquaculture. They are high-priced seafood products with excellent demand in the South East Asia and Japan. Sea Cucumber is a Chinese delicacy, Roe of sea urchins is a Japanese delicacy. If these resources are properly tapped through sea bed culture it is possible to earn a substantial amount of foreign exchange earning to our country.

The Department of Biotechnology has been very kind enough to extend financial assistance to publish this volume and I extend my heartfelt thanks to them. The effort put up by Dr. G Santhana Krishnan and his colleagues to coordinate the publication work is well appreciated. I am sure this publication covering various aspects of seaweed farming will be of immense help to the investors in seaweed farming.

(M SAKTHIVEL)
CHAIRMAN
MPEDA

hatchery production for seed should be scaled up to meet the growing demands. Other commercially important species like *Holothuria nobilis* in the Lakshadweep should be tried for seed production. Some farmers have already stocked juveniles of *H. scabra* and grown them in enclosed areas. There is demand from farmers for the seed of sea cucumbers. In order to meet the growing demand for *Beche-de-mer* from the International markets and also to earn more foreign exchange for the country culture practices have to be taken up in sea cucumbers in large scale in India.

CONTENTS

PART I

SEA WEED CULTURE

N. Kaliaperumal
Central Marine Fisheries Research Institute
P.B.No. 2704, Kochi - 682 031
Kerala, India.

SEAWEED CULTURE

Introduction

Seaweeds or marine algae are the primitive type of plants and they grow abundantly in the shallow waters of sea, estuaries and backwaters. They flourish wherever rocky, coral or suitable substrata are available for their attachment. They belong to four groups namely green, brown, red and blue-green algae based on the pigmentation, morphological and anatomical characters. Seaweeds are one of the commercially important marine living and renewable resources of our country. They contain more than 60 trace elements, minerals, protein, iodine, bromine, vitamins and several bioactive substances.

Seaweed uses

The phytochemicals namely agar, carrageenan (agaroid) and algin are manufactured only from seaweeds. The red algae such as *Gelidiella, Gelidium, Pterocladia* and *Gracilaria* yield agar. Some other red algae *viz Hypnea, Eucheuma, Chondrus* and *Gigartina* are the major sources for production of carrageenan. The algin can be obtained from brown algae like *Sargassum, Turbinaria, Hormophysa, Cystoseira, Laminaria, Undaria, Macrocystis* and *Ascophyllum.* These phycocolloids are used as gelling, stabilizing and thickening agents in food confectionery, pharmaceutical, dairy, textile, paper, paint, varnish industries etc. Apart from these biochemicals, other chemical products such as mannitol, iodine, laminarin and fucoidin are also obtained from marine algae. Many protein rich seaweeds such as *Ulva, Enteromorpha, Caulerpa, Codium, Monostroma* (green algae); *Sargassum, Hydroclathrus, Laminaria, Undaria* and *Macrocystis* (brown algae); *Porphyra, Gracilaria, Eucheuma, Laurencia* and Acanthophora (red algae) are used as human food in countries like Japan, China, Korea, Malaysia, Philippines and other southeast Asian countries in the form of soup, salad, curry etc. Jelly, jam, Chocolate, pickle and wafer can also be prepared from certain seaweeds. The food value of seaweeds depends on the minerals, trace elements, protein and vitamins present in them. They also control goitre disease.

Marine algae are also utilised in different parts of the world as animal feed and fertilizer for various land crops. In India, freshly collected and cast ashore seaweeds and seagrasses are used as manure for coconut plantation either directly or in the form of compost especially in the coastal areas of Tamil Nadu and Kerala. Seaweed manure has been found superior to the conventional organic (farm yard) manure. The high amount of water soluble potash, other minerals and trace elements present in seaweeds are readily absorbed by plants and they control deficiency diseases. The carbohydrates and other organic matter present in seaweeds alter the nature of soil and improve its moisture retaining capacity. The liquid seaweed fertilizer obtained from seaweed extract can be used as foliar spray for inducing faster growth and yield in leafy and fleshy vegetables, fruits, orchards and horticultural plants. The trace elements and growth hormones (cytokinin) present in the liquid seaweed fertilizer act as growth promoters and increase the yield by 20 to 30%. It gives successful results on potatoes, Cauliflower, cabbage, brinjal, Lady'sfinger, chillies, grapes etc. In India, seaweeds are now used mostly as raw material for the production of agar and sodium alginate. They are also consumed in the form of agar jelly and porridge.

Seaweed distribution and resources in India

More than 10,000 species of marine algae have been reported from all over the world. It has been estimated that the seaweed resources of the world comprise about 1460 million tonnes (wet weight) of brown algae and 261 million tonnes (wet weight) of red algae. The total annual seaweed production is about 1721×10^4 tonnes (wet weight). The major sources of seaweeds are in the northeast, western central and southeast Atlantic and the eastern central and northwest Pacific regions. India with a long coastline of 6100 km, has a vast resource of seaweeds along her open coasts and estuarine areas. The luxuriant growth of several species of green, brown and red algae occur along the southeast coast of Tamil Nadu from Rameswaram to Kanyakumari, Gujarat coast, Lakshadweep and Andaman-Nicobar Islands. Fairly rich seaweed beds are present in the vicinity of

Bombay, Karwar, Ratnagiri, Goa, Varkala, Vizhinjam, Visakhapatnam and in coastal lakes like Pulicat and Chilka.

About 700 species of marine algae have been recorded from different parts of Indian coast including Lakshadweep and Andaman Nicobar Islands. Of these, nearly 60 species are commercially important seaweeds. From the seaweed resources survey carried out in the intertidal and shallow water areas of east and west coast and also Lakshadweep so far by the Central Marine Fisheries Research Institute (CMFRI) and other research organisations such as Central Salt & Marine Chemicals Research Institute (CSMCRI) and National Institute of Oceanography (NIO), it is estimated that the total standing crop of all seaweeds in Indian waters is more than one lakh tons (wet weight) consisting of 6000 tons (wet weight) of agar yielding seaweeds, 16000 tons (wet weight) of algin yielding seaweeds and the remaining quantity of edible and other seaweeds. The CMFRI and CSMCRI have jointly surveyed the seaweed resources in the deep waters (5 to 22 m depths) of Tamil Nadu coast from Dhanushkodi to Kanyakumari during 1986-1991. A total number of 100 algal species occurred in the deep waters and the total estimated standing crop from 1863 sq. km area was 75,372.5 tons (wet weight). The quantitative analysis of economically important seaweed encountered in this survey reveals the feasibility of commercial exploitation of *Gracilaria, Sargassum and Hypnea* from deep waters and their utilization for the production of agar, sodium alginate and carrageenan by the Indian seaweed industries.

The CMFRI has also conducted seaweed resources survey in 63 estuaries and backwaters from Madras to Athankarai in Tamil Nadu and Pondicherry during 1988-89. The agarophytes *Gracilaria arcuata, Gracilaria verrucosa* and carrageenophyte *Hypnea valentiae* occur in harvestable quantities in some of these estuaries and they could be exploited for commercial utilization.

Seaweed industries and commercial exploitation of seaweeds in India

There are a number of agar and algin producing seaweed industries situated at different places in the maritime states of Tamil Nadu, Andhra Pradesh, Kerala, Karnataka and Gujarat. Now the red algae *Gelidiella acerosa, Gracilaria edulis, G. crassa, G. foliifera and G. verrucosa* are used for extraction of agar and species of *Sargassum* and *Turbinaria* for sodium alginate. All the seaweed industries depend on the raw materials being exploited from the natural seaweed beds occurring in the southeast coast of Tamil Nadu (from Rameswaram to Kanyakumari and Gulf of Mannar islands). The commercial harvesting of seaweeds from these areas is going on since 1966. The data collected by the CMFRI on the seaweed landings of Tamil Nadu from 1978 onwards show that the quantity of agar yielding seaweeds landed annually varied from 248 to 1289 tons (dry weight) and algin yielding seaweeds from 651 to 5537 tons (dry weight) during the years 1978 -90.

Since 1980 many agar and algin extracting industries are coming up in India. As the demand for raw material of agar yielding seaweeds is more and their natural resources along Tamil Nadu coast are less, there is paucity in supply of raw materials to agar industries. This can be overcome by exploiting the agar yielding seaweeds from other localities along the east and west coast including Lakshadweep and Andaman - Nicobar Islands and also by cultivating them on large scale. The quantity of algin yielding seaweeds *Sargassum* and *Turbinaria* available in Tamil Nadu and other parts of Indian coast including Lakshadweep and Andaman-Nicobar is quite adequate to meet the raw material requirement of algin industries as only about 50% of standing crop is harvested from Tamil Nadu coast.

Seaweed Culture

Seaweeds are cultivated for supply of raw material to the seaweed industries and for their use as human food. There are several advantages in the cultivation of seaweeds. In addition to a continuous supply of alga, crops of single species could be maintained continuously. By adopting scientific breeding and other modern techniques of crop improvement, the yield and quality of the seaweed could also be improved. Further, if seaweed culture is carried out on large scale, natural seaweed beds could be conserved purely for obtaining seed materials.

There are two methods for cultivation of seaweeds; one by means of vegetative propagation using fragments from mother plants and the other by different kinds of spores such as zoospores, monospores, tetraspores and carpospores. In the vegetative propagation method, the fragments are inserted in the twists of ropes, tied to nylon twine or polypropylene straw and cultured in the nearshore areas of the sea. The fragments are also cultured by broadcasting them in outdoor ponds and tanks. The fragment culture method is a simple one and gives quick results. In the culture of seaweeds from spores, the spores are first collected on nets, bamboo splits, polypropylene straw and other suitable substrata; reared to germlings or young plants in the hatchery / nursery and then transplanted to the desired sites where they grow to harvestable size plants. In this method the spores take more period for their development to harvestable size plants when compared with the growth of fragments in the vegetative method.

Seaweed cultivation in foreign countries

The seaweed culture in abroad at present is almost entirely confined to the Orient, reaching its peak of sophistication in Japan and China. The seaweeds under commercial scale cultivation in the Indo-Pacific region are *Porphyra* and *Eucheuma* (red algae); *Undaria* and *Laminaria* (brown algae); *Caulerpa, Enteromorpha* and *Monostroma* (green algae). The important seaweeds for which commercial scale cultivation has been developed are *Gracilaria, Hypnea, Chondrus* and *Gigartina* (red algae) and *Macrocystis* (brown algae). The Japanese and Korean *Porphyra* industry, the Chinese *Laminaria* industry and the Philippine *Eucheuma* industry are now mainly based on the cultured seaweeds. The techniques adopted for cultivation of different species of seaweeds on commercial scale are given below.

Porphyra

Many species of *Porphyra* are cultivated on very large scale in countries like Japan, Korea and Taiwan. The plants are induced to produce monospores in nursery tanks by various thermal and chemical treatments. The monospores get attached to synthetic fibre net by passing the nets through the tanks containing spores. The nets are stored in 20 to 24°C for several months with the monospores remaining viable. This preparation of seedlings is done during winter from December to March. Then these nets with seedlings are hung horizontally on floating racks which are made of bamboo and set in shallow coastal areas where the water is clear and well protected from storm and heavy wave action. Within 15 to 20 days after setting the nets, the seaweed grow to 10 to 15 cm in length and the first harvest is made. The remaining plants continue to grow and harvest is repeated 3 to 4 times before the net is replaced.

Eucheuma

This red alga is cultured on commercial scale in Philippine waters. The seedlings of *Eucheuma* weighing 100 to 150 gm are tied at one end of thin plastic strip (polypropylene straw) and the other end is tied to the nylon monolines installed 0.5 to 1.5 m above the bottom of the sea using mangrove wooden poles. Once the plants reach a weight of 1200 to 1500 gm, they are harvested by pruning to 500 gm and the process continues.

Undaria

This brown alga is commercially cultivated on large scale in Japan and Korea by adopting the artificial spore collection technique developed in 1960. Twine frames made of synthetic fibre yarn of 2-3 mm diameter are used for zoospore collection and culture of germlings. The zoospore from mature plants of *Undaria* are released in concrete or plastic tanks filled with seawater and they are collected on twine frames. The seedlings which develop on twine frames and then the frames are transferred and suspended in the sea from a raft to raise the germlings into healthy young plants until they grow to 2-3 cm in length. During autumn (September-November) when the water temperature in the sea falls below 20°C, seedling twines are attached to 10-20 mm diameter synthetic fibre rope at suitable intervals. Sometimes the twine is cut into short pieces of 5-6 cm length and inserted in twists of the ropes. The harvest is made when the plants grow more than 50-60 cm in length by hauling the rope to a boat and cutting the plants with sickle.

Laminaria

Many species of brown algae is commercially cultured on large scale in China and Japan of which *Laminaria japonica* is the common one. The basic technique involved in artificial propagation of *Laminaria* consists of collecting zoospores from mature plants in late autumn and lodging them on short ladders made of bamboo split and hung from floating rafts in the sea. Young plants appear on the ladders in January and they reach harvestable size of more than 3 m in length in 4 to 5 months. The harvest of fully grown plants is made from boats.

Caulerpa

This edible green alga is commercially cultivated in ponds connected to the sea through feeder canal in Philippines since 1970. The chopped fresh pieces of mature *Caulerpa lentillifera* are planted in the ponds (7000 kg/ha of pond) and the water level of the ponds is maintained to a minimum depth of 50 cm by adjusting flow of seawater by the sluice of the feeder canal. Fertilizers like NPK are used to enhance the growth of *Caulerpa* and fertilizing is done once in a month. The harvesting of the crop is made in about 2 to 3 months from a small flat bottom boat using a scoop net.

Enteromorpha and *Monostroma*

These edible green algae are cultured on commercial scale in Japan similar to *Porphyra* on the nets suspended horizontally at intertidal level near river mouths. They are cultured along with *Porphyra. Monostroma* is cultured separately also.

Gracilaria

This agar yielding red alga is cultured successfully at Taiwan in shallow coastal flats and ponds since 1962. The species most commonly cultured is *Gracilaria verrucosa* . *Gracilaria gigas* is also cultured in some areas. Each plant is cut into pieces and they are planted uniformly on the bottom of the ponds usually in April. 3000 to 5000 kg of fragmented plants are planted in a pond of one hectare size. They are usually fixed on bamboo sticks planted on the bottom or covered with old fishing nets to prevent them drifting to one side or one corner of the ponds. Either organic or inorganic fertilizer is used to accelerate the growth. The harvest is made by hand or by using scoop nets in 10 days from June to December.

In Malaysia *Gracilaria cylindrica* and other species of *Gracilaria* are cultured by spore collection technique. Spore setting is done in the hatchery on nylon or linearly stressed polyethylene raffia which are wound on PVC frames. These spore bearing lines are transferred to the culture site in the shore area and their ends are attached to stakes. The spores grow and reach harvestable size plants after four months. The first harvest is done after 4 months of outplanting and subsequent harvests are also made.

Hypnea, Chondrus and *Gigartina*

These are carrageenan yielding red algae. *Hypnea musciformis* is cultured in outdoor plywood tanks at Summerland key and Florida. A continuous flow of seawater is supplied to the tanks and it is agitated with continuous flow of compressed air pumped through a sparger located along the deep end of culture tanks. The culture tanks are enriched with sodium nitrate, ammonium nitrate or ammonium sulphate as source of nitrogen and trisodium phosphate as phosphate source. In Philippines *Hypnea* is cultivated in protected areas of the sea by suspending the plants. Similar to *Hypnea, Chondrus crispus* and *Gigartina* spp. are propagated in detached form in agitated ponds or tanks.

Macrocystis

In the United States, seedlings of *Macrocystis* are cultured on plastic rings and the rings are set on rocky substratum of the sea using underwater epoxy cement. Recently methods for mass culture of *Macrocystis* germlings and their disposal in the sea have been developed. The germlings attached to polyethylene film substrate or glass fibre cloth substrate are cultured in a refrigerated room in long trays through which chilled, filtered and sterilized seawater is passed. Then the germlings are scraped from the substrates, suspended in seawater and dispersed on rocky bottom by pouring them down through a hose. Some times dispersal is done with the help of divers.

Seaweed culture in India

In India only experimental scale cultivation of a number of agar, carrageenan, algin and edible seaweeds such as *Gracilaria, Gelidiella, Hypnea, Cystoseira, Hormophysa, Caulerpa, Ulva* and *Acanthophora* is attempted since 1964 by the CMFRI, CSMCRI and other research organisations at different field environments using various culture techniques. These experiments reveal that *Gelidiella acerosa* can be successfully cultivated on coral stones and *Gracilaria edulis, Hypnea musciformis* and *Acanthophora spicifera* on long line coir ropes and coir rope nets. The methods of cultivation and yields for these four species are given below.

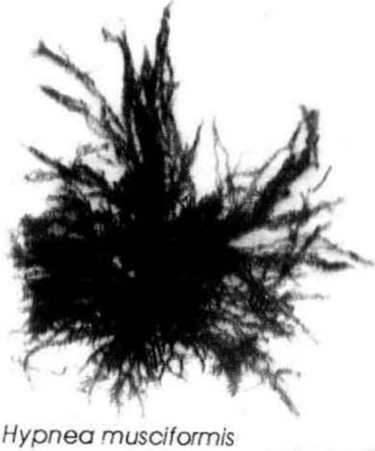
Gracilaria edulis

Cultivation of *Gracilaria edulis* was carried out by the CMFRI in the nearshore areas of Gulf of Mannar and Palk bay at Mandapam. These experiments revealed that *G. edulis* can be successfully cultivated on commercial scale in the open shore environments during November to March in Gulf of Mannar and during June to September in Palk Bay side of Mandapam area. The seaweed was cultivated on coir rope nets, HDPE rope nets and nylon monolines. The fragments of the plants were directly inserted in the twists of coir rope nets, tied at mesh intersections of HDPE rope nets with nylon twine and hung on nylon monolines using plastic strips (Polyethylene straw). In these experiments a maximum yield of 14 fold increase and an average yield of 3 fold increase over the quantity of seed material introduced were obtained after 80 days and 60 days respectively.

In this method one kg of seed material would yield on an average 3 kg/m^2 of net after 60 days. In one hectare area of nets (1000 nets) 30 tons of fresh *G. edulis* could be obtained in one harvest. Six harvests could be made in a year.

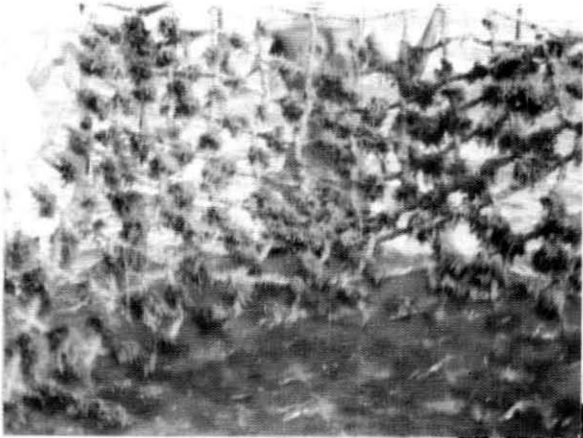
For cultivation in one hectare, 1000 nets of 5 x 2 m size, 2000 casuarina poles of 1.5m height and 10,000 kg of fresh seed material (for initial introduction) are required. The cost of 2000 casuarina poles is Rs. 16,000 and cost of 1000 coir rope nets is Rs. 40,000. The seed material will be collected for the initial introduction from the natural beds and from the cultured crop for subsequent seeding. Wages for fabrication, seeding,

Turbeneria ornata



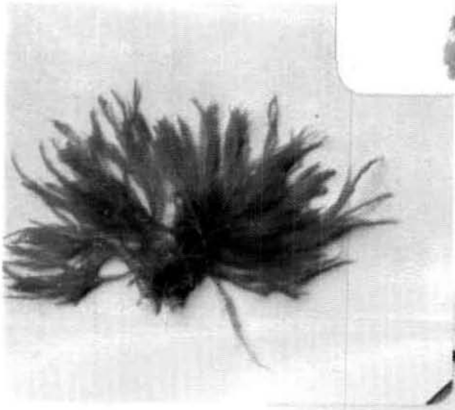
Hypnea musciformis

Ulva lactuca

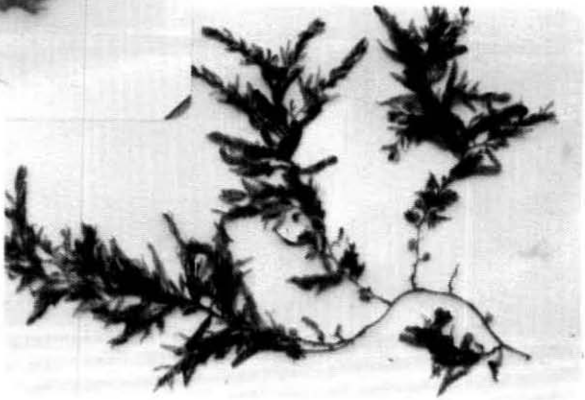


Gracilaria edulis

Sargassum ilicifolium



G. arcuata



S. tenerrimum

harvesting and maintenance of the seaweed farm for 4 persons at the rate of Rs. 15 per day for 360 days works out to Rs. 21,600. The total expenditure for one year would be Rs. 78,000 including miscellaneous expenditure of Rs. 400.

The estimated cost is arrived at on the assumption that a minimum of four harvests could be made in a year. A total of 120 tons (wet weight) of crop could be obtained from four harvests in a year when the yield is 3 kg / m2. If the seaweed is dried (75% moisture) and marketed at a rate of Rs. 3000 per ton, the net profit would be Rs. 12,000 for one year. The profit will be high when agar is produced from the cultured seaweed and then marketed.

Attempt was also made by the CMFRI to cultivate this species on long line coir ropes and nets in the lagoon of Minicoy Island of Lakshadweep by vegetative propagation method. Very encouraging results indicating high potential of more than 8 fold increase in yield was obtained after 60 days growth. The pre-monsoon (March to June) and post monsoon (October to February) seasons are found suitable for successful farming of this agar yielding seaweed on commercial scale.

G. edulis was cultivated by the CSMCRI in a sandy lagoon at Krusadai Island near Mandapam on long line ropes. Fragments of 2.5 to 3.0 cm length removed from the apices of healthy plants were inserted in the twists of ropes. These seeded ropes were tied to bamboo poles planted to the sea bottom and adjusted at a level of one foot above the bottom. The plants attained a length of 35-40 cm in about 5 months. Three harvests were made at the end of 5,8 and 10 months after planting and the total harvest during one year was about 3.5 kg from one meter length of rope.

Recently *G. edulis* culture by spore shedding method was carried out by the CMFRI at Mandapam. The tetraspores and carpospores were liberated from mature plants on circular cement blocks and cultured to germlings in the laboratory. Then the cement blocks with germlings were transferred to the sea and tied to coir ropes. Young plants appeared on the cement blocks after one month and they grew to harvestable size within another 4 or 5 months.

Gelidiella acerosa

This agarophyte was cultured by the CMFRI by tieing small fragments of the plants along with their substratum (coral piece) to coir ropes interwoven on G.I. pipe frames. The frames were tied in submerged condition to poles fixed in the inshore waters. The plants reached harvestable size after 75 days and the yield was one fold increase over the quantity of seed material used. The fragments of the seaweed were tied at the mesh intersections of HDPE rope nets and introduced at 4 m depth in floating condition with the help of plastic buoys and anchors. Two fold increase in yield was obtained after 60 days growth. The fragments of this red alga were also tied to nylon twines at regular intervals. The seeded twines were wound on the nails fixed to small coral stones, which were kept in iron cages and cultured at 2 m depth in the sea. The plants reached harvestable size after 5 months with more than 3 fold increase in yield.

Experimental field cultivation of *G. acerosa* was also done by the CSMCRI in the nearshore area at Ervadi using coral stones as the substratum. An annual yield of 33 fold increase over the seed material was recorded in these experiments and the economics is available with CSMCRI.

Hypnea musciformis

This carrageenan yielding red alga was cultivated by the CSMCRI in the lagoon of Krusadai island. Vegetative fragments of *H. musciformis* were used as seed material and cultured in long line ropes. Four fold increase in biomass was obtained after 25 days growth.

Acanthophora spicifera

This edible and carrageenan yielding red alga was cultivated by the CMFRI in the nearshore area of hare Island near Mandapam at 1 m depth following vegetative propagation method. Vegetative fragments tied with polypropylene straw were fastened to nylon monolines. The plants reached harvestable size in 25 days and the yield was 2.6 fold increase over the weight of seed material introduced. This plant was also cultured successfully in pond at Mandapam. The pond was connected to the sea through a feeder canal and hence there was regular inflow and outflow of seawater depending on the high tide and low tide respectively. The fragments of the plants were tied at the mesh intersections of HDPE rope nets with nylon twine and the seeded nets were tied in submerged condition to the palmyra poles erected in the pond. The seedlings grew to harvestable size after 45 days yielding 3.6 fold increase over the quantity of seed material in the latest harvest. The remnants of the plants on the nets were allowed to grow for another one month and the second harvest was made which yielded more than 2 fold.

Post harvest technology of seaweeds

The harvested seaweeds are brought to the shore and dried on the beach. The dried seaweeds are weighed, packed in gunny bags and despatched to seaweed industries. The percentage of moisture content and purity decide the price for seaweeds. The rate for dried *Gelidiella acerosa* ranges from Rs. 7000 to 9000 for *Gracilaria* from Rs. 2500 to 3000 and for *Sargassum* and *Turbinaria* from Rs. 1200 to 1500. The agar fetches a price of Rs. 220 to 400 per kg and sodium alginate Rs. 80 to 100 per kg depending on the grade and their qualities. The process for extraction of agar, carrageenan and algin are outlined below.

Agar

The seaweeds are cleaned to remove other unwanted algae and foreign matters and washed thoroughly before extraction of phytochemicals. For the extraction of agar, the washed seaweeds are leached in soft water and boiled in fresh water by passing steam. The agar gel is collected in trays, cut into pieces after it is cooled at room temperature and kept in cold storage for 1 or 2 days. The trays containing frozen agar are removed from the cold storage, thawed to remove suspended impurities and then dried in the sun. The dried agar strips are bleached with sodium hypochlorite or chlorine water and sun dried again. Agar is marketed as strips or as powder.

Carrageenan

The cleaned dry seaweed in stainless steel is heated under milk alkaline condition on a boiling water bath. The heated seaweed sample was blended to a paste and heated further. Filter aid is added to the mixture, stirred and filtered hot under pressure. Sodium chloride solution is added to the filtrate. The mixture is poured with rapid stirring into twice its volume of isopropanol. The carrageenan precipated is strained through fine cloth, washed twice with isopropanol, shredded, dried overnight in a oven, weighed and ground to powder.

Algin

For extraction of alginate, the algae is maceraed with ten times the weight of sodium carbonate and the extract is acidified to obtain alginic acid. It is mixed with either sodium or calcium salts to make sodium or calcium alginate. In another method, the seaweeds are first treated with acid or calcium chloride to reduce the salt content. Sodium alginate in crude form extracted by digestion with sodium carbonate is treated with Calcium chloride solution to form calcium alginate and then acidified before converting to sodium alginate.

Seaweed harvest calender

As now the demand for raw material from agar manufacturing industries is more, the agarophytes *Gelidiella acerosa* and *Gracilaria edulis* are being over exploited from Tamil Nadu coast. Because of the extensive and unresctricted commercial harvest of these seaweeds throughout the year, there is depletion in the stock of these red algae from the natural seaweed beds in Mandapam area during recent years. In order to conserve the natural stock of the commercially important agar and algin yielding seaweeds in Tamil Nadu coast and also to get consistant crop every year, the harvest calender (Table 1) should be followed for commercial exploitation of these seaweeds. This will ensure the regeneration and regrowth of seaweeds by vegetative and reproductive growth to harvestable size plants for the next harvesting season. A single harvest in a year is recommended for some years for *Gelidiella acerosa* and *Gracilaria* spp. However, in areas where there are rich growth of these algae, harvesting may be made twice in a year as given in Table 1.

Table 1. Calender for commercial harvest of economically important seaweeds from Tamil Nadu coast

Sl. No.	Seaweed	Period of occurence	Suitable period for harvest
Agarophytes			
1.	*Gelidiella acerosa*	Throughout the year	January to March & July to September
2.	*Gracilaria edulis*	-do-	January to March & August to September
3.	*Gracilaria crassa*	- do-	- do -
4.	*Gracilaria foliifera*	- do -	- do -
5.	*Gracilaria corticata var. corticata*	- do -	June to August & November to December
6.	*Gracilaria verrucosa*	March to November	May to August
Alginophytes			
7.	*Sargassum wightii*	Throughout the year	October to December
8.	*Sargassum myriocustum*	- do -	May to August
9.	*Sargassum ilicifolium*	- do -	July to September

Contd...

Sl. No.	Seaweed	Period of occurence	Suitable period for harvest
10.	*Turbinaria conoides*	Throughout the year	October to December
11.	*Turbinaria ornata*	- do -	October to December
12.	*Turbinaria decurrens*	- do -	December to January
Carrageenophytes			
13.	*Hypnea musciformis*	- do -	December to March
14.	*Hypnea valentiae*	- do -	January to March

Transfer of Technology on seaweed culture and Training in seaweed culture and utilization

The culture technology developed for *Gracilaria edulis* by the CMFRI was transferred to the local fishermen of Mandapam and nearby fishing villages under the Lab-to-Land programme of the Institute. The CMFRI is also organising short term training course every year on seaweed culture and utilization to the interested seaweed utilisers, private entrepreneurs and Govt. officials.

Prospects

The bays and creeks present in the open shore along the east and west coast, lagoons of coral reefs in the southeast coast of Tamil Nadu, Andaman-Nicobar Islands and atolls of Lakshadweep have immense potential for cultivation of seaweeds where commercial culture could be undertaken by the seaweed utilisers and private entrepreneurs by availing the financial assistance from banks and other funding agencies connected with rural development programmes. Seaweed cultivation on large scale could not only augment supply of raw material to the seaweed industries, but also provide employment to the coastal population which will help in improving their economic status and thus help in rural upliftment. The edible seaweeds such as *Porphyra, Caulerpa, Ulva, Enteromorpha and Acanthophora* can also be cultivated and used for human consumption in our country.

The untapped algal species like *Gracilaria verrucosa, Hypnea, Cystoseira, Hormophysa, Ulva, Enteromorpha* and *Caulerpa* could be exploited from their natural beds and used for extraction of agar, carrageenan, sodium alginate. In India at present only agar and sodium alginate are produced from seaweeds. The other phytochemicals particularly carrageenan can be produced by utilising the huge resource of *Hypnea* spp occurring in our waters. The edible seaweed products like jelly, jam, pickle, wafer etc can also be prepared and marketed.

The brown algae *Laminaria* and *Macrocystis* are used for production of methanol in some developed countries. The species of *Sargassum* and *Turbinaria* available in large quantities at different parts of Indian coast could be used for this purpose. The huge quantity of cast ashore seaweeds from our coastline may be utilised as a source of energy for producing methanol, hydrogen and biogas and as fodder, manure and for liquid seaweed fertilizer. The seaweeds may also be used for extraction of bioactive agents and producing many important pharmaceutical products.

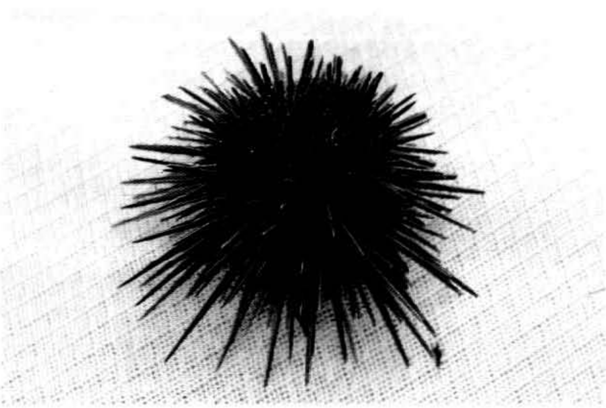
There is very good demand for certain seaweeds in foreign countries such as Japan which are now under exploited or unexploited in our country. Hence they may be exploited and exported to earn foreign exchange to the nation. At present some quantities of agar and sodium alginate are also exported. The seaweed industries in India could not produce the required quantity of agar and sodium alginate (particularly agar) either for local consumption or for export due to paucity of raw material. Hence importing of raw material from other countries could also be attempted so that production of these phyto chemicals could be increased to meet the local requirement of our country and to boost the export of these value added marine products.

PART II

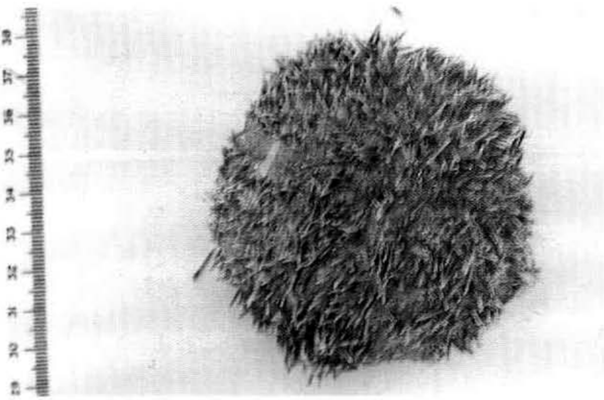
SEA URCHIN CULTURE

D.B. James
Central Marine Fisheries Research Institute
P.B.No. 2704, Kochi - 682 031
Kerala, India.

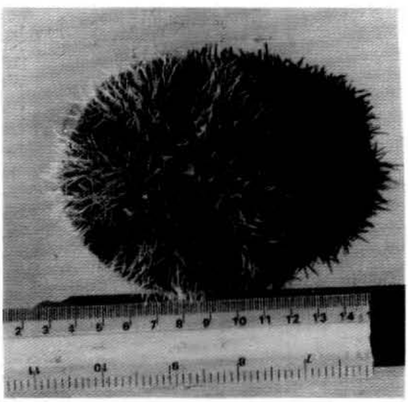
Stohopneustes variolaris



Toxopneustes piliolus



Tripneustes gratilla



SEA URCHIN CULTURE

1.1. Introduction

Ripe Sea urchin eggs are considered as a delicacy by the Japanese and one kilogram of the same costs 200 U.S. Dollars. According to the FAO's annual statistics for 1984 approximately 54,000 tonnes of sea urchin eggs were harvested. Although it has excellent export potential very little information is published on the subject. James (1989) summerised all the information available on the industry. Although there are more than 50 species of sea urchins from the shallow waters of India there is no export of the eggs from this country. On the mainland of India and in the Andaman and Nicobar Islands and also in the Lakshadweep valuable species of sea urchins exist whose eggs can be exported profitably. There is an ever increasing demand for this product in the global markets. It is gratifying to note that in recent years the local export companies are evincing keen interest in this product and some of the Japanese have also come for on spot study of our resources.

1.2. Resources, Cultivable species, Biology and Exploitation

The eggs of sea urchins like *Pseudocentrus depressus* and *Hemicentrotus pulcherrins* are said to be very tasty and valuable. Another sea urchin *Acanthocidaris crassispina* which is used for sea urchin industry in Hong Kong is said to be moderately good. However the above species are not available in the seas around India. In the world 14 species belonging to 10 genera are found to be edible. In India the eggs of four species can be tried on experimental basis. A field key is given below to identify the species based only on the colour and external appearance.

Field key to the Indian species

1. Black in colour with long spines .... *Stomopneustes variolaris*

1'. Spines small, colour not entirely black 2

2. Looks more like a flower under water, hand becomes numb on handling due to toxins ....*Toxopneustes pileolus*

2'. Does not look like a flower under water, no danger in handling in live condition 3

3. Spines white and short .... *Tripneustes gratilla*

4. Spines somewhat long and banded .... *Temnopleusrus toreumaticus*

Stomopneustes variolaris

This species is characteristic of rocky shores. It is abundant in Visakhapatnam, Muttom near Cape Comorin and also at Karwar where the shore is rocky. It is somewhat gregareous and bores into rock for protection against wave action. At Visakhapatnam a resource of 1224 metric tonnes of live material is estimated in 30 kilometer coastline at an average of 8.5 numbers per sq.m. It is found in good numbers in Andamans around Port Blair and also found in the Gulf of Mannar and Lakshadweep. The concentration of this sea urchin is more in the crevices of rocks and sheltered areas than in open rocky coasts. The diameter of the shell is 100 mm. and therefore the quantity of eggs is considerable.

Toxopneustes pileolus

This species is more valuable than the previous species for the eggs. In some of the Islands of Lakshadweep this species is abundant in the lagoons. This species is collected from the Islands of Chetlat, Kiltan, Kadamat, Amini and Kalpeni. It is likely to occur in all the Islands of Lakshadweep. This species occurs in good abundance in the lagoon of Amini Island. At some places 3-5 numbers are distributed per sq. m. It grows to a large size and each specimen weighs 200-300 g. Ripe eggs in large specimens weigh nearly 200 g. It is also known from the Gulf of Mannar and the Andaman and Nicobar Islands.

Temnopleurus toreumaticus

This species is distributed in the Gulf of Mannar, Palk Bay and the Lakshadweep. Large quantities of this species are caught in the fishing trawlers from the Palk Bay. The shell has a diameter of 40 mm. A few years back this species was purchased in good quantities for its eggs.

1.2.1. Exploitation

In India practically there is no exploitation for sea urchins since they are not locally consumed, and the potential for export has not been tapped.

However, the fisherman near Cape Comorin collect *Stomopneustes variolaris* for the shell which is used as curios. They remove the spines and clean the shell which becomes white in colour. This can be used as ash trays also. Some of them eat the ripe eggs in raw condition.

The timing of harvest of the eggs is very important and the quality and quantity depends on the right time of harvest. When the eggs reach maximum weight it should be harvested. Males and females can be separated based on the colour and consistency of the eggs. However it is not possible to tell the stage of development without opening the shell. So proper records regarding the ripening of the egg should be maintained. An interesting phenomenon is observed regarding the release of eggs. When the first sea urchin releases the eggs this induces the other sea urchins to release their eggs whether the egg is ripe or not.

The method of harvesting sea urchins vary with locality and size of operation. Sea urchins are collected by divers using snorkel and SCUBA equipment.

1.3. Farming Methods

1.3.1. Natural seed resources and collection methods

Seed of sea urchins is often encountered in the algal collections since sea urchins are vegetarians and they feed on algae. Seed of *Stomopneustes variolaris, Salmacis virgulata* and *Temnopleurus toreumaticus* are often collected with algae. Seed of *Stomopneustes variolaris* is collected during the month of October and the diameter of the shell varied from 11-16 mm. Seed of *Salmacis virgulata* is collected in July. Sometimes large quantities of seed of *Temnopleurus toreumaticus* is collected in the drag net and also trawl nets. The best way to collect seed of sea urchins is to use drag net and *Thallu Vallai* over algal beds. Also smaller trawl nets can be operated on algal beds for shorter durations to collect the seed.

1.3.2. Hatchery technology for seed production

Inducing the sea urchins is relatively simple. Larvae can be produced by stripping the gonads. A piece of shell with ripe gonad induces them to release the eggs. The larvae can be fed on mixed culture of diatoms. Sea weeds are given when the shell diameter is 3 mm. since the yield after feeding on seaweeds is extremely good.

1.3.3. Nursery rearing

Favourable results can be obtained by piling up rocks in suitable site or by building a beach in a small area and releasing the sea urchins in these areas. They can be fed by putting seaweed in a net and fixing it securely so that it will not be washed away by waves. Such suitable areas have to be first located for nursery rearing.

1.3.4. Grow-out systems

Raft type culture is done for sea urchins. A suitable location for this type of culture must have strong flow of sea water. The area should be easily accessible. The raft can be built in the usual way. It's size should be large enough to withstand damage but not so large as to cause interference with the flow of sea water inside the raft. The sea urchins will be placed in a basket. The mesh should be of standard size. The basket should be set at a depth of approximately 4 m. in areas of 7-10 m. depth. Sea urchins feed during nights. Seaweeds should be put in the baskets for feeding. They should be fed once in ten days. If the seaweed discolours or wither it has to be changed. The daily ration for sea urchins should be about 3% of their total weight.

Seed of *Salmacis virgulata* was reared in Aquarium tanks at Mandapam. The diameter of the shell increased to 27 mm in 84 days. Growth in natural environment is expected to be faster.

1.4. Post Harvest Technology

1.4.1. Utilization

The sea urchin eggs should be processed very quickly after it is collected within four to five hours. Eggs are taken by breaking the shell with a knife, proceeding carefully so as not to damage the delicate eggs. The eggs are separated from the shell by tweezers. It is reported that the Japanese have mechanised the removal process but in any case it must be done carefully since the appearance of eggs is very important for the Japanese market. After removing, the eggs are placed on a draining surface and washed in ice water before it is graded and packed fresh or processed. The eggs are graded by colour, bright orange ones are more desirable. When the colour tends to be red it indicates a high fat content which in turn shortens the shelf life. Temperature is an important factor in handling and processing the eggs intended for the fresh market. The eggs must be kept from losing water and the outer bag of egg is kept intact all the while maintaining good flavour. Some chemical treatment are also possible.

Air freight is a must for fresh sea urchin eggs which has to be transported to long distances. Spacing is important as the delicate product must be kept from jostling and allowed to drain while being kept moist and cold. Live sea urchins can be refrigerated and air lifted. This method is used by Canadian harvesters shipping to France. Sea urchins can be kept in cold running sea water without food for two weeks without decreasing the quality and quantity of the eggs.

Sea urchin eggs should be frozen before shipment. After thawing the eggs softens resulting in undesirable odours and bitter taste if preventive measurers are not taken.

Several other ways of processing and preserving the eggs are also employed. It may also be salted. This is often the method chosen for low quality and it is not intended for the fresh market. The eggs are sometimes steamed and then frozen and used as an alternative for the fresh eggs. It can also be preserved in alcohol but this changes the product considerably making it unsuitable for fresh market.

The egg is eaten raw with a drop or two of lemon juice or with soy sauce. In Japan the sea urchin egg is known as *Uni* and the fermented egg is eaten with rice. Raw *Uni* is eaten by keeping in the middle of *Sushi* which is cooked rice, wrapped in dried seaweed.

1.4.2 Marketing

In the past, limited areas of the world valued sea urchin egg and obtained their supply locally. Now the demand exceeds supply in some places and new market for under utilised resource of the sea has been recognised.

Japan and Korea are the largest consumers of the sea urchin eggs. Japan also harvests and processes more eggs than any other country but the demand is so strong that they must import supplies. Because of their commanding position in the market Japan is able to set standard of quality and price.

A number of countries export sea urchin eggs and these include the United States, Canada, North and South Korea, the Philippines, Chilie, Mexico, Australia and New Zealand. The shelf life of the egg is only three hours and therefore it has to be air lifted. This means that all the steps from harvest to market must be accomplished in this brief time. Less valuable forms of eggs may be shipped frozen or preserved in other ways and these can be sometimes shipped by surface. In 1988 fresh sea urchin egg is sold at the rate of 10 US $ for 50 g in retail outlets in Japan. This works out to 200 US $ per kg. Sea urchin imports by Japan during 1985-1987 is given below in Table II.

Table II. Sea urchin imports by Japan during 1985-1987 in metric tonnes

Country	1985	1986	1987
Korea RP	1991	1158	1110
Korea DPR	258	239	252
PR China	145	225	194
Taiwan PC	55	61	18
Hong Kong	26	57	44
Phillippines	37	79	65
Canada	148	176	190
USA	888	1243	1564
Mexico	19	98	125
Chilie	183	263	122
Australia	-	3	138
Turkey	-	0004	-
Total	2857	3601	3697

1.5. Prospects

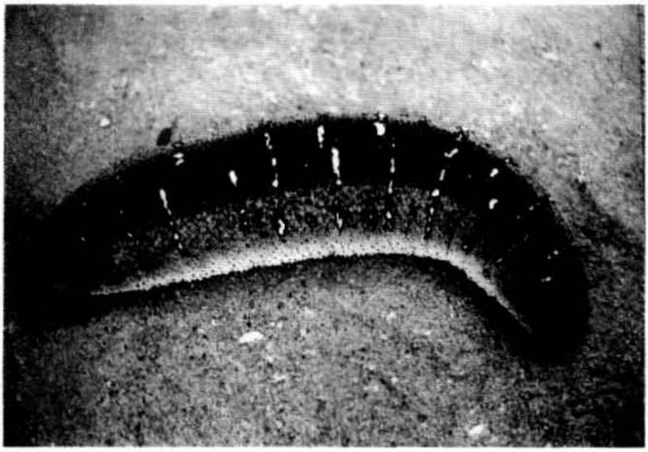
There are excellent prospects for the export of sea urchin eggs from India. James (1990) summarised all information regarding resources, harvesting, recovery, handling, processing of eggs, utilization, mariculture potential, export and marketing of sea urchins in a popular article. As stated earlier there are about 50 species of sea urchin in the sea around India and atleast half a dozen of them have good market potential. There is no internal market for this product in this country. The whole product has to be exported and the unit value is also very high being 200 US $per kg. Some time back the eggs of smaller species *Temnoplerus toreumaticus* was collected on trial basis. Eggs of larger species like *Stomopneustes variolaris* and *Tripneustes gratilla* also can be tried. Culturing some of the species can be tried in the Gulf of Mannar and Palk Bay, Andaman and Nicobar Islands and also be Lakshadweep. India should do well to tap this potential resource for export to earn the much needed foreign exchange for the country.

PART III

SEA CUCUMBER CULTURE

D.B. James
Central Marine Fisheries Research Institute
P.B.No. 2704, Kochi - 682 031
Kerala, India.

Holothuria scabra



Actinopyga echinites

Thelenota ananas

SEA CUCUMBER CULTURE

1.1. Introduction

According to the FAO's annual statistics for 1984 the world echinoderm harvest in 1983 amounted to approximately 80,000 tonnes. In 1989 India exported 51.5 tonnes of *Beche-de-mer* valued at Rs.1.23 crores. There is a growing demand for the *Beche-de-mer* from India. Some of the companies in Singapore are interested to import 10 tonnes every month.

The echinoderms or spiny skinned animals such as the sea cucumbers and sea urchins have good commercial value. The most popular product is processed sea cucumber or *Beche-de-mer*, a Chinese delicacy .

1.2 Resources, cultivable species, biology and exploitation

There are about 650 varieties of sea cucumber known from various parts of the world. In the Seas around India, nearly 200 are known of which 75 are known from the shallow waters within 20 metres depth. Of these about a dozen species are of commercial value. In India at present six species are used in processing. For processing a sea cucumber should be large in size and the body should be thick and hard. Sea cucumbers with white sticky threads inside the body and also those which have soft and thin skins are not preferred.

A field key is given below to distinguish the various species in the field without resorting to internal examination of the animals.

Field key to the genera of sea cucumbers used in processing

1. Surrounding the anus five white 'teeth' are present .... *Actinopyga*

1'. No teeth surrounding and anus 2

2. Ejects white sticky threads on collection ....*Bohadschia*

2'. No such white sticky threads in the body..............3

3. Body becomes gelatinous and disintegrates on exposure to air ....*Thelenota* and *Stichopus*

3'. Body does not disintegrate on exposure to air ....*Holothuria*

Genus *Actinopyga*

Species belonging to this genus can be easily identified in the field due to the presence of five white 'teeth' around anus. They grow to a medium size of 350 mm length. The body walls are thick and species are of moderate commercial value. Surprisingly members of this species are unknown from the Gulf of Mannar till 1989. At present two species are extensively processed though a third one is also known from the Gulf of Mannar. Species can be differentiated in the field based on colour.

Field key to the species of *Actinopyga*

1. Uniformly black in colour all over the body...........*A. miliaria*

1' Body not uniformly black 2

2. Colour uniformly brown all over the body ....*A. echnites*

2'. Colour not uniformly brown 3

3. Colour brick red on the upper side and white on the lower side ....*A. mauritiana*

4. Colour dark brown with ashy-white circular area around the anus ....*A. lecanora*

Genus *Thelenota*

It is a massive form reaching a length of 700 mm. and the live weight varies from 3 to 6 kg. Shape is distinct and characteristic with numerous pointed papillae arranged in groups on the upper side.

Genus *Stichopus*

Members belonging to this genus are usually four sided with some projections all over the body. Some species grow to a length of 900 mm.

Field key to the species of *Stichopus*

Colour is green and body is four sided ....*S. chloronotus*

Colour is yellowish and body is massive, loaf-shaped arched on the upper side and flat on the lower side .... *S. variegatus*

Genus *Holothuria*

Most of the common and most valuable species belong to this genus. The body is long and tubular. Some of them lie on the open, some bury in the sand, some live among the coral crevices. They occur in various colours. By far this genus is the most important in sea cucumbers since most valuable species come under this genus.

Field key to the species of *Holothuria*

1. Body is loaf-shaped with side projections in the living conditions under waters ....*H. nobilis*

1' Body tubular in shape 2

2. Colour completely black all over .... *H. atra*

2'. Colour not black 3

3. Black on the upper side with white or light yellow bands across the body; lower side white in colour with black dots ....*H. scabra*

3'. Light brown in colour with spiny projects all over the body ....*H. spinifera.*

1.2 Biology

The biology of the most important species *Holothuria scabra* is given below:

Holothuria scabra is known to reach a maximum length of 400 mm. It breeds twice in a year in the Gulf of Mannar. The first spawning season is during March to May and the second one is during November - December. Size at first maturity for females is estimated at 213mm and for males at 210mm. The fecundity is estimated at ten lakhs. The longivity is estimated as ten years. At the end of first, second, third, fourth and fifth years it reaches a length of 136 mm, 225 mm, 284 mm, 322 mm and 348 mm. respectively. In 18 months this species reaches sexual maturity. (B.K. Baskar, Personal communication).

1.2 Exploitation

The easiest method to collect them is to pick them with hand during low tide. This method is applicable for only those species which are found near the shore.

Sea cucumbers are usually collected by skin diving in shallow waters of 2 to 10 metres depth. Divers go in country boats with sails in the morning at 6 A.M. and return in the afternoon. In each boat four to six persons go for diving. Even small boys are employed in diving. The divers take net bags in which the live holothurians are put and brought to the shore. Since 1985 the divers are using aluminium plates for the feet as improvised flippers. These give them greater mobility under water. They can cover greater distances under water with ease and collect more material. Most of the material used for processing is collected in this way only.

Since sea cucumbers are bottom dwelling animals they enter into trawl nets during trawling. They are collected as bycatch.

During the last 17 years another net locally known as *Tallu valai* has been introduced in the Gulf of Mannar and Palk Bay. It is a type of trawl net without otter boards. The net is operated over sea grass beds and on muddy bottoms within four metres depth. The net is dragged by sail boat with one to three sails. In this net the sand fish *Holothuria scabra* is collected along with juvenile prawns and fishes.

1.3 Farming methods

1.3.1 Natural seed resources and collection methods

During February 1978, a natural bed of seed of *Holothuria scabra* was located at South Point near Port Blair (Andamans). The seed ranged in length from 65-160 mm. They were found in the intertidal region and could be collected easily during the low tide. A natural bed of seed of *H. scabra* was located in Kuntikalgut near Pamban. The seed can be collected during low tide by hand picking.

1.3.2. Hatchery Technology for seed production

Here the hatchery technology for seed production of *Holothuria scabra* is described in detail. The Central Marine Fisheries Research Institute has achieved a breakthrough in inducing the sea cucumber *H. scabra* to spawn in the hatchery and produce seed for the first time.

Collection of brood stock material

Brood stock collection is an important aspect in any culture practice. The brood stock is collected from the wild from the commercial catches meant for processing. Only large and healthy specimens alone were selected for this purpose. Those which were injured during the capture were rejected. They were stocked in one tonne tanks with sand brought from the natural beds. The sand is arranged in six inch thickness to enable the sea cucumbers to bury in the sand.

Maintenance of the brood stock

The success of the hatchery depends on the healthy condition of the animals maintained. The water in the tanks is changed every day and the sand is changed every fortnight. If the water is not changed regularly the sea cucumbers will throw out all the internal organs including the gonads and such specimens do not serve any useful purpose for the hatchery experiments. Fresh algae from the sea is brought and this is ground to fine paste in a mixie and put in the water atleast twice in a week. The sea cucumbers live on the organic matter present in the mud. The algal paste settles down to the bottom and this is consumed by the animals along with the mud. If proper food is not provided the animals become shrunken and gonad is reabsorbed. It is desirable to keep 20-30 adults in one tonne tank.

Collection timing

Collection timing is very important for the success of the hatchery management. Although *H. Scabra* spawns round the year, two spawning peaks one in March-May and the other in October-December were noticed.

It is desirable to collect the brood stock material during the spawning season so that the chances of spawning are more since most of the specimens will be ripe and ready to release the eggs. A small rise in temperature is enough to stimulate them to shed the eggs. Another aspect is that there is no known method to ripen the specimens. Therefore it is desirable to conduct these experiments during the breeding season of the animals.

Brood stock management

It is always good to keep the water in the brood stock tank in fresh condition. The whole water is daily changed. Aeration has to be provided for the tanks to keep the animals in healthy condition. Excreta and dirt in the tank should be removed immediately. The behaviour of the individual breeders should be constantly watched.

Spawning

The main aim of artificial breeding is to successfully obtain quality seeds. Details of natural spawning and induced spawning are given below.

Natural spawning

When the eggs are fully ripe, the male and female breeders release the eggs and sperms naturally without any inducement. At first the male releases the sperms, which induce the female to release the eggs in about two hours time. The eggs are generally released around 3 P.M.

Induced spawning

Stimulation by heat only give results in case of *H. scabra.* First the temperature of the water of brood stock tank is noted and this is raised to 5°C by adding hot sea water. The ripe specimens are so sensitive to temperature changes that a rise of even 3°C is enough to trigger them to release the eggs. When the water in the brood stock tanks is changed by sea water from the sump or when the specimens collected from the wild are introduced to sea water from the sump, if ripe specimens are available they immediately react and release the eggs.

Spawning behaviour

In sea cucumbers the sexes are separate and it is not possible to distinguish the sexes externally. Only microscopical examination of the gonads will indicate whether they are males or females. At the time of spawning also it is possible to differentiate the sexes since the behaviour of males and females is different. In all cases the males only first spawn and this is followed by the females. In case of *H. scabra* the males first lift the anterior end and exhibit swaying movements. After exhibiting such movements for sometime the males start releasing the sperms from the gonopore situated at the upper side near the head region. The male when once it starts releasing the sperms it keeps on going this way for about two hours. In the meanwhile if there is a ripe female in the sample it starts reacting to the sperms released in the water. The females start ascending at the corner of a tank and head region becomes bulged due to pressure created inside the body. The head region every time comes out of water a little and again gets into water. After a few attempts like this the female releases the eggs in a single spurt and lies at the bottom of the tank. The eggs are ejected out in a powerful jet reaching to a height of about three feet. The egg mass released is light yellow mucus-like substance. The powerful jet helps in the dispersal of the eggs over a wide area.

Fertilization

It is important to ensure a high survival rate in the artificial breeding by obtaining high quality eggs. Therefore it is necessary to handle the eggs carefully as soon as they are released. The union of male and female elements take place outside in the water. After the eggs and sperms are released the breeders are removed from the tank. The eggs are washed several time in order to remove the excess sperms which might pollute the water in the tank resulting in reduced fertilization and a large number of deformed embryos.

Early development

The female usually releases about one million eggs. About 75 million eggs can be stocked in 750 litres of water. After fertilization the eggs undergo division and transform into three types of larvae. The first and second type of larvae are produced in 24 hours. On the tenth day the third type of larvae is formed. By thirteenth day some of them transform into miniature sea cucumbers and attach to the sides of the tank. The body is tubular with five tentacles at the head region. It has one foot at the rear end. This serves to anchor the animal to the bottom. As days advance more and more feet develop all over the body. They have a habit of moving to the edge of the tank and remain just below the surface of water. Soon they settle down to the bottom of the tank.

Rearing of larvae

Rearing tanks and other tanks used in breeding, especially the new tanks, must be scrubbed clean and filled with water for 20 days, during which period the water is changed repeatedly in order to lower the pH to less than 8.5. Before the tanks are used, they are scrubbed and filled with water containing 40 ppm bleaching powder and then washed clean with filtered sea water before the larvae are released.

Rearing density

Strict control of rearing density of the larvae, i.e. the number of larvae per ml of water is first calculated. At present there are two methods to rear the larvae, still water rearing and flowing water rearing. Second stage larvae concentrate during their early and middle stages at the surface of water. If the density of the larvae is more they will form as a ball and sink resulting in death. Therefore rearing density should be controlled to ensure better survival rate. The desirable density of larvae is 300-700 per litre. In one tonne tank having 750 litres of water 3,75,000 larvae can be stocked.

Selection and counting of the larvae

After fertilized eggs are removed to rearing tanks, they develop into the second stage larvae in 30 hours. The bottom of the rearing tank should be cleaned thoroughly. Healthy larvae occupy the surface layer of water, while deformed ones and dead embryos generally stay in the lower layer of the water column or at the bottom of the tank. All the dead individuals, deformed larvae and sediment should be siphoned out in order to clean the tanks. After the tanks are cleaned, the water in the tanks should be gently stirred so that the larvae can be uniformly distributed. A sample is then taken for counting the larvae. Samples are taken separately from the two ends and the middle of the tank in a 250 ml beaker. The sample is uniformly stirred and one ml sample is taken in a pipette and put in a plankton counting chamber. The number of larvae are counted in each ml. Like this two more samples have to be taken in a pipette and the average of three counts is taken as an indication of the density of the larvae. The result of the count would show whether the density is desirable or not. The period of second stage larval development can be divided into three stages, viz., early, middle and late stages. As they develop from one stage to the next, the bottom of the tanks must be cleaned completely once, or the larvae moved to another tank. Normally the larvae are taken out after every three days so that the tanks can be cleaned thoroughly to avoid infestation of other organisms. On other days the water level is reduced to more than half by keeping the seive inside the tank. The sediment must be removed to keep the water fresh. An upto date information on the survival rate at each developing stage is necessary.

Water management

In the course of rearing, the larvae eject faeces and consume dissolved oxygen constantly. Some of the larvae die in course of time. These and the left over food produce harmful substances like Hydrogen Sulphide and Nitrogen wastes. In addition bacteria produce rapidly with rise of temperature. Poor water quality directly affects the normal development of larvae. Therefore proper water management and sanitation is essential. Regular cleaning of tanks and changing of water are essential. The dirt and deformed larvae at the tank bottom are siphoned out every day. While water is changed by keeping the seive inside the tank, the mesh size of the seive must be smaller than the larvae. Normally 80 seive is used since the larvae and even the eggs are more in size than the seive. While the water is being changed with help of a seive someone should constantly stir the water lightly all round the tank. This will prevent the loss of larvae during water change, since siphoning would normally force the larvae to stick to the sieve causing mechanical injury to the larvae. The sediments at the bottom of the tank should be siphoned out completely every three or four days.

Larval feeding and feeding rates

Suitable and high quality microalgae and correct feeding rates are the key to successful rearing. As the larvae progress in development, the elementary canal is well formed and the larvae must be given diet immediately. The feeding mechanism of the larvae consists of conveying the suspended bits of organisms and unicellular algae into the alimentary canal through the mouth parts by the swaying of the hairlike structures round the mouth. The effectiveness of various microalgae were tried. The results showed better growth rate when fed with the microalgae *Isochrysis galbana*. The mortality rate is also less. After four to five days the larvae are also fed with mixed culture. This chiefly consisted of the phytoplankton *Chaetoceros* sp.

The larvae require different quantities of diet during different developmental stages. Unicellular algae are fed twice in a day, but the quantity given each time depends on the particular stage of larvae. In general 20,000-30,000 per ml in the rearing tank water is maintained. The microalgae *Isochrysis galbana* cultured usually has a concentration of 80,000 cells per ml. When the bloom is good it reaches one million mark. The quality of diet given should be increased or decreased depending on the quantity of food in the stomach of the larvae. This can be visually checked every day before feeding them. Unicellular algae during the peak period of their reproduction are most preferred diet for the larvae.

Environmental Factors

Monitoring of the environmental factors is of paramount importance since the larvae and the seed are sensitive to the environmental changes and easily succumb when conditions are adverse.

Temperature

The ideal temperature for rearing of the larvae was found to be 27-29°C. The temperature of the water should be noted twice in a day, both in the morning and also during the afternoon.

Dissolved oxygen

Dissolved oxygen level varies with water temperature. The higher the temperature, the lower the dissolved oxygen level. The normal range for dissolved oxygen is 5-6 ml/litre. Always aeration is given to the larval tanks throughout the day to see that the oxygen level does not go down much. For one tonne tank generally two aerators are provided one at either end.

pH

Under normal conditions, the rearing sea water is generally alkaline with pH of 7.5-8.6. Tests have shown that the larvae of *H. scabra* adopt to a fairly wide range of pH. However when pH rises over 9.0 and drops below 6.0 the moving ability of the larvae weakens and growth stops. Therefore the pH of the water must be between 6.0 and 9.0.

Salinity

Salinity of normal sea water is 35‰. If the salinity is low all the larvae will die. The lethal critical salinity is 12.9‰. The optimum salinity for larval development ranges from 26.2 to 32.7‰. In this range the higher the salinity, the quicker is the development. Too high or too low salinity adversely affect the normal development of the larvae, resulting in large number of deformed larvae causing death. Salinity estimation is, therefore an important routine work throughout the entire rearing period. A salinity refractometer is now commonly used for quick salinity estimation. If the specific gravity of the water is found out the measured value can be converted into salinity value.

Ammoniacal Nitrogen

The ammoniacal nitrogen of sea water is very low. The sources in the breeding tanks are mainly the metabolites of larvae, the unconsumed diet and decomposing organisms. Too much accumulation of nitrogen can be harmful for the larvae. The larvae can develop normally with an ammoniacal nitrogen content of 70-430 mg per cubic metre of water. When its content is over 500 mg per cubic metre of water it will have harmful effect on the development and growth of larvae.

1.3.3. Nursery Rearing

The larvae after going through three states settle on hard surface when food is sufficient and also when proper substratum is available for them to settle. If these two conditions are not satisfied they continue to swim in the tank for a long time. Therefore correct feed is given for the larvae and often settlers are provided for them to settle.

Types of settling bases

Two types of settling bases are tried for the larvae. In the first type polythene sheets are taken and kept in a tank outside the hatchery where there is good sunlight. Into these tanks filtered sea water is circulated continuously for four or five days. Benthic diatoms and other algae settle on the plates. These plates are taken inside the hatchery and suspended in the tanks which have advanced larvae about to settle down. The hard surface and the food induces them to settle the larvae on the plates. One disadvantage with settlers of this type is that the benthic larvae which settles on the plates comes off completely after four or five days. In other type of settler the polythene sheets are kept in a tank having sea water. To this some algal extract filtered through 40 μ is poured. Usually Sargassum alga is used to make the extract and this is put in the tanks with small quantity of sea water. The algal extract will stick to the plates. The water is changed daily and fresh extract is put in small quantities. After four or five days the polythene sheet is covered with fine coat of algal extract and this serves as a good settling base for the larvae. If food is not provided on the settler the larvae after settling will die. The settling bases should not have any toxicity and should be easily available and also should be inexpensive.

Diet for the seed

After settling down the seed have only weak moving ability. Fresh sea weeds are collected and first cut into small bits and then put in a mixie and ground into fine paste. This is filtered by using 40 μ seive initially. After one month 80μ seive is used since the seed will be in a position to take bigger food particles. This filtered extract is daily given to the seed both in the morning and also in the evening. The seed is found to feed actively on the algal extract and grow well due to high protein content.

Density for the seed

When the larvae develop into seed, they begin to crawl. Most of them stay on the settling bases. After 15 days of settlement, they can be seen with naked eye. The number of seed should be estimated. A random sampling is made with a frame of 400 sq.cm. The samples should be collected from different portions of the tank. The sampling area of each tank must be over 5% of its total area.

In order to achieve increased survival rate, it is necessary to control appropriately the settling bases at the optimum level. Too many of seed in limited area and insufficient diet will be adverse to the growth and survival. Hence, after they are counted, their density should be adjusted to an optimum of 200-500 individuals per one square metre.

Predators and their control

Predation

Copepods and ciliates are the main predators on the second stage larvae since their movements are sluggish. They attack the larvae at the sides and injure the body. Finally the larvae die due to the injuries caused.

They also harm the seed by reproducing fast in the rearing tanks and competing for food with the seed. Algal extracts given for the seed is found in the alimentary canals of the copepods. They also wound the body surface of the seed with their mouth parts and tear the skin of the seed. Infested seed assumes a ball shape and they die gradually. The second stage of larvae is the most vulnerable for the attack of the predators because of their sluggish movements and due to their extended life in that stage for several days.

Predator control

Control trials on copepods with different chemicals at different concentrations have been conducted. Chemicals containing organo-phosphorus can be tried. Copepods can be killed with 2 ppm dipterx in two hours with no harmful effects on the seed. However it is necessary to give careful attention to the preparation of dipterx solution of appropriate concentration. The solution should be evenly sprinkled into the tank and the water of the tank must be changed completely after two hours. This is very important otherwise it will affect the seed.

1.3.5. Grow-out systems

After the seed is grown for a month or two in the nursery it has to be transferred to the sea for further growth. By the end of two months most of the seed will reach 20 mm in length. There is vast difference in the growth of the seed belonging to the same brood. Therefore some culling is necessary. Fast growing seed is separated and transferred to the grow-out systems. The seed can be grown under three different conditions depending on the number of seed on hand.

In the first method rectangular iron cages of the size 3 x 2 feet are taken and they are closely woven with 2 mm. nylone rope into 900 sq. mm. net work. Fine velon screen is taken and stitched as lining for the rectangular ox type cages. The mesh for the velon screen should be very small other wise the sand placed inside the box will escape. Along with fine sand, algal powder is also kept as food for the seed. Four casurina poles are driven into the sea bottom at a depth of one metre and the boxes and securely tied to the poles and kept at the bottom. After introducing the juveniles into the box cage the lid is properly closed and stitched in order to prevent the seed from escaping into the sea. These boxes are removed every month to clean the cages from the fouling organisms and also to take the length and weight of individual sea cucumbers. All the sides of the rectangular box cages are thoroughly scrubbed with brush to remove the fouling organisms. This operation not only helps to remove the fouling organisms but also allows free flow of sea water into the box. Since space is limited large number of seed cannot be grown by this method. Due to limited area the growth is also found to be somewhat slow.

In the second method an old one tonne tank is fixed at the bottom of the sea at a depth of one and half metres. Four casurina poles are driven at the four corners of the tank and the tank is securely tied to the poles. Before fixing the tank at the bottom of the sea it is first filled with fine sand to one fourth from the natural habitat. This should be free from predators such as crabs and other unwanted organisms. Fresh algae from the sea is collected and dried. Then the dried algae is made into powder and this is mixed with the fine sand kept in the tank. The algal powder helps in the better growth of the seed. The tank is covered by a velon screen and placed at the bottom of the sea. The specimens are examined and average length and average weight of the specimens is taken. The growth of the specimens reared in the tank was found to be better and faster due to more space and good circulation of water.

In the third method pens are erected in shallow water in sheltered bays. The pens can be made of bamboo screens or palmyrah rafters. When seed is in large number pens of 25 sq.m. are erected to grow the sea cucumbers. The pens have to be periodically examined to see that they are not damaged by crabs and other wood boring organisms. If the damaged portions are not detected and repaired then sea cucumbers will escape into sea.

1.4. Post harvest technology

It is a cottage industry needing very little investment and mainly based in rural areas along the beaches. The processing is simple. This mainly involves in removing the internal parts, boiling in sea water for an hour or so and then putting it out for sun drying. Sand fish which is then most expensive from India is buried for 10-12 hours after boiling them thoroughly cleaned and boiled once again and dried. Chinese settled all over the world use *Beche-de-mer*. Chinese settled in U.S.A. and Germany and other countries pay a premium and purchase expensive *Beche-de-mer*. At present our processing is crude, unscientific and also unhygienic. Expensive *Beche-de-mer* comes from countries like Korea. India will do well to learn the correct processing methods to get more foreign exchange for the country. To increase the value *Beche-de-mer* is packed in polythene covers so that the material will not be spoiled due to the moisture in the atmosphere since this substance absorbs moisture. They are then packed in attractive cartons to catch better market.

1.4.1. Marketing

There is no internal market for the *Beche-de-mer* in India. So the whole product is exported. Hong Kong and Singapore are the world markets for *Beche-de-mer*. Hong Kong is the foremost country in the world by importing 5000 to 6000 tonnes of *Beche-de-mer* every year. India chiefly exports to Singapore. From Singapore our material is re-exported to Hong Kong and Chinese ports. It is not just physical movements at Singapore for our material since it is re-processed to some extent to add to the value of the product.

Government of India put a ban on the export of *Beche-de-mer* which is less than three inches in length as a measure of conservation in 1982. While conservation and management are essential for any resource the only answer to this problem is large scale farming of the sea cucumbers.

1.5. Prospects

With the breakthrough achieved by the Central Marine Fisheries Research Institute in 1988 in inducing sea cucumbers to shed their eggs and to produce seed there are excellent possibilities for culture of the sea cucumbers in selected area. The seed so produced can also be used for sea ranching programme to enrich the natural populations which are depleted due to overfishing. The prospects for the culture of sea cucumbers in India are excellent. Juvenile sea cucumbers can be grown in enclosed bays to marketable size by using simple methods. There is no need to construct farms with bunds at great cost since the sea cucumbers move not much from the area where they are introduced. Suitable sites have to be located in natural beds which are sheltered. The question of feeding with artificial diet does not arise since they subsist on the organic matter present in the mud or sand. Several economically important species are available in the Seas around India. There are about a dozen economically important species distributed in the Gulf of Mannar and Palk bay, the Andaman and Nicobar Islands and in the Islands of Lakshadweep. Some of the species distributed in the Andaman and Nicobar Islands and also at the Lakshadweep are more valuable than those found in the Gulf of Mannar and Palk Bay. Therefore in order to diversify the industry both in space and species first the juveniles of commercially important species should be collected and grown in the Andaman and Nicobar Islands and also at the Lakshadweep.

So far seed of *H. scabra* alone is produced in a limited manner. The

FOREWORD

Seaweed is identified as the medical food of the 21st century because of its unique life-supporting properties such as vitamins, minerals and trace elements. India's rich untapped seaweed resources can open a new chapter in health-food production of our country through farming. In order to make a beginning in this direction the Marine Products Export Development Authority is trying to project the importance of seaweed in 'INDAQUA', the First Aquaculture Show in India. The pioneering work done by CMFRI in this field and the effort taken by Dr. N.Kaliaperumal and his fellow scientists to compile this volume deserves special appreciation.

Similarly India's rich resources of sea cucumber and sea urchins are totally untapped for aquaculture. They are high-priced seafood products with excellent demand in the South East Asia and Japan. Sea Cucumber is a Chinese delicacy, Roe of sea urchins is a Japanese delicacy. If these resources are properly tapped through sea bed culture it is possible to earn a substantial amount of foreign exchange earning to our country.

The Department of Biotechnology has been very kind enough to extend financial assistance to publish this volume and I extend my heartfelt thanks to them. The effort put up by Dr. G Santhana Krishnan and his colleagues to coordinate the publication work is well appreciated. I am sure this publication covering various aspects of seaweed farming will be of immense help to the investors in seaweed farming.

(M SAKTHIVEL)
CHAIRMAN
MPEDA

hatchery production for seed should be scaled up to meet the growing demands. Other commercially important species like *Holothuria nobilis* in the Lakshadweep should be tried for seed production. Some farmers have already stocked juveniles of *H. scabra* and grown them in enclosed areas. There is demand from farmers for the seed of sea cucumbers. In order to meet the growing demand for *Beche-de-mer* from the International markets and also to earn more foreign exchange for the country culture practices have to be taken up in sea cucumbers in large scale in India.