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Scientific solutions for sustainable aquaculture

Sea Cucumber Farming : An Eco-Friendly Practice

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Marine aquafarming activity in India, which by itself is on a small and sporadic scale, has received a setback in recent years due to incidence of disease, pollution and also legal problems. Consequently most of the marine aquafarms are now in disuse.

The revival and popularisation of marine aquafarming assumes special significance at this time of decreasing trend of fish production. The best way of making a begining in this line is to introduce and promote sea cucumber culture.

Sea cucumber can be termed as the earthworm of the sea, although it is not a worm. It keeps on feeding on the mud at the bottom of the sea or a farm and subsists on the organic matter present in it. It removes all bacteria and decaying organic matter from the bottom and contributes to keeping the environment clean and healthy. Farming of sea cucumbers is a eco-friendly operation. It does not cause any damage to the environment.

Processed sea cucumber *Holothuria scabra* fetches a good price in the international market. This favourable aspect has been somewhat neutralised in a good cause by the Ministry of Environment and Forests, Government of India which has brought all the sea cucumbers under Schedule I of wild life Protection Act of 1972 in 2001. The collection of all animals under this schedule is strictly bann Sea cucumbers have been al recommended for inclusion und Appendix II of the Convention International Trade in Endanger Species of Wild Fauna and Flora (CITE to conserve their declining populatio These provisions entail the obtaining special permission from the Ministry Environment and Forests, Governme of India for harvesting farmed s cucumbers raised from the se produced in a hatchery too.

The author visited some of t hatcheries and farms of the se cucumber *Apostichopus japonicus* China in October, 2003. China h perfected the technology for the hatche

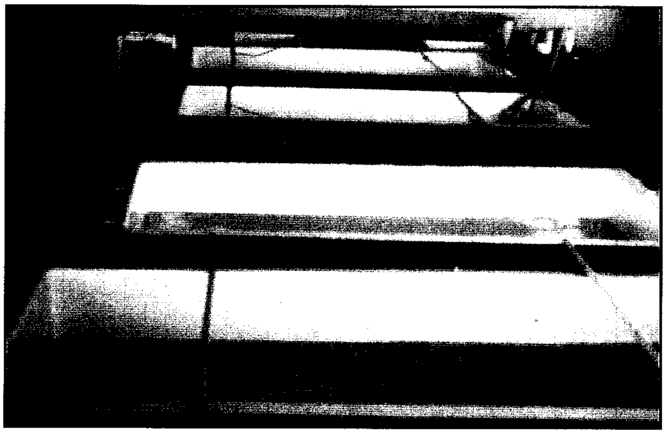

Fig 1 : Sea cucumber hatchery at Tuticorin Research Centre of CMFRI

Fig 2 : Algal Stock culture room

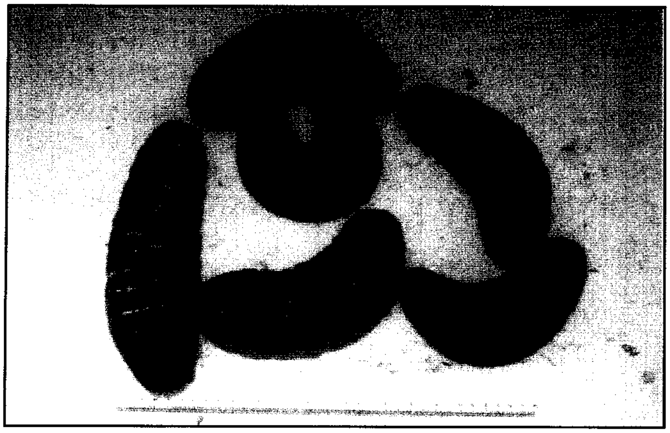

Fig 3 : Broodstock of *Holothuria scabra*

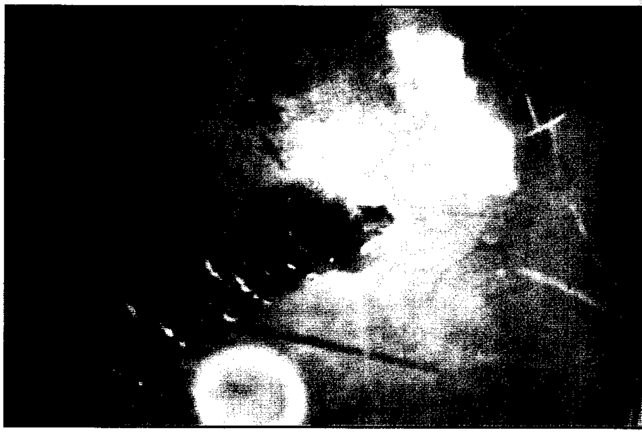

Fig 4 : Male of *H. scabra* releasing sperms

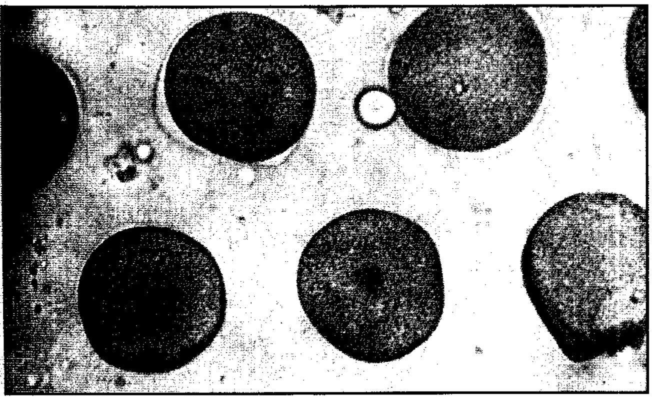

Fig 5 : Fertilized eggs (one of them showing polar body)

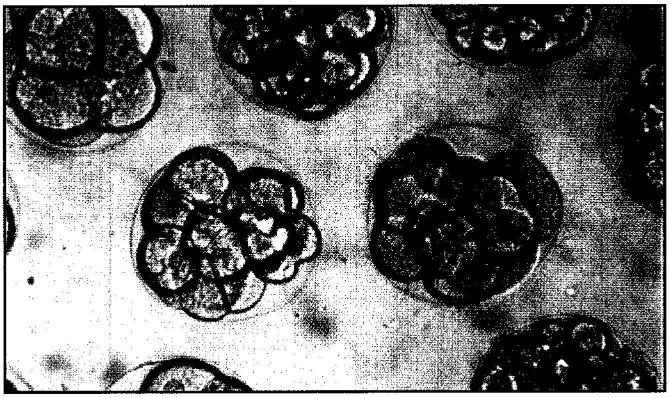

Fig 6 : Blastula

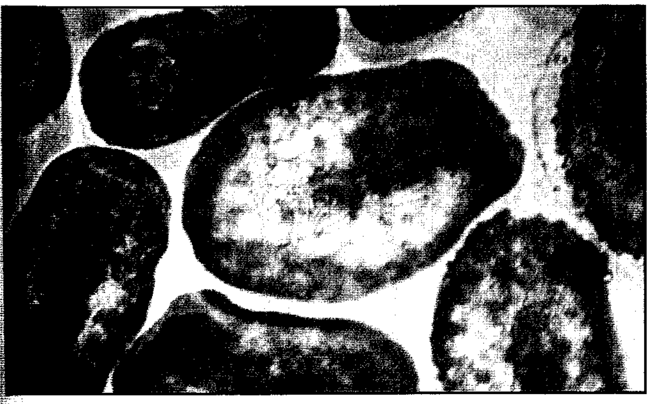

Fig 7 : Elongated Gastrula

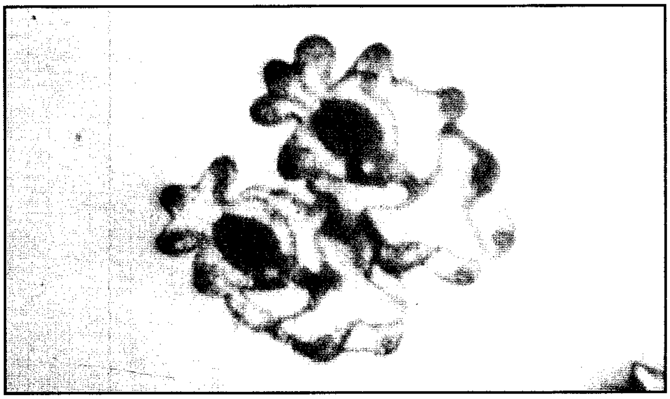

Fig 8 : Late Auricularia

Fig 9 : Early Auricularia

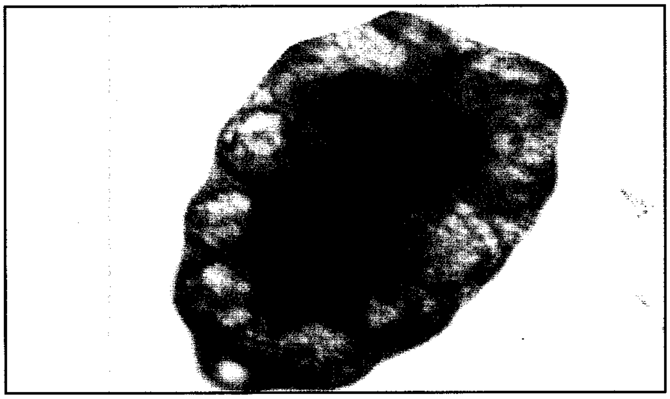

Fig 10 : Early Doliolaria

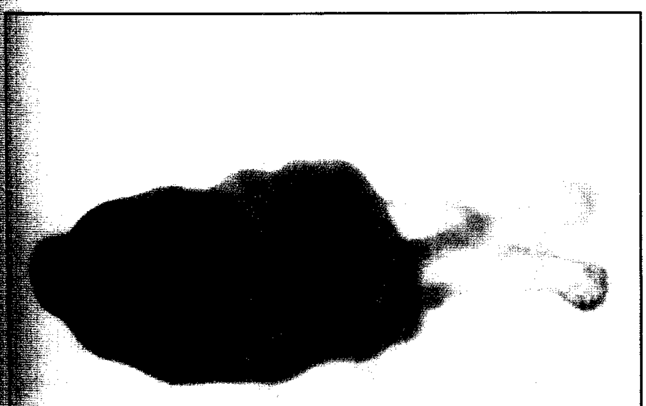

Fig 11 : Late Doliolaria

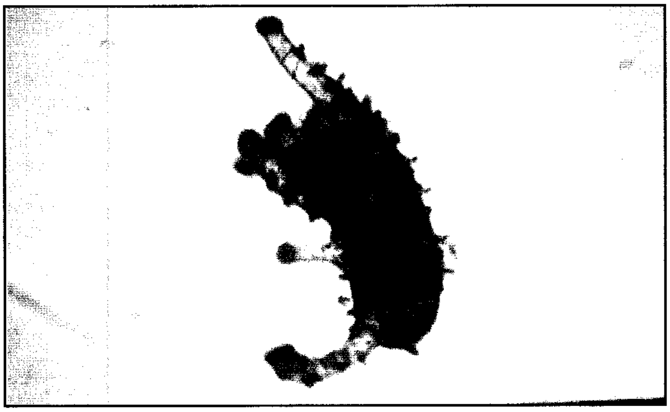

Fig 12 : Pentactula

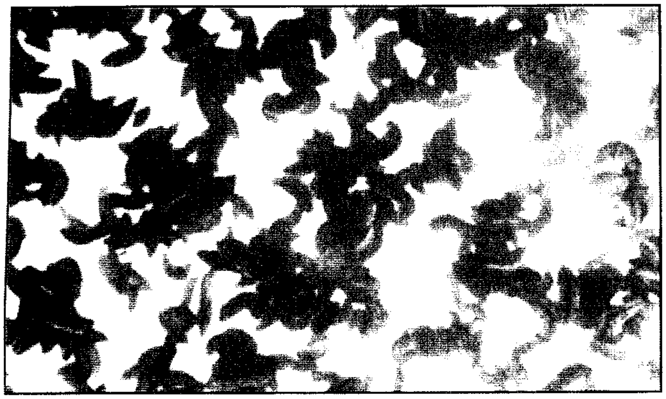

Fig 13 : Two month old juveniles produced in the hatchery

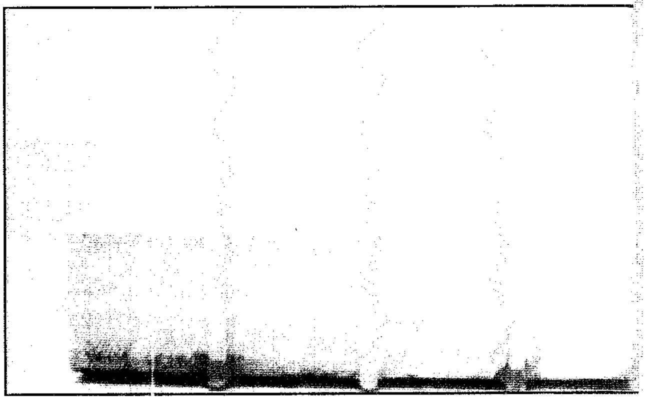

Fig 14 : One tonne tank

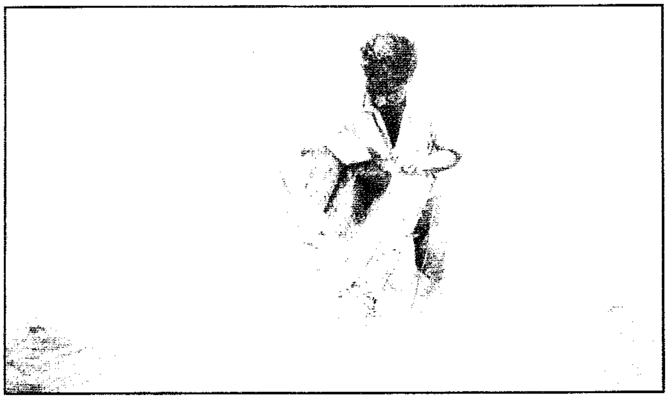

Fig 15 : Cleaning of rectangular cage

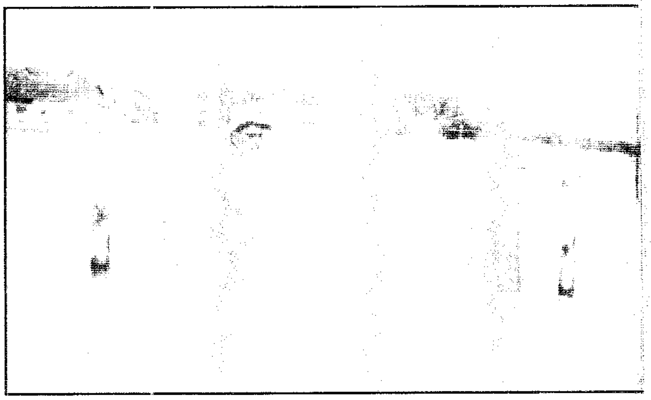

Fig 16 : Velon screen cage

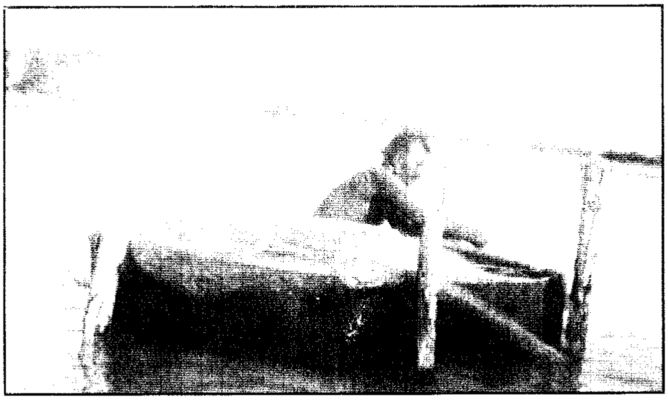

Fig 17 : Netlon cage installed in Karapad Bay

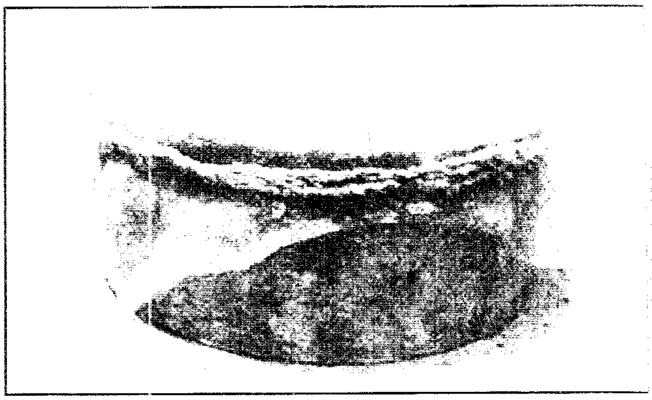

Fig 18 : Concrete ring before installation

Fig 19 : Shrimp farm at Tuticorin where hatchery produced sea cucumber is stocked

Fig 20 : Juveniles of *H. scabra* grown in a shrimp farm production of sea cucumber seed and also their farming. Survival of seed in a spawn settlement zone is 80-90% in *A. japonicus*. However it should be borne in mind that the species farmed in China is different and its habits are also different. *A. japonicus* lives freely at the bottom of the farm, whereas *H.scabra*, Indian species, has the burrowing habit.

Chen (2002) presented an overview of the sea cucumber hatchery operations, sea cucumber farming and its sea ranching practices in China. James (2004c) published a paper on the hatchery and farming of *A. japonicus* in China with suggestions for the Indian farmers. These methods have to be now modified to suit present Indian conditions and species of culture.

In this communication an effort is made to bring out various aspects of sea cucumber hatchery and farming of sea cucumber for the benefit of the farmers who are interested to take up its farming, besides listing all references on hatchery and farming of sea cucumbers from India at the end of the paper to help those who are interested in the setting up of sea cucumber hatcheries and in farming sea cucumbers. List of equipment needed to set up sea cucumber hatchery and the economics of sea cucumber farming are also given.

The seed of the most valuable Indian sea cucumber species *H. Scabra* was produced for the first time by James *et al.* (1988). The process of seed production was also described in detail by James *et al.* (1994). Following a similar technology, other coutries like Australia, Indonesia, the Maldives, Solomon Islands, and Vietnam have been producing the seed of this valuable species and are farming them at present. Hatchery operations and farming of *H. scabra* are dealt with in detail by James & James (1993), James 1993, 1994 a & b, 1996 a-d, 1997, 1998b, 1999 and 2004 a-f). James *et al.* (1993) also reported on the spawning of another commercially important species of sea cucumber *Actinopyga mauritiana*. James (1993) authored a paper on sea ranching of sea cucumber.

Selection of the Hatchery Site: Suitable site selection is important for establishing a viable sea cucumber hatchery. The success of the hatchery operations mainly depends on several factors in respect of the site.

The following are the primary requirements to be considered while selecting a site for the hatchery.

1. Sea cucumber hatchery must be located close to the sea shore with adequate supply of good seawater free from pollution, suspended particles, silt etc.

2. The salinity of the seawater must be between 30 and 40 ppt throughout the year.

3. The hatchery must be away from industrial and domestic sewerages. It should be away from a river mouth so as to avoid any significant dilution of salinity during monsoon.

4. The sea bottom must be rocky or coralline so as to get clean seawater throughout the year.

5. Supply of freshwater must be ensured at the hatchery site.

6. Approach road must be available for convenience of inward transportation of hatchery needs and movement of hatchery produce to the outside.

7. Hatchery area should be such that it would not normally be affected by cyclones and other natural calamities like sea or soil erosion.

8. The hatchery must have access to power supply.

9. The area from hatchery to the farm site should be free from fishing related shore activity.

Facilities for the Hatchery: The basic facilities required for the production of sea cucumber seed are described hereunder.

Building: The hatchery must have a minimum plinth area of 24 m X 12 m with light roofing (Fig. 1). The flooring should be paved with Cuddapah or Kota stone providing proper slope. A straight gutter has to be provided running in the middle along the entire length of the hatchery floor for the collection and flow-out of any water that spills during operation and to keep the floor clean. Ventilation facility must be provided at the sides of the hatchery building to maintain clean air inside the hatchery.

There has to be a conditioning room (6.0 m X 8.0 m) with a roof covered with asbestos sheets and a false ceiling with thermocol underneath for conditioning broodstock of sea cucumbers prior to inducement for spawning. The temperature of the conditioning room has to maintained between 18-25°c by using air conditioners.

Seawater Supply: Only filtered seawater has to be supplied to the hatchery. One alternative for organising such a supply is to provide seawater filter system consisting of a draw well, sedimentation tank, filter bed, storage sump, overhead tank and PVC delivery lines to the hatchery. Seawater, drawn into the well by gravitation through a 15 cm diameter pipe, is to be pumped into the sedimentation tank using one hp electric pump set, to allow the larger particles to settle at the bottom. The clear supernatant seawater has to be then passed through the filter bed. The filter bed consists of fine river sand at the top, and charcoal, pebbles and granite stones at the bottom. The filtered seawater, pumped to the storage seawater sump (20,000 lit capacity), may be pumped in turn to the overhead tank (10,000 lit capacity) using one and 7.5 hp electric pumpsets respectively.

Air Supply System: The air supply system consists of air compressors, filters, PVC air grid, polyethylene tubes, diffuser stones and air regulators. Air compressor with one hp electric motor gives a high output at low pressures. Air storage tank gets automatically cut-off when it is full with air, thereby allowing the compressor sufficient respite. The air flow is regulated by passing it through a series of filters for removing oil and moisture content in the air. An air pipe of 25 mm dia has to run along the entire length of the hatchery and the air is to be drawn at required places from pipelines through polyethylene tubes and diffuser stones and adjusted with the help of a gate valve connected to the polyethylene tubes. By keeping a standby compressor the air supply system can be well managed.

Generator: Three phase standby generator of 10 KVA capacity operated by a 16 hp diesel motor is to be used in case of power failure.

Conditioning Room: The conditioning room may have to be 6 m X 8 m in size with thermocol ceiling, as already stated. Two air conditioners (1.5 tonne cap each) are to be installed in the room for maintaining temperature at the desired level, at which mature sea cucumber can retain sexually ripe gonads. The sea cucumbers are kept in 100 l FRP rectangular tank provided with muddy-sand at the bottom of the tank. To this, small quantities of algal powder are to be added from time to time. This forms an excellent food for the broodstock.

Spawning Tank: A perspex rectangular tank of 100 l capacity is to be arranged for spawning of sea cucumbers. Jumo thermometer, silica cased immersion heater and an aerator are to be fitted to the tank during the thermal stimulation and these are to be connected to an automatic ECE controller.

Larval Rearing Tanks: One tonne capacity FRP rectangular (200 cm X 100 cm X 50 cm) tanks are to be used for rearing the larvae of sea cucumbers. Five to ten such tanks are required. These tanks must have smooth inner surface with white colour which will help in observing the larvae clearly.

Juvenile Rearing Tanks: The settled juveniles have to be reared in one tonne FRP tanks similar to larval rearing tanks. Five to ten such juvenile rearing tanks are required for the hatchery. These tanks should have smooth surface and provided with fine mud at the bottom for the rearing of the juveniles to take place in conditions as in the natural environment.

Algal Culture Tanks: The tanks to be used for algal culture can be similar to the earlier two types. These tanks must have smooth white inner surface required for mixed algal culture. The seawater in the algal culture tanks is agitated with a pair of diffuser stones. The mixed algae cultured in these tanks are suitable for feeding the juveniles of sea cucumbers. *Isochrysis galbana* is given to the larvae as feed and this can be cultured under controlled temperature conditions. The culture room (Fig 2) has stock of 18 kinds of microalgae as feed for the larvae.

Other Equipments: Different mesh size (40μ, 80μ and 200μ) seives, a good microscope to observe the condition and to measure larvae, a haemocytometer to count algal cell concentration, a plankton counting chamber to estimate the larval density are the other requirements for a sea cucumber hatchery. The pH meter, thermometer, refractometer, and oxygen estimating unit are the equipments used for monitoring the water quality. Glassware such as trays, beakers, conical flasks, embryo cups, petri dishes, pipettes, microslides, cover slips, plastic containers such as buckets, basins, mugs and perspex tanks are the other requirements.

Full list of equipment required for the hatchery is given in the Annexure.

Personnel Requirement

One Scientist and a Supervisor with thorough knowledge on hatchery management, one Technical Assistant with experience in larval estimation, stocking, measurement and algal cell counting and two skilled helpers to change water in the related tanks for the larvae/juveniles and feeding them daily will be required for the mass production of sea cucumber seed in the hatchery and to rear them in the farm. Provision of seawater system both for the larvae and juveniles will minimise the labour in the hatchery. Thus, man power may have to be deployed mostly for effective management of juveniles in the culture area.

Hatchery Operations

***Collection of broodstock material*:** Upto the present time there is no special net or device to collect sea cucumbers exclusively. *Holothuria scabra* is distributed in the Gulf of Mannar, the Palk Bay, the water around Andaman and Nicobar islands and off the West Coast of India. James (2000b) stated that *Holothuria scabra* var. *versicolor* is also known to inhabit deeper waters of Lakshadweep. Sea cucumbers coming in the trawl nets cannot be used as brooders, since they often throw out the intestine and gonads which are prone to damage it is desirable that broodstock, material is collected from the commercial catches brought by skin divers for hatchery use, same way as the author has done. The diving season for the sea cucumbers is from October to March in the Gulf of Mannar and from March to October in the Palk Bay. Therefore the sea cucumbers can be collected round the year from the commercial catches. Only large, healthy and uninjured specimens (Fig. 3) used to be selected by the author to serve as the broodstock. The specimens are stocked in one tonne capacity FRP tanks with mud brought from natural beds. The mud is placed in a six inch layer to enable the sea cucumbers to bury themselves.

***Maintenance of Broodstock*:** The success of the hatchery depends on the healthy condition of the broodstock. The seawater in the tanks has to be changed every day and the mud too has to be changed, although once in every fifteen days. If the seawater becomes stale, sea cucumbers will cast out the internal organs including the gonad rendering themselves useless for breeding purpose. It is desirable to have two sets of tanks for the maintenence of the broodstock. As followed by the author, it is essential to remove the mud once in every fifteen days from the tanks, clean them thoroughly with bleaching powder and put in the sun for drying to kill all the bacteria. Despite all precautions, sometimes bacteria attack the broodstock and kill them. When such infection is noticed the infected ones have to be immediately removed, killed and buried above the high water mark. Otherwise the infection quickly spreads among the other broodstock. Morgan (2000) reported on the bacterial infection of the broodstock of *H. scabra* in Queensland, Australia. Fresh algae brought from the sea is ground to a fine paste in a mixie and small quantities of this paste are put in the broodstock tanks once in seven days. Care should be taken not to put too much of the paste since it will make the seawater foul. The sea cucumbers feed on the organic matter present in the mud. The algal paste settles to the bottom of the tank and this is consumed by the sea cucumbers along with mud having organic matter. If proper food is not provided the sea cucumbers become shrunken and the gonad gets reabsorbed rendering the animals unfit for spawning purposes. It is desirable to keep not more than 20-30 adults in one tank.

***Collection Time*:** Collection time of the broodstock is very important for the success of the hatchery operations. In the Gulf of Mannar, at Tuticorin, *H. scabra* is known to have two spawning peaks one in March-May and the other in October-December. Battaglene (1999) also reported two spawning peaks for *H. scabra* in the Solomon Islands. It is essential to collect the broodstock material during the spawning season since the chances of induced breeding are more at that time. This is because most of the specimens will be ripe and ready to release the sperms and eggs on stimulation.

Thermal Stimulation: This is by far the best and the most reliable method available at present to induce sea cucumbers to spawn. This method is widely used all over the world. First the temperature of water in the broodstock tank is noted. Seawater is heated with an immersion rod separately and this heated seawater is carefully mixed with normal sea water slowly to get the desired temperature (3 to 5°c above the normal sea temperature). In the natural habitat sea cucumbers usually spawn at dusk when the tide is rising. This enables the eggs to get widely distributed. Morgan (2002) explained that spawning trials were conducted at dusk since the natural spawning took place during dusk.

Spawning behaviour: In *H.scabra* the sexes are separate but it is not possible to separate the sexes based on external features. However at the time of spawning it is possible to differentiate the sexes since the spawning behaviour of males and females is different. In all cases only the males spawn first and this is followed by the females. In case of *H. scabra* the males first lift their anterior end and exhibit swaying movements. After exhibiting such movements for sometime the males start releasing the sperms in a fine stream from a single opening situated on the upper side near the anterior end. While releasing the sperms the anterior end is raised like the hood of a snake (Fig.4). Usually it takes three hours for the males to release the sperms after they are subjected to thermal stimulation. The males, once they start releasing the sperms, keep on doing so for one or two hours even when they are disturbed. A distinct projection is discernible at the opening in the case of males at the time of spawning. In the meantime, if there are ripe females in the same tank they start reacting to the sperms released into the water. The anterior end of the female gets bulged due to the pressure built inside the body. The eggs are released in two or three powerful spurts to enable the eggs to get dispersed over a wide area. In case the female attached to the corner of a tank just below the top level of water, the egg mass often falls outside the tank. The egg mass released is light yellow and mucus-like in consistency.

Fertilization: Fertilization is external. When once the eggs are released they are instantaneously fertilized by the sperms present in the water. It is important to ensure a higher rate of survival in artificial breeding through obtaining of high quality eggs, and this is possible. The imperative need is to handle the eggs carefully as soon as they are released. If more than one male starts releasing the sperms in the same tank, the others are removed since the sperms from more than one male makes the whole water milky-white which is not disirable. The fertilized eggs are washed several times in fresh seawater 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 releases nearly two million eggs at a time. The number of eggs released is related to the size of the female. The eggs (Fig.5) are spherical, white and just visible to the naked eye. The diameter of the eggs varies from 180 to 200 μ. About 0.75 million eggs can be stocked in 750 litres of water. After fertilization the first polar body is formed within 2-30 minutes. The first cleavage takes place after 15 minutes. Early blastula (Fig.6) is reached after 40 minutes. In three hours the blastula is fully formed. After 48 hours elongated gastrula (Fig.7) appears. It is oval in shape and motile.

Fertilised eggs, blastula and elongated gastrula may be seen at Fig 5, 6 and 7. Regarding larval stages, these are described hereunder.

Auricularia Larvae: On the third day early auricularia (Fig.9) is formed. It is slipper shaped, transparent and pelagic in habit. As days progress, late auricularia (Fig.9) is formed. The preoral loop in the anterior and the anal loop in the posterior, are distinctly formed. These bands help in the locomotion. The digestive tract consists of mouth, an elongated pharynx and pear-shaped stomach. The sides develop distinct projections. At the end of each projection, round hyaline sphere is seen. The early auricularia larva measures on an average 560 μ. The late auricularia larva has an average length of 1.1 mm.

Doliolaria Larvae: On the tenth day some of the auricularia transform into doliolaria larvae. The early doliolaria larva (Fig.10) is barrel-shaped with five bands around the body. These larva measure 460-620 μ. Doliolaria are non-feeding and highly motile larvae. They move fast in the anterior direction. Rapid changes occur inside the body and the adult features of the sea cucumber set in at this stage. The late doliolaria (Fig.11) elongates and three tentacles develop at the anterior end. This stage lasts for a short duration of two or three days.

Pentactula Larvae: On the 13th day some of the doliolaria transform themselves into pentactula larva (Fig.12). The penactula is tubular with five tentacles at the anterior end and has a single tubefoot at the posterior end which helps in locomotion. The pentactula creeps over the sides and the bottom of the tank. They have a tendency to aggregate at the edge of the tank. The larvae actively feed on benthic algae and detrital matter. After two months they reach a length of 20 mm. (Fig.13).

Rearing density: Strict control over rearing density of the larvae has to be excercised. The larvae can be reared in still waters or running waters. If the density of the larvae is more, they will form as a ball and sink to the bottom of the tank and die. Therefore the rearing density should be controlled so as to ensure better survival rate. The desirable density of the larvae is 300-700 nos per litre. In a one tonne tank with 750 litres of water 3,75,000 larvae can be stocked.

Selection and Counting of Larvae: After fertilization, the eggs are removed and transferred to rearing tanks. They develop into early auricularia in 48 hours. Bafore transfer, the bottom of the rearing tank should be cleaned thoroughly. Healthy larvae occupy the surface layer of water, while deformed larvae generally stay at the lower layer of water column or at the bottom of the tank. All the dead individuals settle at the bottom. Deformed larvae and sediment should be siphoned out in order to keep the tanks clean. All the larvae are taken out and put in beakers of 10 l capacity. Mild aeration is given to the larvae. The water is uniformly stirred and one ml sample is taken in a pipette and put on a plankton counting chamber. The number of larvae are counted. Like this three samples have to be taken and 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 auricularia 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 in two days after shifting the larvae to another tank. Normally the larvae are taken out once in two days so that the tanks can be cleaned thoroughly to prevent bacterial infection. On other days the water level is reduced to more than half by keeping a seive inside the tank. The sediment must be removed so as to keep the water fresh. Up-to-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 the course of time. These and the left over food produce harmful substances like hydrogen sulphide and nitrogen wastes. With the rise in temperature bacteria also develop. Poor water quality directly affects the normal development of the larvae. Therefore proper water management and sanitation is necessary. While water is changed through a sieve kept inside the tank, the mesh size of the seive must be smaller than the larvae. Normally 80 μ seive is used since the larvae and even the eggs are larger in size than the mesh of the seive. While the water is being changed some one should constantly agitate the water lightly all round the tank. This will prevent the loss of larvae during the water change, since siphoning would normally force the larvae to stick to the sides of the tank. The sediments at the bottom of the tank should be siphoned out completely once in every three or four days.

Larval feed and feeding rates: Morgan (2002) advised that the larvae should not be overfed. Suitable and high quality microalgae and correct feeding rates are important for the success of rearing. As the larval development progresses, the alimentary canal also gets well formed. For this reason the larvae must be fed from this stage itself. The feeding mechanism of the larvae consists of conveying the suspended material or organisms and unicellular algae into the alimentary canal through the mouth parts by swaying of hair-like structures round the mouth. The effectiveness of various microalgae in this respect was tried. Better growth rate was obtained when fed on microalga *Isochrysis galbana.* When fed on this microalga the mortality rate was also found to be less. Battaglane (1999) stated that better growth and survival of the larvae was noticed when fed on *Rhodomonas salina* and *Chaeteceros muelleri* in Solomon Islands. He also stated that the larvae fail to metamorphose when fed on *Isochrysis galbana* or *Tetraselmis chuii.* After four or five days the larvae are also fed with mixed phytoplankton culture, chiefly consisting of *Chaetoceros* spp.

The larvae require different quantities of diet during different developmental stages. Unicellular algae are fed twice a day, but the quantity given each time depends on the particular stage of the larvae. In general 20,000 to 30,000 nos of larvae per ml in the rearing tank water is maintained. The microalga *Isochrysis galbana* usually cultured has a concentration of 80,000 cells per ml. When the bloom is good it reaches one million mark. The quantity 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 the most preferred diet for the larvae.

Culture of Microalgae

Culture of microalgae for consumption by the larvae can be taken up at this stage. Phytoplankters are mostly unicellular algae which are efficient in utilising the solar energy to convert the inorganic substances into organic compounds suitable for primary consumers in the aquatic environment. They have a high protein content that is easily digestible. Because of these qualities phytoplankton serves as a primary producer forming the base of aquatic chain. These qualities have created a high demand for the micro-organisms constituting the phytoplankton in the hatchery operations as essential feed.

Environmental Factors

Monitoring of the environmental changes is of paramount importance since the larvae and the juveniles are sensitive to these changes and they succumb when environmental conditions are adverse.

Temperature: The ideal temperature for the 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 temperature. The higher the temperature, the lower the dissolved oxygen level. The normal range for dissolved oxygen is 5-6 ml/l. Water in the larval tanks has to be aerated continuously throughout the day so as to ensure that the oxygen level does not go down significantly. For a one tonne tank generally two aerators have to be provided, one at each end.

pH: Under normal conditions the rearing seawater is generally alkaline with pH of 7.5-8.6. Tests have shown that the larvae of *H. scabra* can adopt themselves to a fairly wide range of pH. However, when pH rises either over 9.0 or drops below 6.0 the locomotion of the larvae decreases and the growth gets arrested. Therefore the pH of the water must always be between 6.0 and 9.0.

***Salinity*:** Salinity of normal seawater is 35 ppt. If the salinity is considerably lower than this the larvae will die. The critical salinity level that is lethal is 12.9 ppt. In fact, the optimal salinity for larval development ranges from 26.2 to 32.7 ppt. In this range, the higher the salinity the quicker the development. Too high or too low salinity adversely affects the normal development of the larvae, resulting in large number of deformed larvae and also causing death. Salinity estimation is therefore an important routine work to be done throughout larval phase. One easier way of assessing salinity is to first measure the specific gravity of the water and then convert it to salinity value.

***Ammoniacal Nitrogen*:** The ammoniacal nitrogen of seawater is very low. The sources of generation of ammoniacal nitrogen in the breeding tanks are mainly metabolites released by 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/cu m, there will be harmful effect on the development and growth of the larvae.

Nursery Rearing: The Doliolaria larvae will 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 there they continue to swim in the tanks for a long time. Therefore correct feed has to be given to the larvae and settling bases have to be provided for them to settle. It has been observed that in case of *H. scabra* the Doliolaria larvae settle down to the bottom of the tank as Pentactula larvae when the feed given is good and adequate. Battaglene (1999) stated that they settle on sea grass leaves in the wild in Solomon Islands.

Types of Settling Bases: Two types of settling bases are tried for the larvae. In the first type tiles with rough surface are kept in a tank outside the hatchery where there is good sunlight. Sea water is circulated in this tank continuously for four or five days. Benthic diatoms and other algae settle on the tiles. These plates are then taken inside the hatchery and suspended in the tanks which have Doliolaria about to settle down. The hard surface and food availabilities induce them to settle on the tiles. One disadvantage with settlers of this type (tiles) is that the benthic algae which settle on the tiles come off completely after four or five days inside the hatchery since there will be no sun light. The other type of settler devices are the polyethylene sheets which are kept in a tank having seawater. To this an algal matter filtered through 50 micron seive is added. Usually species of *Sargassum* are used in the preparation of the algal matter that is put in the tanks. The algal extract will stick to the polyethylene sheet. Fresh extract is put daily in the tanks and the water therein is also daily changed. After four or five days the polyethylene sheet is covered with a coat of algal extract and this serves as a good settling base for the larvae. If the food is not provided on the settling bases the larvae will die. The settling bases should not have any toxicity.

***Diet for the Juveniles*:** After settling down, the juveniles will retain only weak moving ability. Algal food, obtained by filtering through 40 micron sieve is given first, followed by algal food obtained by seiving through 80 micron seive, after 30 days. This filtered algal food can be given to the juveniles daily in the mornings and also in the evenings. The juveniles are found to feed actively on the algal matter and grow well due to the protein content. After 30 days the larger ones (10-15 mm) are separated and put in a tank with fine mud. To this, daily quota of algal matter is to be given. After 60 days fine algal powder has to be added.

***Juvenile Density*:** When the larvae develop into juveniles they begin to crawl. Most of them stay on the settling bases. After 15 days they can be seen with naked eye. This is the earliest conducive stage for the estimation of the number of juveniles. A random sampling has to be made with a light frame of 400 sq.cm. The estimates should be made from either end and also from the middle of the tank. To get realistic estimates the sampling area should be over 5% of the tank area. In order to achieve increased survival rate, it is necessary to control the density of the juveniles on the settling bases at the optimum level. Too many juveniles in a limited area and insufficient diet will adversely impact the growth and survival of the juveniles. Therefore, after they are counted, their density should be adjusted to an optimum of 200-500 induviduals for one sq.m.

Feeding the Holothurian Larvae with Microalgae: The success of the hatchery operations depends upon the continuous production and supply of high quality feed. The speedy growth of the larvae is related to the selection of feed with high protein content and it should be possible to culture them on a mass scale for supply to hatcheries. The microalgal species produced for being given as feed should have to be acceptable to the larvae of the cultured organisms. During the initial stages of hatchery development the sea cucumber larvae were found to thrive well with a sufficient supply of phytoplankton. Quick development and high survival rate could be achieved with the supply of easily digestible flagellates belonging to the algal classes Chrysophyceae and Heptophyceae. Quality of feed differs with different development stages. Combination of selected species of algae was found to yield good results. The larvae of *Holothuria scabra* were fed on *Isochrysis galbana, Dicrateria* sp. and *Dunaliella* sp. The growth and survival rate was found to be more when fed on *Isochrysis galbana*. In addition to a mixed microalgal a mixed culture of diatoms dominated by *Chaetoceros* spp also was found suitable in enhancing the growth rate of the sea cucumber larvae.

The details and methods of microalgal culture, isolation techniques of required species especially serial dilution, culture technique, culture media such as 'Conway' or Walne's medium, Miquel's medium, TMRL (Tang Marine Research Lab.) medium etc, outdoor culture of mixed algae, stock culture maintenance, mass culture of flagellates; different phases in mass culture of algae such as Lag or induction phase, exponential phase or growing phase, decline phase, stationery phase, death phase etc., determination of cell concentration, different factors affecting microalgal culture, harvesting of cultured algae and problems and constraints faced in microalgal culture have been elaborately given and discussed in different Special Publications and Brochures particularly in the 'Transfer of Technology Series' of CMFRI authored by Gopinathan (1993).

Predators and Their Control

Predation: Copepods and ciliates are the main predators on the auricularia larvae. The reason for this is that the movements of these larvae are sluggish. They attack the larvae at the sides and injure their bodies. Finally the larvae die due to the injuries caused to them. They also harm the juveniles by reproducing fast in the rearing tanks and competing for the food with the juveniles. Algal extract given as feed for the juveniles is also found in the alimentary canals of the copepods. Infested juveniles assume ball-like shape and they die gradually. The auricularia larva is the most vulnerable for attack by the predators because of their extended life 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 Diptrex in two hours with no harmful effects on the juveniles. However, it is necessary to be careful and give attention in the preparation of Diptrex solution of appropriate concentration. The solution should be evenly sprinkled into the tanks and the water of the tank must be changed completely after two hours. This is very important. Otherwise it will affect the juveniles also. According to Battaglane (1999) KCL can be used since it does not harm the juveniles but effectively kills the tropical copepods.

Selection of Farming Site

Suitable site selection is an important basic requirement for successful sea cucumber farming. The success of the farming operations mainly depends on several factors concerned with the site.

The following are the primary requirements while selecting a site for the farm.

1. The farm must be located at a place where the seawater flows into the farm during high tide and go out during low tide allowing good exchange of water.

2. The salinity of seawater must be between 30 and 35 ppt throughout the year. Low salinity will kill the juveniles and in high salinity the growth of the juveniles will be slow.

3. The sea bottom must be muddy with organic matter on which the juveniles feed. Care must be taken to see that no hydrogen sulphide formation is there due to putrification.

4. Connecting road must be there for the transport of the juveniles and also to take the harvested material for processing.

5. Farming area should not be affected by cyclones and other natural calamities such as sea or soil erosion.

6. Farming area should be free from other fishing operations.

7. Farming site must be provided with electricity.

In a period of around sixty days the juveniles reach a length of 20 mm. At this stage it is desirable to stock them in the farm, since keeping them in the hatchery is expensive and this is also not conducive for their growth. The juveniles produced on successive occasions would need to be first grown under one of several varying conditions: In old one tonne tanks, rectangular cages, velon screen cages, netlon cages, concrete rings and finally in shrimp farms at different places like Karapad Bay, and in confined areas such as Gulf of Mannar, and Valinokkam Bay (Gulf of Mannar) and such other places. The results of experiments conducted in these areas by James *et al.*(1996) and James (1998) are presented here under.

Rectangular Cage : The rectangular cage was made of iron rods of 7 mm diameter. They were three feet long and two feet wide and were in the form of rectangular boxes with a lid (Fig. 15). On the outer side of the cage nylon rope of 2 mm thickness was knotted to the frame. The distance between two knots was 30 mm. The cage was lined inside with fine velon screen to prevent the mud going out. The cage was fixed at the bottom of the sea at depth of one metre with four casuarina poles. Rectangular cages were installed at Karapad Bay and Valinokkam Bay to study the growth of the juveniles. Since the rods were made of iron they got rusted after a few months. The cage had to be therefore replaced.

Velon Screen Cage : The velon screen cage (Fig. 16) was 2 sq.m. in area. It was made of velon screen of 4 mm mesh to allow free flow of water. The length of the cage was two metres and the breadth of the cage was one metre. The height of the cage was two metres. The cage was fixed at a depth of two metres on an algal bed using four poles, one at each corner of the cage. They were further strengthened by four more poles driven at the middle of each of the four sides to keep the cages in position and protect them during high gales. The bottom of the cage also had velon screen for easy and complete retrieval of the juveniles. To keep the bottom of each of the cages stable, four big stones were kept at four corners of each of the cages. After the juveniles were stocked the top was covered by velon screen and stitched so that fish and crabs may not enter the cages. Velon screen cages were installed both at Karapad and Valinokkam Bays. Since the mesh of the velon screen was small, algae and mud blocked the openings. For this reason, the outer side of the cage had to be periodically brushed to keep the circulation of water.

Netlon Cage : Netlon cage (Fig. 17) was cylindrical in shape with an area of 1.65 sq.m. Diameter of the cage was 1.5 m and the height of the cage was 1.3 m. The mesh size was 5 mm. The netlon cage was erected in the sea at a depth of 1 m. The cage was fixed to the bottom with the help of four stout casuarina poles. The top of the cage was covered by velon screen by stitching to prevent the entry of other organisms. Every week during low tide two buckets of mud was put in the cage to offset the loss since the mesh size of netlon was big and mud escaped into the Bay. The netlon material became brittle after some months in the sea and the cage had to be replaced.

Concrete Ring : Concrete rings of 2 feet and 4 feet diameter were used in the harbour area. The height of rings was one foot. At the bottom of rings velon screen was placed to prevent the juveniles from burrowing and escaping.

The top of the ring was also covered by velon screen (Fig.18) to prevent the entry of other organisms. The concrete rings lasted for a number of years in the sea. Rings with larger diameter couldnot be used since they were heavy to handle. Results of the experiment are given by James (1998a).

Procurement of Seed

It is well known that the juveniles of sea cucumbers do not occur near the shore. Those occuring in the deeper waters and are elusive and not readily available for collection. Only during February 1978, hundreds of juveniles of *Holothuria scabra* were seen near the shore at Sesostris Bay in Port Blair (Andamans). The length range of the juveniles was 65-160 mm (James 1983). Another aspect is that the seed could not be collected from the wild due to the ban imposed by the Government of India in 2001. At present CMFRI is producing seed in small quantities which they are using for their experiments. Recently CMFRI has produced the seed of *Holothuria spinifera*, another species used for processing, though not as valuable as *H. scabra* [Asha and Rodingo (2001) and Asha & Muthiah (2002)]. Under these circumstances people who are interested to farm sea cucumber have to set up hatcheries to meet their requirements.

Eco-Friendly Practice

It is well known that much of the feed given to the shrimps in a shrimp farm goes as a waste and settles down at the bottom enriching the bottom soil but at the same time polluting the environment. Sea cucumbers are the best candidate species for farming under these circumstances since they are detritus feeders and subsist on the organic matter present in the mud. The seed produced in the hatchery at Tuticorin Research Centre of CMFRI was grown in a shrimp farm (Fig.19) on an experimental basis. The growth of the juveniles was found to be three times faster when they were grown in shrimp farms. Since the environment was kept clean the shrimps also grew. It was an eco-friendly practice which did not harm the environment and both shrimps and sea cucumers could grow faster. Pitt & Duy (2004) reported that the juveniles of *H.scabra* increased in weight from 30g to 300g in 90 days in a farm at Vietnam. Similar results were obtained in a shrimp farm when the juveniles were grown along with shrimps. The results were presented by James *et al.*(2002). Juveniles can be stocked at 1.5 lakh nos in one hectare of pond area. They can be grown along with shrimps or can be farmed separately. High energy feeds like the ones that are given for the shrimps should be given to them. They grow very fast and within one year they attain marketable weight of 350 g. The juveniles grown in a shrimp farm are shown in Fig.20.

Lessons from China

China also faced the problem of disease in shrimp farms. They successfully converted many of the shrimp farms into sea cucumber farms and also dug new farms in the same site to avoid disease. The sea cucumber A*postichopus japonicus* takes 15-18 months to reach marketable size due to cold climate. Here in India *Holothuria scabra* will reach marketable size in less than 12 months, if they are fed with the same feed given to the shrimps. Perhaps we can also follow the Chinese method by converting some of the shrimp farms closed due to disease problem into sea cucumber farms. Juveniles have to be produced on a large scale for farming and also for sea ranching programme to enrich the natural populations.

Economics

Indicative economics of sea cucumber farming (Investments and recurring expenditure) are given hereunder.

Hatchery Seed Production

Total number of tanks required : 6 nos (1 tonne capacity) Stocking rate of auricularia larvae : 3.75 lakhs/1tonne tank.

Total auricularia stocked in one run : 1 million nos.

Expected production (nos) of juveniles (10%) : 1 lakh

Survival of juveniles at the end of 18 months : 40%

Net production of harvestable sea-cucumbers : 40,000 nos

Capital Expenditure (Rs)

A. *Building and tanks*

Hatchery shed with light roofing (30 m x 10 m)	1,20,000
Room for Generator/Compressor (27 sq.m. @ Rs. 800/- per sq.m.)	21,600
Seawater sump 14 sq.m. @ Rs. 850/- per sq.m.	11,900
Sedimentation tank 8.4 sq.m. @ Rs. 850/- per sq.m.	7,140
Filter bed 4.5 sq.m. @ Rs. 850/- per sq.m.	3,825
Pump house 14.6 sq.m. @ Rs. 850/- per sq.m.	12,410
Overhead tank - 10,000 lit capacity	60,000
Total	**Rs. 2,36,875**

B. *Fibreglass Tanks*

1 tonne capacity Broodstock/larval/ juvenile FRP tank - 6 no @ Rs. 8000/- =	48,000
100 lit capacity spawning FRP tank - 4 no. @ Rs. 800/-	3,200
200 lit capacity mixed culture FRP tank- 1 no @ Rs. 1200/-	1,200
Total	**Rs. 52,400**

C. *Major Equipmets*

10 KVA Generator - 1 No	60,000
Air Compressor - 1 No	15,000
7.5 HP Electric pump - 1 No	10,000
1.0 HP Electric pump - 2 Nos	7,000
Microscope, pH meter, salino-meter	35,000
Chemical balance	5,000
Furniture	25,000
ECE Controller, Silica cased immersion heater, jumo thermometer	4,000
Air conditioner - 2 Nos	50,000
Total	**Rs. 2,21,000**

Total capital cost (A + B + C) Rs. 5,13,400

Recurring Expenditure (Rs)

A. *Interest*

On Rs. 3,98,625 @ 15%	77,100
B. *Depreciation*	
On building and fibreglass tanks @ 5%	14,600
On equipment @ 10%	22,100
C. *Salaries*	
One Technician @ Rs. 2000/- per month for 18 months	90,000
Two helpers @ Rs. 500/- per month for 18 months	27,000
D. *Contingencies*	
Plasticware, flexible PVC hoses, glassware, bolting silk, etc.	8,000
Energy cost (Electricity and Diesel)	30,000
Chemicals	4,000
Other contingencies	10,000
E. *Maintenance*	10,000
F. Annual lease for land	6,000
Total recurring expenditure (A to F)	2,98,800

Realisation And Profitability of Sea-Cucumber Production

Total Sea-cucumber production : 40,000 nos.

Cost of each sea-cucumber : Rs. 28/-

Total amount realisable (40,000 x Rs.28) : Rs. 11,20,000

Less : Non-recurring and Recurring

Expernditure (Rs. 5,13,400+Rs. 2,98,000) : Rs. 8,12,200

Net Profit : Rs. 3,07,800

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ANNEXURE

List of Equipments Required

Equipment/ facility		Quantity required
Generator (10 KVA)		01
Air compressor 200 ~ 220 1420 RPM 50 HZ S 1 Rating output 0.75 KW AMP 73		1
Fibreglass rectangular Broodstock/larval/Juvenile rearing tanks (1000 lit capacity)		6
Fibreglass rectangular (100 lit capacity) spawning tank		4
Fibreglass tank rectangular (200 lit capacity) Mixed culture tank		2
Binocular microscope		1
Mixie		1
ECE controller		1
Jumo thermometer (0-50° C) (For thermal stimulation)		1
Silica cased immersion heater		1
Air-conditioner 2 tonne capacity		2
pH meter		1
Salino-refractometer (Temperature compensated) (0-50°C)		1
Chemical balance		1
Thermometer (0-50°C)		3
Laboratory glassware		
Beaker 10,000 ml		6
Beaker 5,000 ml		6
Beaker 3,000 ml		4
Beaker 1,000 ml		6
Beaker 500 ml		6
Beaker 250 ml		6
Conical flasks 250 ml		5
Oxygen bottles 125 ml		10
Volumetric pipettes (assorted sized)		10
Burettes (10 ml)		2
Burettes (50 ml)		2
Petridishes (150 mm dia)		2
Embryo cups (50 x 50 mm)		6
Micro slides (in box)		2
Micro slides (in box)		1
Cover slips (in box)		2
Plankton counting chamber (1 ml capacity)		2
Plasticware		
Plastic buckets (15 lit)		6
Plastic buckets (5 lit)		6
Plastic buckets (3 lit)		6
Basins (20 lit) capacity		6
Polyethylene flexible hoses (20 mm dia)		10 m
PVC pipes (150 mm dia for seives)		6
Polyethylene sheets (for mixed algal culture)		10 m
Bolting silk cloth	40 microns	1 m
	80 microns	1 m
	140 microns	1 m
	180 microns	1 m
	200 microns	1 m
Velon screen	1 mm mesh	30 m
	4 mm mesh	30 m
Tank cover cloth (Black)		30 m
Nylon rope (2 mm)		10 kg
Nylon rope (5 mm)		10 kg
Casuarina poles (3 m length)		50 Nos
Seawater drawing and distribution grid made of 50 mm and 25 mm grid PVC pipelines and valves.		as required
Aeration grid of 25 mm rigid PVC pipelines with copper nozzles, 5 mm polyethylene tubes, plastic 'T' joints and regulators and diffuser stones.		as required