# The Status of Mariculture in North China

Chang Yaqing[1],Chen Jiaxin[2]

(1.Key Lab of Mariculture and Biotechnology.Dalian Fisheries University,Dalian, Liaoning, 116023, P.R China;2.Yellow Sea Fisheries Research Institute Chinese Academy of Fisheries Sciences, Qingdao, Shandong,266071, P.R China)

## Introduction

China has a long history of mariculture production. The mariculture industry in China has obtained break through in the all artificial nursery and cultural technique of shrimps, mollusca and fishes of high commercial value since 1950s, which has advanced the development of mariculture industry.

The first major development was seaweed culture during 1950s, prompted by breakthroughs in breeding technology. By the end of the 1970s, annual seaweed production reached 250,000 metric tons in dry weight ( approximately 1.5million tons of fresh seaweed ). Shrimp culture developed during the 1980s because of advances in hatchery technology and economic reform policies. Annual shrimp production reached 210,000 tons in 1992. Disease outbreaks since 1993, however, have reduced shrimp production by about two-thirds. Mariculture production increased steadily between 1954 and 1985, but has been exponential since 1986, mostly driven by molluscan culture. Molluscan culture in China began to expand beyond the four traditional species: oyster,cockle,razor clam and ruditapes clam in the 1970s,Mussel culture was the first new industry to emerge ,followed by scallop aquaculture in 1980s. Abalone culture has become a major industry in 1990s. Traditional oyster and clam cultures have also advanced and expanded in recent years.Now more than 30 species of marine mollusks are cultured commercially in China. Because of the rapid development in recent years, molluscan culture has become the largest sector of the Chinese mariculture industry, accounting for 81% of the total production in weight.

Therefore, the industrialization level and culture technique of the major species in China has reached international advanced level, in which some area is leading world level. China is becoming the largest country in mariculture.

Marine aquaculture has grown rapidly over the last decade. It is predicted that the marine cultivable areas in China including shallow seas, mud-flats and bays are proximately more than 1.33 million hectors as most artificial cultivation of marine plants and animals can be applied within the 10 m isobath based on the current culture technologies. In 2002, the cultivation areas and the output reached 1,352,000 hectors and 12.1 million tons

## Part I The principal marine species cultured in north China

| | |
|---|---|
| **Molluscan** | *Crassastrea gigas*、*C.plicatula*、*C.rivularis*、*C.talienwhensis Chlamys farreri* 、*Argopecten irradians* 、*Patinopecten yessoensis*、 *Mytilus edulis*、*Ruditapes philippinarum*、、*Meretrix meretrix*、*Cyclina sinensis*、*Mercenaria mercenaria*、*Mactra antiquata*、*M.veneriformis*、*Saxidomus purpuratus*、*Tegillarca granosa*、*Scapharca subcrenata*、 *S.broughtonii*、*Sinonovacula constricta Haliotis discus hannai*、、 *H.gigantea*、 *Rapana venosa*、 *Bullacta exarata* |
| **Marine fish** | *Pagrosomus major, Lateolabrax japonicus, Fugu* sp., *Paralichthys olivaceus, Scophtbalmus maximus, Cynoglossus semilaevis, C. trigrammus, Kareeius bicoloratus, Verasper variegates, Sebastodes fuscescens, Mugil cephalus, Liza tade, Hexagrammos otakii, Seriola aureovittata* |
| **Crustacean** | *Penaeus chinensis, P. monodon, P. japonicus, P.merguinsis, P. vannamei, Eriocheir sinensis, Callinectes sapidus, Scylla serrata* |
| **Seaweed** | *Laminaria japonica, Undaria pinnatifida, Porphyra yezoensis* |
| **Echinoderm** | *Apostichopus japonicus, Strongylocentrotus intermedius, S. nudus* |

## Part II. Hatchery seedling production technology of main cultured species in north China

### 2.1. Molluscan

many species of mollusks(eg.scallop,oyster and abalone),their seeds are hatchery produced with well-developed technology. In the following sections, scallop and abalone hatchery procedures are described

#### 2.1.1 Scallop(eg. *Patinopecten yessoensis*)

##### 2.1.1.1 Breeding and Larval Rearing

<u>Broodstock Culture</u>

In late winter or early spring, broodstock is selected .They are then transferred to conditioning tanks where, water temperature was 2~3℃ then water temperature is increased daily by 0.5 or 1℃ until it reaches 7 ℃ This temperature is kept stable to wait for spawning. During conditioning, broodstock is fed either an artificial diet or unicellular algae, mostly *Phaeodactylum tricornutum, Chaetoceros muelleri, Monochrysis simplex, Isochrysis galbana, Tetraselmis tetrathele* and *Nannochloropsis oculata.*

Spawning, Fertilization and Hatching

Once spawning occurs,the water is prepared with the temperature at 10.5℃ . When the density of eggs reaches about 30 eggs per ml, the aeration must be stopped and the parent scallops taken away from the tanks. After the spawning is over, the water in the hatching tanks should be stirred with the swing boards for 30 minutes to prevent the eggs from sinking to the bottom.

Larval Cultivation

The rearing density depends on the rearing technique, food supply, capacity of tanks and quality of larvae. It ranges from 5–15 larvae per ml . During the period of larval rearing, the feeding behavior and growth of larvae are observed every morning before the water is renewed. In general, the normal larvae are usually swimming in the upper and middle layers of the water. The feeding ration can be adjusted according to the food content in larvae's stomach. The number and shell length of larvae should be counted and measured every two or three days.

The growth and development of larvae are closely related to salinity, temperature, rearing density, water quality and food supply. Under suitable rearing conditions as mentioned above, the eye spot, which is located in the stomach region, will appear 18 days after fertilization, with the shell height at 190 to 200 µm.

Spat Collection

The appearance of eye spot is an indication that the larvae are approaching the settling stage. Once the eye spot appears, the larvae should be sieved and transferred into another well-cleaned tank. The spat collectors are then put into the tank for larvae to settle on as soon as the transfer is completed. Two kinds of collectors are commonly used in north China. One is made of palm fibre rope and the other of pieces of polyethylene net.

2.1.1.2 Nursery culture

Nursery or intermediate culture involves transfer of the spats to the open sea and rearing them until they attain 7 mm in shell height. Before transfered, the rearing water temperature should be lowered by 1–2℃ every day to approximate the temperature of the sea. This is important for increasing their survival. Each transfer leads to better survival and better growth rate. The water temperature of the sea area must reach 5℃ when the spats are transferred.

Because of the differences in the size of spats, condition of the sea area, culture materials and management, high mortality occurs after the spats are transferred to the open sea. At present, the survival rate in nursery culture ranges from as low as 10 % to 30–40 %.

Two kinds of materials are used at present. One is a plastic pipe, 60 cm long and 25 cm in diameter, covered with plastic net (mesh smaller than the shell height of the spats) at both ends. The other is more common ,which is made of polythene bags. The size of the bag depends on the size of the spat collectors and is generally 30×40 cm. Every 10 bags are strung together on a rope.

2.1.2 Abalone (eg: *Haliotis discus hannai* )

Commercial abalone seed production was accomplished in 1987 in Dalian, Liaoning. From 1987, abalone aquaculture in China grew steadily with most research focused on the development of hatchery seed production techniques and grow-out modes. A series of key techniques involving spawning, larval rearing, and juvenile and seed nursing were established. Sufficient seed supply is crucial to the development of abalone mariculture. All abalone seeds are hatchery produced with sophisticated technology The technology to produce hybrid and triploid abalone has been successfully developed by researchers. It is ready to be introduced to the commercial production sector.

2.1.2.1 Seed hatchery production

Broodstock Selection and Conditioning

Seed production typically begins in early spring with broodstock conditioning at gradually elevated temperatures and stabilization at 20℃. The most widely used and effective method for abalone to ripen is by effective accumulative temperature (EAT) control. Meanwhile, plenty of algal food, *Laminaria japanica*, *Undaria pinnatifida*, and *Ulva pertusa* should be provided with this conditioning method.

Spawning and Hatching

To induce spawning, well-developed abalones are exposed to air for desiccation and then subjected to ultra-violet-irradiated seawater. Adult spawning is usually induced by combined thermal shock and UV-treated seawater exposure. Males usually are induced 1 h later than females because the former are more sensitive to inducement than the later. Fertilized eggs are incubated at 21℃ to 22℃.

Larval Cultivation

.Approximately 60 h postfertilization, *H. d. hannai* larvae are ready for settlement. Eyed larvae are set on the collecting plates made of transparent corrugated plastic with diatom-precoated for *H. d. hannai*. The diatoms must be supplied in sufficient quantities as well as in good quality to ensure the growth and survival of postlarvae. Water quality and light level should be carefully controlled during this critical period.

Juvenile nursery

Juveniles are manually moved from settlement plates to nursery culture plates at approximate size of 3-7 mm. For H. discus hannai, spat are usually transferred to large punctured plastic plates with dark color. During early juvenile stages, an artificial diet is exclusively used as food supply. Several commercial diets, from various diet producers, are available to aquaculturists. The major ingredient of artificial diets is dried kelp powder and fish meat powder. Fresh kelp is the principal food for older juveniles. The quality of artificial diet plays an important role in postsettlement survival.

2.1.2.2 Challenges to abalone mariculture

Mortality frequently occurs during the first month of the juvenile phase, following the movement of juveniles from settlement plates to the nursery culture plates, especially when the juveniles are taken-off the diatom plates at <5 mm shell length. It is generally believed that the change of feeding habits is the major cause of this high mortality. Survival in this critical nursery period has dropped to lower than 5% at the lowest level during the early 1990s. Survival of early juveniles has been much improved by hybridization breeding, declining juvenile density in the collecting plate, and extension of diatom feeding, therefore, allowing for removing the juveniles, at a larger size than normal, to the nursery culture plates (Zhao & Zhang 2000). In particular, hybridization was made between Japan and China's broodstock to produce hybrid seeds.

When all diatoms on the settlement plate are consumed, juvenile abalone (approximately 2-3 mm) are transferred to another batch of transparent corrugated plastic plates on which diatoms are well covered. Therefore, size of juvenile abalone reached 5-7 mm when transferred to the nursery culture plate, enhancing the adaptive ability of juveniles to artificial diets. The practice of transferring juvenile abalone is now becoming part of routine hatchery procedure. With the application of hybridization and plate-transfer techniques, production of H. d. hannai remains stable in the northern Chinese coast areas.

This problem, however, was not solved completely due to incomplete understanding of the physiologic variation associated with the change of feeding habits, following larval metamorphosis. In addition, a lack of quality control, with respect to broodstock, often leads to failure of utilization of heterosis. Hybrid abalone seeds have now been widely adopted throughout the northern coasts. Nevertheless, breeding of high quality lines of abalone will be the best solution in terms of genetic modification.

Availability of adequate commercially formulated diets is another problem for the abalone aquaculture industry in China. Abalone is a slow feeder, therefore, reducing leaching of water-soluble ingredients from artificial diets would be key to good diets. Furthermore, dietary essentials should be balanced to meet the nutrient requirement of abalone. As yet, however, nutritional requirements of the cultured species have not been fully demonstrated.

## 2.2 Echinoderm

### 2.2.1 Sea Cucumber, *Apostichopus japonicus*

*Apostichopus japonicus* is the only species in sea cucumber to be cultured in north China. This is due to its high meat quality and to the success of the techniques used in commercial hatcheries

In the early 1980s the shortage of sea cucumber seed was a bottleneck for developing aquaculture. The Ministry of Agriculture prioritised setting up hatcheries of sea cucumber (*Apostichopus japonicus*) and improving techniques of seed production. Since then, sea cucumber farming has been becoming a vigorous sector in mariculture.

The procedure for artificial reproduction of sea cucumber is as follows:

#### 2.2.1.1 Broodstock Condition and Spawn

<u>Broodstock collection</u>: from late May to early July;

<u>Broodstock care in land-based tanks</u>: 30 individuals $m^{-3}$, DO over 5 mg $L^{-1}$, feeding rate about 5–10% of body weight;

<u>Spawning stimulation</u>: thermal shock (water temperature raised by 3–5℃) and desiccation followed by seawater jet for 10–15 minutes;

Fertilisation: Artificial spawning allows the hatchery operators to better control the concentration of spermatozoa and the stocking density of eggs. The Maximum density was 1 million eggs $m^{-3}$ in hatchery tank;

Hatching: The hatching rate may exceed 90 %.

2.2.1.2 Larval rearing

Rearing the pelagic stages of *A. japonicus* requires considerable attention and constant monitoring of the culture medium.

Larval density

In order to ensure a fast growth and high metamorphosis rate, larval density should be maintained at between 3 to 4 $x10^5$ individuals/$m^3$.

Feeding

The use of different species of microalgae is crucial for the development of the larvae. *Dunaliella euchlaia, Chaetoceros gracilis, C. muelleri, Nizschia closterium* and *Phaeodactylum tricornutum* can be used to feed the larvae. The most important species are *D. euchlaia, C. gracilis* and *C. muelleri*, whereas *Dicrateria zhanjiangensis, Isochrysis galbana* and *Chlorella* sp. are usually added as a supplement and are never used alone. For a balanced diet, a mixture of 2 to 3 species is highly preferable. The microalgae are fed at a concentration ranging between 10 000 and 40 000 cells/ml. Food levels are increased gradually as the larvae develop. In order to enhance larval growth and decrease the rate of malformation of the young sea cucumbers, marine yeast and/or photosynthetic bacteria (PSB) are often supplied.

Water quality

High quality seawater in a sea cucumber hatchery is an important prerequisite. Research findings indicate that numerous physical and chemical factors (e.g. temperature, pH, salinity, ammonia, dissolved oxygen, heavy-metal concentration, turbidity, etc.) will influence the success of a culture. As these parameters tend to vary significantly from one region to another, careful monitoring of the seawater quality is essential.

Selection and use of settling bases

The traditional substrates used for the settlement of the sea cucumber juveniles are frames fitted with fine polyethylene (PE) or polypropylene (PP) cloth. In recent years, some hatcheries have started to use PE corrugated plates measuring 50×50 cm fixed together in stacks of 8-10 pieces. This latter method has been used with some success. In the traditional method, benthic diatoms need to be cultivated on the settling bases before they can be used. Currently, some hatcheries no longer cultivate benthic diatoms, but rather provide a food supply soon after the juvenile sea cucumbers have settled. This method has two advantages: no equipment is needed to rear benthic diatoms and the settling plates are easier to clean during routine hatchery operations. The settled sea cucumbers are fed with benthic diatoms that have been using mesh bags or other materials placed in the rearing tanks and with a powdered macroalgae soup typically prepared using *Sargassum* spp. such as *S. thunbergii*. The correct feeding rate is essential to ensure a high survival rate of the juveniles.

2.2.1.3 Juvenile rearing

Rearing juvenile sea cucumbers may take several months, but may require as long as 6 months if the rearing conditions are not favourable.

Food

The food must be free of contamination, of the right particle size and contain all the essential nutrients. A balanced diet not only accelerates the juvenile sea cucumbers' growth rate, but also increases their survival rate.

Transfer of the juveniles

Juvenile sea cucumbers are particularly vulnerable during the early rearing stages. High mortality rates are caused by high density, overfeeding, faeces on the settling plates and competition for space amongst themselves and other opportunistic organisms such as *Ciona intestinalis*. This species of tunicate can also secrete a toxin that can kill juvenile sea cucumbers. Therefore, juveniles should be regularly transferred to new settling plates, sorted by size and injured individuals transferred to separate tanks. Light anaesthesia is usually used to reduce stress and facilitate handling of the sea cucumbers. *Microsetella* sp.

(Ectinosomatidae) is commonly found in rearing tanks and can form large colonies in a short time killing all the sea cucumber juveniles in 1-2 days when the situation gets out of control. Trichlorfon, a biocide, was formerly used to kill *Microsetella* sp., but the copepods have developed a strong resistance to the biocide and therefore have become difficult to eradicate. In 2003, a new and effective pesticide known as “Mei Zao Ling” was developed by the author. This product has little side effect on the sea cucumbers.

Nursing of juvenile sea cucumbers

As the juveniles grow, the water quality and dissolved oxygen must be maintained at the optimal level. Increasing aeration and water exchange rates becomes necessary. The oxygen level has to be maintained above 5 mg/l. It is also important to use formulated feed that can be digested and absorbed easily. Experimental results have shown that the growth rate of juveniles fed on the formulated feed is at least two times higher than that of individuals fed on traditional feed during the 20 to 30 day period. In recent years, studies on a series of formulated diets revealed that diet is a key factor for improving the survival and growth rates of juveniles in the nursing stage.

As the accumulation of excess food and faeces increase, harmful germs tend to multiply rapidly and can cause very serious disease outbreaks among the juvenile sea cucumbers, including what is known as the ‘stomach ulcer’. Another disease is ‘white muscle syndrome’ which causes muscle tissues to turn white and rigid. More applied research is urgently required to find effective remedies to these problems.

2.2.2 Sea Urchin

2.2.2.1 Broodstock management

Broodstock should be 3~4 years in age and 6~7cm in test diameter. The shell of broodstock shouldn’t be damnified. To the control of the reproductive maturation, the photoperiod and water temperature are considered to be important (Pearse, 1986). Experimental broodstock cultivation has shown that multiple spawning is possible when well-feed sea urchin is cultivated in darkness in relatively warm water (Leahy, 1978). So after caught, the mature sea urchin were put into the dark tanks and reared with the filtered seawater (8.0~15.5℃ in temperature and about 31.5‰ in salinity). The density of broodstock less than 20 sea urchin per stere and fed with enough *Laminaria japanica*. There have airstones to provide the oxygen the broodstock needed. The water in the tanks needed to be changed once a day and 1/2 in volume each time. Every four days, the tank should be changed all the water to clean the dejection of the bottom.

2.2.2.2 Induce to spawning, fertilization and hatching

There are three ways to induce spawning:

1) mature sea urchins are easily induced to spawn by injecting

1~2ml of 0.5M KCl solution;

2) Putting the sea urchin in the shade and in running seawater;

3) Taking out the mouthpart can be used to induce to spawn also

After induced, the sea urchins are put into sea water to spawning. The female and the male sea urchin are put separate.

After the eggs and sperms were enough, the eggs were collected to a plastic barrel and mixed some sperms to fertilize with the eggs. The quantity of the sperm is enough if there are 10~100 sperms around each egg.

The fertilized eggs hatched 20~30eggs/ml in the hatching barrel and rinsed off the excess sperm once an hour. Before hatching, the water should mix round twice an hour to avoid the fertilized eggs deposit at the bottom of the barrel. The hatching temperature should between 16 ~18℃. After approximate 16 hours, the fertilized eggs will hatch out.

2.2.2.3 Larvae rearing

Culture vessel

Pond (10~20$m^3$) or aquarium (1.4$m^3$) can be used as the culture vessel.

Planktonic microalgae for larviculture

Many species of cultured algae support rapid growth and development through metamorphosis. The planktonic microalage size, concentration, flavor and the stage of larval development are influence larval feeding rate and selection. The diet experiment divided into two groups: the first group fed with *Chaeterceros gracilis*, the second group fed with the mixture of *Isochrysis zhanjiangensis* and *Nitzschia clostertum* (1:1).

The planktonic microalgae is reared in 15~30℃ in temperature, 7000~10000 Lux in photometer. The nutrient salts included 5~20mg $NaNO_3$, 0.5~1mg $KH_2PO_4$, 0.05~0.2mg $Fe(NH_4)_3(C_6H_5O_7)_2$ and in 1000ml volume. In the process of rearing, the water should prevent from polluting by other algae. After the density increased to 1million cell/ml, it can fed to the larvae.

Larvicuture management

After the blastula float with little active movement in the surface of the water, the health larvae should be selected, estimated the quantity and transferred to the culture pond. The water should be changed twice a day with half of the water each time using the net cage.

Larvae development involves growth and elaboration of the larvae body. After three to four days, the larvae have developed to the early pluteus stage that requires planktonic microalgae as food. The planktonic microalgae should fed four times one day and 5000~40000 cells/(ml·day) (four to eight- armed larvae).

The density is initially 1.0 larvae/ml, but decreases to 0.4~0.7 individual /ml at the end of the eight-armed larvae. The photometer should less than 300Lux. The salinity of seawater is 30~31.5‰, temperature is 16~18℃, dissolved oxygen is 6.5~8.0mg/l and PH is 7.9~8.3.

2.2.2.4 Benthic diatom cultivation and settlement

As the formation of rudiment of the juvenile echinoid, the development of the larvae is arrested because the metamorphic competence is achieved. Settlement presents a variety of problems for echinoid larvae. Larvae must detect suitable habitat to switch from planktonic living to benthic living. Induction of settlement and metamorphosis occurs in response to environmental factors that signal the availability of suitable benthic habitat (Lawrence,2001). And 0.5M KCl solution also can be used to induce the metamorphosis.

The attachment which induced the settlement use the polyvinyl chloride wavy plates (42×33cm, each group has 20 plates) covered with the benthic diatom which serves as the food source for the juvenile sea urchin. The plates should inoculated with the benthic diatom on both sides 20~30 days advanced. Nutrient salts are added to stimulate algal growth. When the larvae appeared podium or thorn, the larvae should put into the tanks that have the plates covered with the benthic diatom. The quantity of the larvae should ensure 300~500 larvae per plate. The tanks should change the water twice a day with half of the water each time.

2.2.2.5 Early juvenile rearing

After all the larvae were metamorphosed, the sea urchin should rear with continuous flow sea water to supply three time sea water one day. The water flow is 100~500%. The photometer should less than 3000Lux. The water should aerate to provide the enough oxygen for the sea urchin. Nutrient salts are added to the tanks every day to stimulate diatom growth. Nutrient salts were used when the rearing of juveniles.

When the juveniles reaches 2~3mm sizes, the sea urchin should transfer to the net cage and feed with *Ulva* sp. and *Laminaria japonica*.

2.3 Seaweed (eg.*Undaria pinnatifida*)

*Undaria pinnatifida* is the main seaweed species under cultivation in Dalian, Dalian area. contribute more than 80% of the the Chinese cultivation yield.

Collecting zoospores

Collection of zoospores begins at about April to June when the plants become fertile. The matured sporophylls are kept in a dark moist container for several hours to induce the mass discharge of the spores. These spores attach themselves to substrates and develop into male and female gametophytes.

Nursing of young sporelings

As young sporelings 3 to 5 cm long become overcrowded in their breeding station, they are moved to grow-out sites when sea water temperature drops below 20℃, e.g. around mid-October in northern China. The purpose of such move is to stimulate their growth to a length of 10 to 25 cm before their transplantation. During this nursing period, young sporelings grow very rapidly.

Transplantation of young sporophytes

At the end of the nursing period, young seedlings are transplanted to kelp culture ropes for final grow-out on floating rafts. The procedure is similar to the transplantation of young rice plants in paddy culture. The outgrowing of sporelings starts in the autumn when the water temperature is below 20℃.

## Part III .The Growout Method in North China

Several culture methods are being practised in north China:

3.1 Floating Raft Culture

There is a long history of using floating rafts for shallow-sea farming. This system can be used for a variety of species such as seaweed (kelp and laver), filtering organisms (scallop, oyster, mussel) and abalone, combined with culture in lantern cages

It has been shown that the major advantages of this culture method are better growth rates and quality. The survival rate is also better when compared to bottom culture methods mainly due to the fact that bottom dwelling predators (e.g. starfish and drills) are unable to reach the cultured oysters. However, with this method, the raft and cages can be easily damaged by a storm and the cages fouled up by a number of benthic organisms and seaweeds. To avoid being blocked up, the cages are periodically cleaned.

## 3.2 Pond Culture

A high proportion of the area under cultivation is devoted to pond culture in marine and brackish waters. Often ,fishers culture shrimp ,crab, or marine finfish, Also some benthic species such as manila clam, razor clam in the pond .In recent years, Pond culture of Sea Cucumber *Apostichopus japonicus* developed in Liaoning and Shandong Provinces and is mainly centred in the Dalian area.The details were described below.

### 3.2.1 Optimal culture pond conditions

Pond size and water quality

Ponds are usually located in the intertidal zone for convenience of water exchange. The salinity should be maintained above 28 all year round, however, it can drop to 24-26 over a short period in summer. Water quality should remain high and it can be renewed by opening and closing the sluice gates. The optimal pond size is usually between 2-6 hectares with a water depth maintained at 1.5-2.5 m.

Pond cleaning and sterilization

The best farming results are obtained in leak-proof ponds with a muddy sand substratum which requires sterilization prior to the rearing phase. This is done by first removing the bottom silt. At this point the pond is filled with seawater and the level adjusted to 0.2-0.3 m. Calcium oxide or bleaching powder is subsequently added.

Settlement substratum

According to the natural behaviour of the sea cucumber, the pond bottom requires a layer of an adequate substratum for larval settlement to occur. Stones, roof tiles, bricks and other suitable structures can be used. The quantity of the substrate should be in the range of 150-1 500 $m^3$/ha, however this can vary depending on the pond characteristics and production method employed. Stones remain the best choice, each of about 15-40 kg in weight. The settlement substratum should be added to the pond one month prior to the introduction of the sea cucumber juveniles.

Water conditioning

In order to ensure the right quantity of diatoms, the water should be inoculated at least 15 days before the juveniles are seeded. The most common fertilizer used is urea at about 30-60 kg/ha.

### 3.2.2 Juvenile rearing and growout

Growout season

The growout season can commence either in September/October or in March/April when the seawater temperature ranges between 10-15 ℃. In a polyculture situation the shrimp postlarvae are usually introduced in May-June.

Transportation of juveniles

The juveniles are placed in temperature controlled boxes for transportation. They should not be fed for 1-2 days prior to this operation. The temperature should be maintained below 18 ℃. The shrimp postlarvae are generally transported in oxygen filled plastic bags with a sufficient quantity of seawater.

Juvenile size and rearing density

The juveniles may be from the wild or hatchery produced. Juveniles usually range between 2-10 cm in length and their stocking density varies depending on the pond conditions, food supply and availability of settlement surfaces. The amount of sea cucumber juvenile released is 15-40 individuals/$m^2$ for individuals measuring 2-5 cm, 15-25 individuals/$m^2$ for individuals of 5-10 cm, and 5-8 individuals/$m^2$ when they are 10-15 cm in length.

There are two methods for releasing the juveniles. The first one is to place them in the sea bottom directly by hand or simply releasing them from a boat using individuals larger than 4-5 cm. The second method, used when handling individuals smaller than 3 cm, is to place the juveniles in mesh bags with an opening at one end. The mesh bags are

30x25 cm in size and each one may contain up to 500 individuals. They are placed beside the settlement substratum.

The shrimp species used for polyculture with sea cucumber are the Chinese or Japanese shrimp. The shrimp postlarvae are usually 2-3 cm in length and are seeded at a density of 3-6 individuals/$m^2$.

Feeding

Sea cucumber juveniles usually do not require any additional food supply. However, the addition of food is necessary to maintain a high rearing density and to favour growth during spring and autumn. Grounded pieces of *Sargassum* and *Zostera* are generally used.

Pond management

The seawater is renewed by opening and closing the sluice gates with the change of tide. About 10-60 % of the total seawater should be exchanged depending on the water quality and temperature in the ponds. In summer, the water level in ponds should be kept higher in order to maintain a lower temperature. The salinity is maintained by regular water changes. The temperature, salinity, pH and oxygen levels should be monitored daily as well as the growth, survival rate and behaviour of the sea cucumbers.

During the winter months, the following additional tasks need to be performed:

1. Maintain the water level at 2 m.

2. Removal of ice formations from the surface of the pond to keep the air-water interface free and ensure acceptable oxygen concentrations in the pond.

Harvest

The sea cucumbers are collected when they reach 150-200 g. Harvesting is done following the drainage of the ponds or with the use of SCUBA diving equipment. The shrimp are generally collected using nets placed at the sluice gates.

3.3 Mud Flat Culture

It is very popular in China because it does not require large quantities of food and it does not pollute the environment.

This system is especially suitable for farming benthic species such as manila clam (*Ruditapes philippinarum*), hard-shelled clam (*Meretrix meretrix*),blood cockle (*Tegillarea granosa*), razor clam (*Sinonovacula constricta*) and seaweed such as *Porphyra* spp.

3.4 Net-cage culture

In China, marine fish farming entered a new era since the 1990s, following the great advances made on understanding cultured species biology and on their rearing technologies. The principal culture method for marine fish is net-cage culture .In north china,the main species fish are Lateolabrax japonicus, Paralichthys olivaceus, Sciaenops ocellatus, Sebastodes f uscescens, *Hexagrammos otakii*, *fugu* sp..

Inshore cage culture is very popular world-wide, especially in China. Advantages include low investment and easy routine management. But this system is one of the main sources of inshore pollution and the main cause for red tides.As most farmers use trash fish to feed cultured fish with a high commercial value, it does not take long before a great quantity of faeces and food residues accumulate on the sea floor and pollute the entire area,Another problem is that floating cages cannot resist strong winds and waves, the losses are very serious.

A new models of cages ,the large-sized current-resistance submerged net cage for mariculture, which developed in our country recently with fairly high-tech can promote the sustainable development in marine fish farming .Meanwhle, the mariculture with the submerged cage has became the main industry of the aquaculture in the field of exploring and utilizing ocean.

3.5 Intensive Culture Indoors

This system is especially suitable for abalone and flounder culture. Abalone can be considered as one of the gastropods that have a high potential for commercial exploitation in the Asia-Pacific region. They command a high price and are highly relished in a number of Asian countries, particularly in China, Japan, and the Koreas. In this system , Concrete tanks are used of around 30-50 cubic meters. A dark PVC basket of 40 cm x 30 cm x 13 cm is in common use, usually in a stack of

8-12 tiers arranged in rows in a tank. The baskets occupy 40-70% of the tank capacity. Fresh kelp ,mostly *Laminaria japonica*, is the primary food during growout,and artificial diets are used when algae are not available. The major husbandry measures include adequate feeding, control of water flow, periodic elimination of abalone waste, and adjustment of the culture density. Usually this grow-out system has a high running cost, including cost for water pumping, heating, and aeration.

## Part IV Polyculture

Polyculture has a long history in freshwater aquaculture in China, and could be applied more in the marine environment. In marine polyculture, bivalves, seaweed, and marine finfish are produced together. By using such complementary species, the waste of one can be converted to protein by the others. In finfish production, for example, feed that is not consumed filters down to suspension-feeding bivalves, or mixes with fecal waste and is taken up by primary producers such as seaweed (harvested directly), or by phytoplankton, which is then consumed by bivalves.

### 4.1 Bivalve and Seaweed Raft Polyculture System

This form of culture shows much promise in increasing sustainability in many types of aquaculture since it maintains a balance of nutrients in the environment and increases the efficiency of protein production.

In Northern China, for example, kelps cultured on rafts provide shading, create sheltered areas less exposed to current flows, release oxygen as a product of photosynthesis and generally improve water fertility. Overall, Laminaria plants create a “mini-ecosystem” in otherwise open shallow seawater, making conditions more favourable for commercial production of scallop and other marine organisms. In turn, scallops and other cultured marine organisms in a polyculture system produce metabolic byproducts, especially dissolved N, P and CO2, which act as natural fertilizers to meet the nutrient requirements of seaweed plants.

4.2 Polyculture in Pond

The main polyculture modes in pond are shrimp–fish (e.g. mullet, tilapia, *Fugu* spp., perch, sea bream etc.), shrimp–sea cucumber, and shrimp–crab.

The shrimp–fish system is the most successful, according to recent reports. Some experts inferred that there are two factors which keep shrimp growing healthily in the shrimp–fish system. One is that predatory fish eat sick or morbid shrimps, thereby eliminating the spread of disease in shrimp ponds. The other is that there is an improved balance in the mini-ecology of shrimp ponds. Effluents rich in organic matter from shrimp culture can also be utilized by bivalves. Many species can filter out small particles and also utilize microalgae from the effluent.

These can be commercially valuable species for harvest or non-valuable species for use as fish-meal.

Another polyculture mode is crab-shrimp-bivalve,and this system is successful in Shandong and Jiangsu province. the crab is blue crab *Callinectes sapidus* ,the shrimp are *Penaeus chinensis, P. japonicus,* or*P.* vannamei ,the bivalve are *Ruditapes philippinarum, Argopecten irradians* or *Sinonovacula constricta.*

**Part V Marine Enhancement**

Since fishing wild stocks can't continue to increase the total yield, particularly the high valued species, which are either depleted or overfished, for increasing demand of human consumption. Enhancement of fishery resources is an important measure to increase the number of individuals to rebuild a depleted stock for one or more species, which can also alter the composition of living resources.

Stock enhancement has been lasted for more than 20 years. It developed very fast in China in recent years. The main species were high-valued species, (See the table below)

Marine enhancement trials in north China

| | |
|---|---|
| Crustacean | *Penaeus chinensis, P. japonicus, P.vannamei* |
| Shellfish | *Patinopecten yesoensis, Haliotis discus hannai, Scapharca subcrenata*、 *S.broughtonii* |
| Marine Fish | *Paralichthys olivaceus, Liza haematocheila, Pagrosomus* |

| | |
|---|---|
| | *major, Pseudopleuronectes yokohamae ,Chelon haematocheilus Pseudosciaena crocea, Sparus macrocephalus* |
| Echinoderm | *Stichopus japonicus, Strongylocentrotus intermedius S. nudus, Hemicentrotus Pulcherrimus* |
| Jellyfish | *Rhopilema esculentum* |

<u>Shrimp</u>

*Penaeus chinensis* mainly distributed in the Bohai Sea and Yellow Sea. It was a very important fishery to the north fishery.During 1985-1992, 8.645 billion juvenile shrimp were released in the Bohai Sea. Shandong province released 200 million juvenile shrimp into the waters around Shandong peninsula in 2004.The recapture rate range from0.001% to 1.88%

<u>Fish</u>

In addition, many fish species have been released into coastal waters in order to increase their stock size, but often intermittence, such as red seabream (*Pagrosomus major*), marbled flounder (*Pseudopleuronectes yokohamae*) and so-iny mullet (*Chelon haematocheilus*), black porgy (*Sparus macrocephalus*), bastard halibut (*Paralichthys olivaceus*). Also the benefit is high, but the input is also high. In recent years, juvenile large yellow croaker (*Pseudosciaena* *crocea*) has been released into the East China Sea to rebuild the depleted stock.

Jellyfish

Since the depletion of some jellyfish fishing ground, the institutions in Liaoning Shandong, Tianjin, Hebie and started experiment of releasing ephyra in the 1980's. During 1994-2003,an average of 69.6 million ephyra were annually released into the bays around the Shandong peninsula by Shandong province, with mean cacth of 4994 t per year. Jellyfish is closely related to environmental condition, therefore, the economic benefit highly varied. the recapture rate was 0.68~2.65% in Liaoning,Shandong and Jiangsu province.

Shellfishes and others

Seabed seeding is used to enhance the shellfishes resources, including scallop, clam, abalone, sea cucumber, trumpet shell, and urchin etc. This method is usually difficult to distinguish with mariculture, but it has an advantage of reducing disease compared with mariculture. Recapture rate of abalone and sea cucumber, is much more predictable than for shrimp. According to data recorded from commercial captures, recapture rate for abalone may be as high as 50 to 70 percent. For sea cucumber, this rate depends more on site selection and improvement, such as increasing sheltered areas.

In general, sea ranching is a good system to enhance or to re-establish a population which has declined, but numerous factors influence results. There is still a long way to go to reach desirable goals.

## Part VI Problem and Solution in the Development of Mariculture

### 6.1 The Main Problems Existed

There are three aspects in China which can be considered as the main limited factors influencing mariculture development in a continual, stable and healthy way.

#### 6.1.1 The quantity and quality of seeds can not follow the current

Two meanings are contained in the aspect discussed about seeds:

1) each seeds of cultivation species cannot obtain the stable supplies;

2) the species bred mostly do not have the process system of artificial selective breeding, and the genetics materials are still equivalent to the wild species. Therefore the growth speed, the disease-resistant ability and quality are urgently needed improvement by systematical artificial selective breeding.

Tens of mariculture species have been or are being developed, the breeding techniques about most of them have matured, and seeds can be provided to farmers and factories. But up to now, besides relatively systematical research about kelp and laver in the aspects of artificial selective and genetic breeding, few breeding research work are made about other species, which contrast sharply with the facts that quantities in the agriculture and stockbreeding mainly depends on the renovation and revolution of the varieties.

6.1.2 Aquiculture disease has unceasingly occurred and also the loss is serious

In China, the aquiculture industry developed considerably quickly, the variety of sea aquatic products has surpassed 40, and the cultivation scale also expands unceasingly, the output increase with a large scale. In the last few years, however, aquiculture disease occurred continually, the country economical loss by billions of RMB every year. Especially since 1993, the loss from shrimp disease occurred seriously. The fish disease, sea scallop disease, kelp disease, abalone disease and so on occurred unceasingly. The fact can be expected, in a quite long period from now on, that how to prevent disease and treat the sickness and reduce diligently the aquiculture loss from the disease to the lowest degree still will be a vital task for those researcher and farmer.

6.1.3 Environmental pollution increases steadily

Here mainly refers is the inshore sea environment condition which has close correlation with mariculture industry. Along with social and economical fast development in the coastal areas, massive industrial waste and the city life sewage has not been processed or processed thoroughly before dispersing into the nearshore sea. The result is that the water quality in the nearshore sea worsens gradually which directly threatens the survival and development of mariculture industry. On the other hand, the environmental pollution from the cultivation industry development is also noticeable. Because many farmers use the bad quality fish food, the fish food coefficient is high, a large quantity of food cannot be absorbed and becomes the harmful organic pollutant. The phenomenon of misusing and abusing some antibiotic, disinfectant and water quality improved medicine sometimes occurs, the influence these medicines to the micro ecological environment is definitely noticeable. In addition, the irrational cultivation layout is also extremely easy to cause water excessively full of nutrition and the harmful algae and disease microorganism massive reproductions, finally harms the survival and the development of sea water cultivation industry.

## 6.2 Suggestion to continual development

### 6.2.1 Develop intensive cultivation and enhance output

In 21st century, Chinese sea water cultivation will convert from extensive to intensive fashion. Intensive cultivation has the virtue of high output, stable production, slight affection to the ecological environment, water saving and so on, and the developmental potential is very big. Through development of high value cultivation species, the sea water cultivation standard will enhanced distinctly. The present task is manufacting and developing modern fishery establishment, such as the development of new anti-storm cage technique, the development of economical practical cultivation water treatment installation, the equipment development of automatic throwing the bait, protecting, managing, and monitoring and so on.

6.2.2. Speeds up the improvement of varieties and enhance cultivation benefit

The application of the biological technology in the mariculture is the hot spot in the current international research, including the new species cultivation, the gender control, the new technology application, germ plasm preservation and disease preventing and controlling and so on. With the support of hi-tech “863” project, the researchers have obtained the important breakthrough in the cellular engineering breeding technique. Triploid and hybrid oyster, scallop, abalone, all-female prawn and flounder, and the kelp ,wakame, laver developed through hi-tech and so on will soon enter the industrial stage. From now on, these aspects will be the emphasis of developing and researching.

6.2.3 Develop health cultivation and prevent a disease

Reasonable layout, scientific management, developing healthy cultivation are the vital steps to prevent the disease from occurring. Something must be done to optimize the cultivation ecological environment, act as circumstances permit to develop the suitable health cultivation pattern, and provide the good survival requirement for the cultivation species. The technology research about disease ecology control should be strengthened, according to the ecology habit of pathogens, disease occurring and expanding can be prevented through removing the surroundings for the pathogens, shutting off the spreading way. Establish the effective immunity and the preventing and controlling technology to the main cultivation disease, develop and manufacture new medicine, construct complete immunities technologies. To the main sea water cultivation disease, the fast examination and diagnosis system in the early stage should be established and the loss disease created should be reduced to the smallest degree.

6.2.4 Develop the high quality feed and enhance the fish food efficiency

Using the high quality feed has the decisive function in enhancing the product quality of the sea water cultivation, reducing the cost, reducing disease, preventing the environmental pollution, raising the economic efficiency and so on. According to surveys from concerned experts, in the increased output value of the cultivation industry, the technical contribution rate is 41%. But in those science and technology country, the improvement rate of the feed application and the feed technique is 65 percent to 70 percent. Thus the use and the popularization of the high quality pellet of all-around nutrition will be the symbol of the progress in aquicultural industry technology. In recent years the scientific and technical operators carry out a series of research to the many kinds of important seawater cultivation animal's nutrition and the feed prescription, but compared with the industrial development demand, the technical level is still low and the represent mainly lies in the coarse prescription for the feed and the laggard process technique. Most of the aquatic products mainly rely on the natural animality feed, which result in high cost, low efficiency and bad quality of sanitation and it is easy to pollute the water area for breed aquatics. We should energetically develop and exploit the artificial feed with high quality, good stability, good tempting, good absorbency and low feed quotiety, and promote the mariculture industry in healthy development.