Marine Fish Cage culture in China

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Cage farming has initiated since late 1970 in China, originally to be introduced to inland aquaculture and later in mariculture.

In late 1970, Huiyang county and Zhuhai City, Guangdong Province tried to farm marine fishes including grouper and sea bream in cages. The experiments obtained success. It was first trial of marine cage farming in China. In 1981, experimental farming had been expanded to commercial scale. Almost all of products were exported to Hong Kong and Macao markets and got significant economic benefit. From 1984, other counties and provinces (Fujian, Zhejiang provinces) began to follow their step of farming marine fish in cages. According uncompleted survey, the quantity of marine fish cages in three provinces (Guangdong, Fujian and Zhejiang) had reached over 57 000; More than 40 species of marine fishes (Annex 1) were farmed. In early stage, cage farming was in artisantal level. The research and development of modern cage systems has only taken place since 1990s, primarily in line with the development of marine fishes like sea bream, perch, cobia and large yellow croaker. Its development has been in a stage with high speed since beginning of 21 century. Hence, the history of offshore cage is less than 10 years.

The majority of farmed fishes are bred in hatcheries in land-base. Hence, the seed supply can meet the demand of cage culture, for example, last year one billion fingerlings of large yellow croaker (*Pseudoscisena crocea*) were bred in Fujian and Zhejiang province. Fujian Province accounted for 70%. But some rear species have to be captured from wild or imported from other countries. They are yellow tail (*Seriola lalandei*), estuary grouper (*Epinephelus tauvina*) and others.

Total quantity of different models of marine cages reached one million, which are distributed in China's coastal provinces and zone. They are Liaoning, Shandong, Jiangsu, Zhejiang, Fujian, Guangdong, Hainan provinces and Guangxi Zhuangzu Autonomous Region. Among them, there are about 3000 offshore cages to be installed. The output from cage culture was about 200 000 tons in 2005.

Inshore cage culture is facing three problems: 1) there is no enough space for its further extension; 2) they cannot withstand the attack of typhoon, so the security of fishermen's life and their property is threatened by the disaster annually; 3) inshore cage farming causes severe environmental pollution through fish metabolite and residuals (trash-fish). The polluted environment becomes the inducement of epidemic diseases. That is why offshore cage culture has been becoming a better way to decrease the pollution.

Developing offshore cage farming is a new way providing employment for fishermen transferring from fish capture to aquaculture. From 2003 to 2010, there are 300 000 fishermen leaving their fishing vessel and looking for other jobs. Thereby, developing offshore cage farming creates the chance for them.

In order to ensure the development of offshore cage farming, Chinese government and relevant authorities strongly support the project both from policies and from fund. Since the beginning of 21 century there have been about six kinds of offshore cages to be developed and extended in coastal provinces. They are HDPE circle cage, metal frame cage, floating rope cage, dish-formed submersible cage, PDW submersible cage and SLW rotatable & submersible cage.

Developing offshore cage farming is not only a matter of pushing mariculture or fishery industry, but it will create significant social-economic influences in future. The near target of offshore cage culture is that marine fish farming will become a main force in Chinese mariculture sector. It is estimated that the output of marine fishes will increase to 500 000 tons or more in 2010.

1. Present status of marine cage culture

1.1. Traditional cages

- **configuration, model, quantity and their distribution**

Until now, the traditional cages still account for majority of marine cages. The total quantity is about one million, which were distributed in China's coastal provinces and zone. These cages are in an artisantal level, hereby the figuration, design of them are small (normally 3m x 3m to 5m x 5m in size, nets with 4-5 in depth), simple (square in forms) and rough (Fig 1). The materials used for these cages are collected from local market including bamboo, wooden board, steel pipes and PVC or nylon nets. Saving investment and easy for manipulation are the principle of their owners, so, most of inshore cages are made by farmers themselves. Due to these cages cannot withstand billow caused by typhoon and swift sea-current, they have to be installed in inshore water and sheltered sites. In some location, the cages to be connected together one by one form a big floating raft stuffing in small inner bays (Fig 2).

Fig 1 traditional cages, simple and rough

Fig 2 inshore cages crowded in inshore water

Most of the cages are distributed in Fujian, Guangdong and Zhejiang provinces and account for 80% of total quantity of marine cages in China (Table 1).

Table 1 The quantity and distribution of traditional cages

Year	Location	Quantity of cages
1993	Guangdong, Fujian, Zhejiang	57000
1998	All coastal provinces	200 000
2000	All coastal provinces	Over 700 000, of which 450 000 in Fujian Province
2004		1 million
Of which	Fujian	540 000
	Guangdong	150 000
	Zhejiang	100 000
	Shandong	70 000
	Hainan	50 000
	Other provinces & zone	100 000

- The reasons for rapid extension

Along with Chinese door open to outside, economic development stimulates the demand of aquatic products, especially live marine fishes. Soaring prices of marine fish in 1990s further accelerate the extension of marine cage culture. Fig 1 and 2 show a farm located in Luoyuan Bay, Fujian Province, for example, in 1990, there were less 1000 cages totally in the bay, but in the highest period (late of 1990s), the quantity of cages reached 60 000 at the same place. At that time the price of farmed live marine fish like red sea bream was about US$ 6 per kg, the productive cost was US$ 2 per kg only. The margin of it reached 200%! No doubt, high margin become one of the main factors expediting the extension. It is a typical sample showing the developing course of inshore cage farming in China.

1.2. Severe problems caused by traditional cages

Due to traditional cages cannot withstand billow caused by typhoon and swift current velocity, so they have to be installed in inshore water or sheltered sites. Lots of the cages stuffed in inshore water cause a series of problems. The first one is pollution cause by metabolite of fishes and residual of feed. Serried cages blocking inner bay lower normal sea-current and water exchange so as to the metabolite and residual start to be accumulated in seabed. According the investigation, the accumulated waste in some severe locations is as high as one meter or more in depth; in the results the capacity of self-depuration in these locations is damaged. Eutrophication, epidemic disease outbreak, lower quality of farmed fish are followed, while poor quality of seawater jeopards to other farmed animals like oyster, scallop by polluted seawater and red tide as well as influence on the ecological environment. According to uncompleted investigation, the loss caused by diseases and red tide is as high as US$ 10 millions annually. In addition, the poor ability against typhoon causes severe economic loss also, for example, the direct financial loses caused by typhoon “Chebi” attacking Fujian Province in 2001 reached US$ 150 million.

Facing up to the severe status, China’s government and relevant authorities have actively encouraged farmers and investors to develop offshore cages. Since late 1990s, offshore cages has been introduced from developed countries including Norway, US of America, Japan and others; while R & D of offshore cages have started in coastal provinces including Shandong, Zhejiang, Fujian, Guangdong. Until now, there are about 6 forms of offshore cages to be developed and installed in all coastal provinces and zones. The practices testified that some of offshore cages can withstand the attack of typhoon, increase the fish output with higher commercial value, abate the pollution as well as gain higher income for fishermen.

Hereby, offshore cage culture will be becoming a main force of marine culture in near future; while inshore cages will be used for nursing to get large fingerling for stocking into offshore cages or releasing into open sea for sea ranching.

2. Developing offshore cages is a stratagem for sustainable development of mariculture

The development of offshore cages in China has initiated since late 1990s. In 1998, first offshore cages (four cages, 40m and 50m long in perimeter) were introduced into Hainan Province from Norwegian Refa Fiskeredskap AS, another 32 offshore cages have been introduced from different countries and installed in coastal provinces including Shandong, Zhejiang, Guangdong and Fujian since 2000. From then on, developing and extending offshore cages have been confirmed as a priority of marine fish farming by Chinese government and relevant authorities.

2.1 The importance of developing mariculture

China has more than 1.3 billion population, and its land natural resources per capita are lower than the world's average. Official statistic data show that China has a land area of 9.6 million km^2, making it the third biggest country in the world. However, the land area per capita is only 0.008 square km^2, much lower than the world's average of 0.3 square km^2 per capita. The tilth area per capita in China is only 7% of world level. It is estimated that the demand of grain and other food will reach 160 million tons by 2030. As a major developing country with a long coastline, China facing up to the serious fact, must take exploitation and protection of the ocean as a long-term strategic task before it can achieve the sustainable development of its national economy.

In developing oceanic fishing industry, China adheres to the principle of "speeding up the development of aquaculture, purposively conserving and rationally utilizing offshore resources, actively expanding deep-sea fishing. Since the mid-1980s, China's mariculture has been rapidly developed, with a large increase in species and expansion of breeding areas. In accordance with the actual conditions of marine fisheries resources, China has actively readjusted the structure of this sector, made efforts to conserve and rationally to utilize off-shore space, so as to make the mariculture industry constantly adapt to the changes in the gain form of marine fisheries.

Since 1990s, Chinese government has been carrying out a series of comprehensive reforms and new policies in fishery sector:

1) Since 1995 China has practiced a new midsummer moratorium system. Every year during July and August fishing is banned in the sea areas north of 27 degrees north latitude. The new system has achieved encouraging economic, ecological and social results, and from this year the midsummer moratorium

area will be expanded to 26 degrees north latitude and its duration will be lengthened to three months.

2) Carrying out “zero gain” of marine capture from 1999, in next year “minus gain” put into practice.

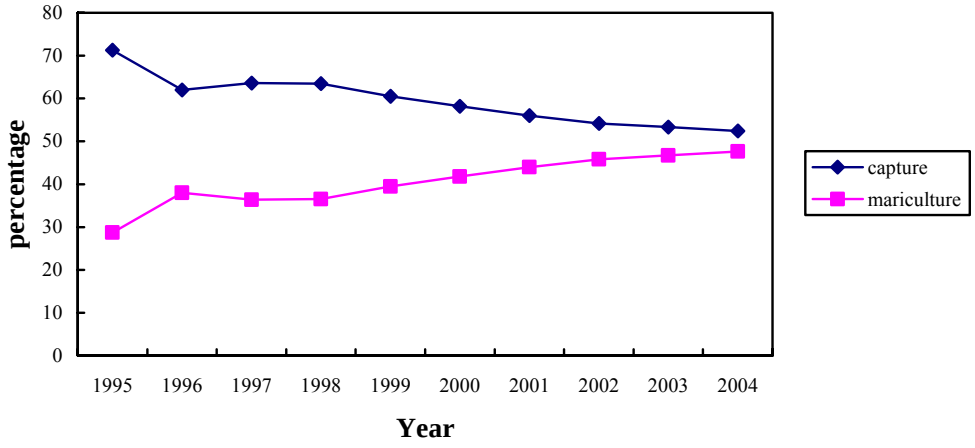
3) 30 000 fishing vessels of varied types have been cut from 2003 to 2010; meanwhile, more than 200 000 fishermen have to leave their fishing vessels and get new jobs including mariculture.

The purpose to implement these new policies is to establish sustainable fisheries through protecting marine resources and by means of mariculture as well as sea ranching. The performance has been obtaining substantial progress, for example, the landing volume from sea was 2.356 million tons in 1995, among which mariculture output accounts for 28.7% (4.1 million tons) only, but, the status has been gradually changed that the proportion of marine culture is continuously increased. The landing volume from mariculture reached 47.6% (13.1 million tons) in 2004 (Table 2 & Fig 3). It is believed that the contribution from mariculture will become majority in total marine output in near future. The gain form of marine fishery will shift from marine capture to mariculture. Developing offshore cage has been consequentially becoming the priority project of Chinese government and investors of different channels.

Table 2 The proportion of mariculture and marine capture

Year	Total output of marine fisheries	Marine capture		Mariculture	
		Output	% in total	Output	% in total
1995	14 391 297	10 268 373	71.3	4 122 924	28.7
1996	20 128 785	12 489 772	62.0	7 639 013	38.0
1997	21 764 233	13 853 804	63.6	7 910 429	36.4
1998	23 567 168	14 966 765	63.5	8 600 403	36.5
1999	24 719 200	14 976 200	60.5	9 743 000	39.5
2000	25 387 389	14 774 524	58.2	10 612 865	41.8
2001	25 721 467	14 406 144	56.0	11 315 323	44.0
2002	26 463 371	14 334 934	54.2	12 128 437	45.8
2003	26 856 182	14 323 121	53.3	12 533 061	46.7
2004	27 677 900	14 510 900	52.4	13 167 000	47.6

Fig 3 Proportion change between marine capture and mariculture



2.2 Financial support from government

Developing offshore cage needs high investment and undertakes high risk. Individual farmers are hardly undertaken the expenses for developing offshore cages and the risk. So, Chinese central government and provincial authorities strongly support the project. Estimated, the sum for the project from different ways reached more than US$ 10 million. For example, 20 projects dealing with offshore cages had been granted and obtained as much as 20 million Yuan (RMB) financial supports in last 5 year. In addition, Zhejiang, Fujian, Guangdong, and Shandong provinces have arranged special funds (more than 50 million Yuan) for developing offshore cages since 2001. The funds are partially for R&D, while directly supporting fishermen to buy offshore cages. These financial supports and favorable policies promote the development and extension of offshore cage.

According to incomplete survey, there are about 3 300 offshore cages in different models to be installed in coastal provinces, of which there are 1800 plastic hose (HDPE) circle cage (floating and submersible) distributed in Zhejiang, Shandong, Fujian and Guangdong provinces; another 1300 floating rope cages installed in Zhejiang, Guangdong and Hainan provinces (Table 3).

Table 3 Quantity and Distribution of offshore cages in China*

Model	Zhejiang**	Shandong	Fujian	Guangdong	Other provinces	Total
HDPE circle	640	495	488	60	100	1800
Floating rope	1083	/	/	150	/	1300
Dish-formed submersible	13	/	/	/	/	13
Other	51	110	/	/	100	180
Total	1787	605	488	210	200	3293

*Cage volume: >500 m^3;

** The figure of Zhejiang Province is collected in first half of 2004; others are the latest

2.3 Models and features of offshore cages

There are about 6 models of offshore cages to be developed. They are:

1) HDPE floating circle cage (Fig 4),
2) Metal frame gravity cage (Fig 5),
3) Floating rope cage (Fig 6),
4) Dish-form submersible cage (Fig 7),
5) PDW submersible cage (Fig 8),
6) SLW submersible cage (Fig 9).

- **HDPE floating circle cage** (Fig 4)

The device of HDPE cage is based on the Norwegian technique that was firstly introduced into China. Due to its simple and easy to be manufactured in existing conditions, while the cost is relatively lower than others. The results indicate that although the cage cannot face up to the attack of typhoon, but they are much better than that of traditional cages. It consists of net frame, nets, and anchoring system. The frame is made of high-density polyethylene (HDPE) and the nets made by nylon. The cage performs good characteristics in open sea with 20-40 meter in depth. For example, in 2003, two cages were used to farm Japanese perch (*Lateolabrax japonicus*) and rockfish (*Sebastes schlegeli*); the stocking density of both species is 10000 fingerlings (10 fingerlings per m^3) per cage. The survival rate is more than 80% after one year grow-out; the harvest reached 4-5 tons respectively. Although it is not high enough, but the higher survival, few chemicals to be used and lower energy cost meet the demand of farmers. The disadvantage of the cage is its lower ability against current. As the current velocity reaches 0.5m/s, the nets will create swing up and down; at 1.0m/s, the

effective volume of the cage will lose 60%. That will seriously influence the cage safety and normal life of farmed fish, and cause contusion of fish body.

Fig 4 HDPE floating circle cage（1-A， 1-B）

Technical parameters of HDPE cage

Model	Circumference (m)	Capacity against wind (Km/hr)	Capacity against wave height	Capacity against sea-current (m/s)
HDPE 30	**30**	**60-100**	**4**	**1.0**
HDPE 40	**40**	**60-100**	**4**	**1.0**
HDPE 50	**50**	**60-100**	**4**	**1.0**
HDPE 60	**60**	**60-100**	**4**	**1.0**
Diameter of HDPE pipe: φ200～φ315mm; Density of HDPE: ρ=0.95g/cm^3， Intensity of HDPE: σ_s = 24MPa，				

The first kind of cages cannot withstand typhoon attack; therefore, submersible cage is devised for installing in the sites being subject to typhoon. The basic device is similar as above cage except for the submersible system. During typhoon coming, it can be submerged 4-10 meters beneath sea surface in 8-15 minutes, after typhoon going out, it is easy to float up to surface in 3-13 minutes. So it is very easy to be controlled to duck down from violent typhoon attack.

The cage can be installed in open sea of 15 meter depth and more that is suitable to China's shallow sea. More important is its lower cost, about US$ 15 per cube meter (effective volume inside of cage), that is about 40% of imported cages.

- **Metal frame gravity cage (Fig 5)**

Metal frame gravity cage has varied forms, like floating or submersible, square or circle. Except for its material used for the cage is different from HDPE cage, the basic principle is same as that of HDPE cage. During the period of 2003 to 2004, two companies in Zhejiang Province introduced the cages from Japan. The practice in open sea testified that the performance of the metal cage has a good ability against swift current, but its metal nets are easy to be eroded by seawater. Now, there are about 30 metal cages (size: 10m x 10m x 8m) to be installed in the province.

Fig 5 Metal frame gravity cage

- **Floating rope cage (Fig 6)**

Floating rope cage is adopted by Japan in 1970s, and then to be used by Taiwan farmers. Since 1990s the cages are widely extended in Hainan, Guangdong and Zhejiang province.

It is a simple offshore cage, exactly it can be sorted into inshore cage, but its good capacity against stronger wind (60-100 Km/hr) and lower cost are welcomed by farmers. The size of a single cage is 6m x 6m x 6 m, which can reach 1000 m^3 to 2400 m^3 combined together cage by cage. The interval between two cages is 3 meters.

First trial to farm cobia in Hainan Province was successful, 11871 fingerlings (0.75-1.0 kg/fish) were stocked in two cages. After 4 months, 8.6 tons of fish were harvested in two cages. The largest fish to be harvested gained 5.5 kg (80cm in body length), smallest 3.2kg (68cm). The productive cost is US$3.5 per kg, margin is US$ 2 per kg.

Fig 6 Floating rope cage

- **Dish-formed cage (Fig 7)**

Dish-formed cage (similar to "Sea station" which is called in USA) was introduced from Ocean Spar Technologies in 2002 and installed in Shengsi County, Zhejiang Province. The Ocean Station is utilized in areas with high seawater current velocities. The design of this cage ensures little reduction of cage volume with current, and can be submerged below the surface. It is shaped like a double cone, with a central spar, and is equipped with variable buoyancy chambers and dead weights so that it may be actively submerged in rough weather and brought back to the surface later for normal operation. Three year practice indicates that the cage introduced from US is excellent for against typhoon and high sea-current velocities, but the crucial shortcoming of the cage is difficult to harvest the farmed fish. A new model of Dish-formed cage was devised in a Zhejiang company. The demerit has been overcome, so it is welcomed by Chinese cage farmers in Zhejiang Province.

Fig 7 **Dish-formed cage (made in Zhejiang Province)**

- **PDW submersible cage (Fig 8)**

All cages mentioned above were introduced from other countries. PDW cage is the one to get **independent intellectual property.** While PDW submersible cage is specially designed for flatfish farming. As well know that flat fishes including flounder, sole, turbot, halibut and others have much higher commercial value in international and domestic market, they are popular to be farmed in China. Normally they are cultured in indoor cement tanks and/or fiberglass containers. The seawater has to be pumped from open sea. Hence, the productive cost is much higher than that in cages. But most of cages mentioned above are not suitable to their ecological habits so as to design the PDW submersible age for the special purposes.

In normal conditions it is submerged to on seabed. During maintaining, net exchange and harvesting, it can be floated to sea surface that is easy for operation. In order to provide a stable environment for farmed fish, the cage nets are in tight status providing a good habitat for flatfish. Meanwhile, the cage is separated into multiple-layer that increases the effective space for flatfish's benthic conditions.

The practices in Yantai Fisheries Research Institute, Shandong Province testified that the cage is good for farming flatfish (flounder and turbot). 50-100 gram (live weight) of flounder (*Paralichthys olivaceus* and *P. lethostigma*) fingerlings are stocked, after 6-8 months the body weight per fish reaches 800 to 1 000 grams at the stocking density of 20 fishes per square meter. During experimental period, the cage had withstanded the attack of typhoon with 90-100 Km per hour of wind velocity, 5 meter's wave height and 1meter per second of current velocity. The cage possesses strong ability against swift current and wave due to submersed on the seabed.

Fig 8 PDW submersible cage (manufactured by FMIRI, Shanghai)

Technical parameter of PDW submersible cage

Model	Effective surface (m^2)	Diameter (m)	Ability against wave height/wind speed) (m); (km/hr)	Ability against sea-current (m/s)
PDW 200	**200, 260**	**12**	**5/100**	**1.2**
PDW 280	**280, 380**	**14.5**	**5-7/100**	**1.2**
PDW 350	**350, 460, 550**	**16.5**	**5-7/100**	**1.5**

- **SLW cage (Fig 9)**

Its special design is adaptable to the direction of current and swift current. Its features are:

- One anchor fixed on seabed will always face up to the current direction;
- it is easy to move to a new position for anchoring;
- strong capacity against current, when the current speed reaches 1.5m/s, its effective volume keep 95% or more;
- Cage body can run like a wheel that will prevent from bio-fouling and easy to exchange the nets.

The characteristics of all offshore cages mentioned above are compared and attached in annexes (Annex 2: Summary on the characteristics of different cages).

Fig 9 SLW submersible cage (manufactured by FMIRI, Shanghai)

Technical parameter of SLW submersible cage

Model	**Effective surface (m^2)**	**Length x Diameter (m)**	**Capacity against wave height/wind speed) (m);(km/hr)**	**Capacity against sea-current (m/s)**
SLW 400	400	16 x 6.5	5/100	1.5
SLW 1000	1000	20 x 10	5/100	1.5
SLW 2000	2000	25 x 12.5	5-7/100	1.5

- **The development of associated facilities**

Offshore cage culture is a complex system that involves so many machines for grading, harvesting, feeding, net-cleaning and maintaining, live-fish transportation, automonitoring and others. China's offshore cage farming is in fledgeless stage; so many performances are in dry running. It is expected that offshore cage farming will start associated sectors up. That will be a big market for fishery facility makers.

- **Fish species farmed in cages**

There are about 30 species (Table 4) of fishes to be farmed both in traditional and in offshore cages, but, the prices of farmed fish is different between inshore cages and offshore cages. It is because that the quality of fish flesh from offshore cages is much better than that from inshore cages, for example, the price of large yellow croaker farmed in offshore cages is about US$ 8 or more per kilo, which is almost double price of the fish farmed in inshore cages. Thereby, the return of offshore cage farming is much better than that from inshore cages.

Table 4 Economically important fishes farmed in cages

Species	Farmed region	
	northern	southern
Large yellow croaker (*Pseudoscisena crocea*)		√
Red drum (*Sciaenops ocellatus*)		√
Cobia (*Rachycentron canadum*)		√
Grouper (*Epinephelus* spp.)		√
Sea perch (*Lateolabrax japonicus*)	√	√
Rock fish (*Sebastodes fuscescens*)	√	
Fat greenling (*Hexagrammos otakii*)	√	
Red sea bream (*Pagrosomus major*)	√	√
Black sea bream (*Sparus macrocephalus*)	√	√
Ovate pompano (*Trachinotus ovatus*)		√
Redfish puffer (*Fugu rubripes*)	√	
Left-eyed flounder (*Paralichthys olivaceus*)	√	
Southern flounder (*Paralichthys lethostigma*)	√	√
Half-smooth tongue-sole (*Cynoglossus semilaevis*)	√	√
Turbot (*Scophthalmus maximus*)	√	

Among them, large yellow croaker is mainly farmed in Zhejiang and Fujian provinces, cobia and grouper in Hainan and Guangdong provinces; some species (Redfin puffer, Red sea bream, red drum and etc.) are bred in northern part of China like in Shandong Province, and farmed in Southern parts like in Fujian province. Notwithstanding so many species can be farmed in cages, it is difficult to select one or two candidates of

marine fishes suitable in northern provinces including Shandong, Liaoning and Hebai provinces round year because the seawater temperature of these provinces is lower in winter (round 1-2 °C), but in summer season it will be over 26 °C or more. The big interval of seawater temperature is hardly to be acclimated by a certain species, for examples, most of farmed fishes in northern provinces cannot overwinter in open sea that has to be moved to indoor tanks if they cannot reach to commercial size. In this case, genetic improvement of fish is a priority project for developing cage farming.

3. Technical issues in developing offshore cages

The history of developing offshore cages is less than 10 years; therefore, it has been in unfledged level, therefore there are so many issues should be resolved

- Increasing the abilities against sea-current， and keeping effective volume of cage facing up to stronger current;
- Developing cages more suitable to the Chinese sea conditions in different regions and for different species, for examples, in northern part for flatfish, in southern part for large yellow croaker, cobia and grouper;
- Producing associated facilities including these machines for feeding, grading, net-cleaning, automonitoring, antifouling, harvesting and others.
- Studying new antifouling dope/paint. At present the cost imported dope is too high to be accepted by farmers.
- Developing more stronger artificial fibers like super-high molecule polyethylene to meet the demand of cage-nets
- Further studying effective formulated feed. Until now, trash-fish has been widely used in some cage farming zones（Fig 10）. Directly using trash-fish has two issues at least, one is wasting protein resources and polluting environment. Although formulated feed has been used in aquaculture for 30 years,
- Healthy farming is a priority project in China, hereby, developing vaccine for fish farming is an urgent target.
- Breeding new varieties which are suitable to offshore cage farming.

Fig 10　Farmer was carrying trash-fish on his shoulder for feeding farmed fish

4. Governmental policy for developing cage culture

1) It is priority to develop offshore cage farming in Chinese mariculture. For examples, Shandong, Zhejiang and Guangdong provinces have planning to install 10000 offshore cages inside 40 meter isobath ; Fujian and Hainan will reach 5000 by 2010 respectively; while Liaoning, Hebai, Jiangsu and Guangxi provinces are also to increase the quantity of offshore cages in near future. By 2010, the total landing quantity from offshore cages will reach round 500 000 tons; there are about 100 000 people to be employed in the sector of offshore cage farming.
2) Developing offshore cage farming is an important way for fishermen working in fishing vessels have been transferred from fishing to other jobs. It is based on two reasons: a) natural resources have been declining; b) According to conventions between China and ROK, China and Japan, and China and Vietnam, about 30000 fishing vessels have to leave their traditional fishing ground, therefore, about 300 000 fishermen have been gradually transferred to other jobs during 2003 to 2010.
3) Promoting sustainable development of fishery industry is a strategic topic. Rationally exploiting offshore zone (inside 40 m isobath) is a vital importance because there is no more room for further developing in inshore waters.
4) It is necessary to meet the demand of increasing population. In 2030, Chinese population will reach 1.6 billion. In accord with the level of 38.7 kg per capita in 2004, the new gain will be 1.16 million tons; furthermore, worldwide market needs more qualified fishes also. Therefore developing offshore cage farming is an effective way to hit the target. According to experts estimated, by 2035, the globe output from aquaculture will reach 62 million tons only; if in accord with 1% gain of consumption, the demand should be 124 million tons. FAO report that the landing volume of marine fish from mariculture is only 4% in total volume of fisheries. From this point view, there is an increasing demand for marine fishes in world market, not only in domestic market, but in global market as well. Developing offshore cage farming is a demand of marine fishes worldwide.

5. Management of offshore cage culture

1) Site selection for offshore cage farming

The site for offshore cage farming should meet the following conditions:

- Depth: more than 10 meters and less 30 meters
- Seabed: plain, open tideway, mud-sandy substratum or rocky bottom
- Current velocity: 50-100 cm/s.
- Seawater temperature in surface: 8-28□, optimum temperature is round 18-26□
- PH: 7.8-8.6
- DO: > 5mg/L
- Transparency: > 50 cm
- Others: accord with seawater standard for fishery

2) Cage's layout
   - The acreage of offshore cages: less than 10% of total farming area;
   - Direction of cages layout: correspond to the direction of sea-current;
   - Arrangement of cages: two groups of cages are installed in parataxis; the interval of two groups is 80-100 meters; the interval between two lines of cages should be more than 50 meters.
3) Selection of species farmed in offshore cages
   - As long as the seawater temperature, salinity, and other basic conditions meet the demand of farmed species, they can be selected as candidates in offshore cage farming;
   - The stocked fingerlings should be quarantined before stocking, no pathogen free and healthy is needed;
   - These seeds should be come from qualified hatcheries and possess good genetic characteristics
4) Stocking requirement of fingerling
   - Healthy and vigorous
   - No parasites and other diseases
   - Size should be graded and consistent; normally the weight per fingerling is more than 100 grams that will guarantee the survival rate and grow up to commercial size during culture season;
   - Stocking density: 30-50 individuals per cube meter or 20 fingerlings per square meter for flatfishes. The yield is about 20 kg/m^3 that depends on species.
5) feed and feeding
   - Feed is one of vital factors; in general, trash-fish has been used in large quantity because it is cheap and easy to buy in local market. But, it is one of disease inducements, even though offshore current can bring most of residual away, but accumulation for long term will get same results as that in inshore cage culture. Normally, the FCR is about 6 to 8 if using trash-fish.
   - It is priority to develop qualified formulated feed;
   - Automatic feeding system is not widely adopted, visual judgment of hunger level is common at most farms. Normally, the feeding frequency is one to three times per day, the feeding quantity depends on ambient conditions like temperature, current, turbidity, wave and others.

Routine management starts from stocking day that includes daily observation, feeding, grading, cleaning nets befouled or net exchanging, and routine recording. As long as pay more attention on routine management, it is guaranteed to get good result.

6. The effect of developing offshore cage on social economic effect

Developing offshore cage farming has created a social domino effect. They are as follows:

1) Expanding the space for mariculture without occupying precious land and consuming freshwater;
2) Abating the eutrophication of seawater and pollution harmful to entire environment as well as farmed fish themselves. Therefore, it is an environmental friendly system;
3) The improvement of design and material used in cages greatly increase the abilities against typhoon and swift current (Table 5), hence the security of marine cage farming has been gained to a new level that guarantee the benefits of farmers and investors;
4) The development of offshore cage augment employment chance for fishermen lost job in fishing vessels.
5) Developing offshore cage brings along a new manufacture of producing offshore cages and accessory instruments/equipments for monitoring, grading, feeding and others.

Table 5 The comparison of economic effect between inshore cage and offshore cage

Items	**Traditional cage**	**Offshore cage**
Survival rate of fish (%)	70%	> 90%
Cage volume (m3)	< 100	> 1000
Capacity against wind (km/hr)	< 100	> 110
Capacity against current (m/s)	< 1	< 1.5
Capacity against wave-height (m)	2	> 6
Life span of cage (year)	< 3	> 10
Sea site suitable the cage	Inshore/sheltered only	offshore
Yield (Kg/m^2)	Round 5	> 20
Ratio of input vs. output	1 : 1.3 – 1.5	1 : 1.5 – 2.0

I want to finish the review with the words published in White Book on The Development of China's Marine Programmes issued in 1998.

"China has put the issue of rational utilization and protection of marine resources and the marine environment into the overall, cross-century plans for national economic and social development, and has adopted the sustainable development of marine programmes as a basic strategy. With the continuing growth of the forces of social production, the further building-up of comprehensive national strength and the gradual awakening of the people's consciousness of the importance of marine protection, China's marine programmes will definitely enjoy still greater development. Together with other countries and international organizations concerned, China will, as always, play its part in bringing mankind's work for marine development and protection onto the road of sustainable development".

Generally, developing marine cage farming is a long term stratagem in terms of mariculture; therefore, the more attention for its development will keep for long time. Its social effect and environmental impacts will be far-reaching. Beyond all doubt, it is indispensable to consider how to improve existing status, to make rational layout and scientific decision-making. That will ensure to establish a sustainable mariculture in China as well as for world fisheries.

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Annexes

Annex 1

Economically Important Fishes bred in hatcheries of China			
Chinese name	**English name**	***Scientific name***	**Origin**
鲻¤	Striped mullet	*Mugil cephalus*	Native
梭鱼¤	Redeye mullet	*Liza so-iuy*	Native
鲈鱼¤	Japanese sea perch	*Lateolabrax japonicus*	Native
遮目鱼/虱目鱼	Milkfish	*Chanos chanos*	Native
军曹鱼，海鲡	Cobia	*Rachycetron canadum*	Native
尖吻鲈*	Sea bass, Barramundi	*Lates calcarifer*	Native
赤点石斑鱼¤	Red spotted grouper	*Epinephelus akaara*	Native
青石斑鱼¤	Banded grouper	*E. awoara*	Native
锐首拟石斑鱼 (驼背鲈/老鼠斑)	Barramundi cod,	*Cromileptes altivelis*	Native & introduced from Malaysis
大黄鱼¤	Large yellow croaker	*Pseudosciaena crocea*	Native
鲵状黄姑鱼	Cuneate drum	*Nibea miichthioides*	Native
眼斑拟石首鱼 *¤ (美国红鱼)	Red drum	*Sciaenops ocellatus*	From USA, 1991
真鲷¤	Red sea bream	*Pagrosomus major*	Native
黑鲷	Black sea bream	*Sparus macrocephalus*	Native
平鲷	Stumpnose bream	*Rhabdosargus sarba*	Native
笛鲷	Snappers	*Lutjanus* spp.	Native
胡椒鲷	Sweetlip	*Plectorhynchus* spp.	Native
大泷六线鱼	Fat greenling	*Hexagrammos otaki*	Native
黑平鲉	Black rock-fish	*Sebastes nigricans*	Native
牙鲆¤	Left eyed flounder	*Paralichthys olivaceus*	Native
漠斑牙鲆* （南方鲆）	Southern flounder	*Paralichthys lethostigma*	Introduced from USA,
夏鲆*	Summer flounder	*Paralichthys dentatus*	Introduced from USA
石鲽	Stone flounder	*Kareius bicoloratus*	Native
黄盖鲽	Marbled sole	*Pseudopriacanthus yokohamae*	Native
大菱鲆*¤	European turbot	*Scophthalmus maximus*	Introduced from UK, 1992
半滑舌鳎	Half-smooth tongue-sole	*Cynoglossus semilaevis*	Native
红鳍东方鲀¤	Red-fin puffer	*Fugu rubripes*	Native & introduced from Japan

* Exotic species introduced from other countries & zones.

¤ Main cultured species in large commercial scale

Annex 2 Summary on the characteristics of different cages

Items	FRC	HDPE	MFC	DFC	PDF	SLW
Anti-wind (grade)	12	12	12	12	12	12
Anti-wave (m)	7	5	5	7	6	7
Anti-current (m/s)	≤0.5/0.5	≤1/0.5	≤1/0.8	≤1.5/1.7	≤1.0/1.2	≤1.5/1.7
Cubage rate (%)	＜50%	＜70%	＜70%	90%	80%	90%
Frame material	PP、PE	HDPE	steel	steel	steel	steel
Site installed	Semi-open	Semi-open	inshore	offshore	Semi-open	offshore
installation	easy	easy	easy	labored	easy	labored
maintain	labored	easy	easy	labored	easy	labored
harvesting	easy	easy	easy	labored	easy	labored
fishes	pelagic	pelagic	pelagic	pelagic	benthic	pelagic
cost	lower	even	even	higher	even	higher

FC: Floating rope cage; HDPE: HDPE circle cage; MFC: metal frame cage
DFC: Dish-formed cage; PDF: PDF submersible cage; SLW.