Marine fish cage culture in China

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INTRODUCTION

Cage farming began in late 1970s in the People's Republic of China, originally introduced in inland aquaculture and later in mariculture. In the late 1970s, Huiyang County and Zhuhai City, Guangdong Province succeeded in farming marine fishes including grouper and seabream in cages. It was the first trial of marine cage farming in China. In 1981 experimental farming expanded to a commercial scale. Almost all of the products were exported to China, Hong Kong SAR and Macao markets. In 1984 other counties and provinces (Fujian, Zhejiang) began the farming of marine fish in cages. According to a survey, the number of marine fish cages in three provinces (Guangdong, Fujian and Zhejiang) has reached over 57 000. More than 40 species of marine fishes (Table 1) were farmed.

Cage farming was artisanal during the early stages of development. The research and development (R&D) for modern cage systems took place only beginning in the 1990s, primarily in line with the development of culture techniques for marine fishes like red seabream (*Pagrus major*), Japanese seaperch (*Lateolabrax japonicus*), cobia (*Rachycentron canadum*) and croceine croaker (*Larmichthys crocea*). Its development has been rapid since the start of this century. Hence, the history of offshore cage culture is less than ten years.

The most-farmed fishes are bred in land-based hatcheries enabling seed supply to meet the demand of cage culture. For example, last year one billion fingerlings of croceine croaker were bred in Fujian and Zhejiang provinces, with Fujian Province accounting for 70 percent. However, seed of some species still have to be captured from the wild or imported. These include yellowtail amberjack (*Seriola lalandei*), greasy grouper (*Epinephelus tauvina*) and others.

The total number of marine cages of different models has reached one million. The marine cages are distributed along China's coastal provinces – Liaoning, Shandong, Jiangsu, Zhejiang, Fujian, Guangdong and Hainan provinces, and the Guangxi Zhuangzu Autonomous Region. About 3 000 are offshore cages. The output from cage culture was about 200 000 tonnes in 2005.

Inshore cage culture is facing three problems:

- there is not enough space for further expansion;
- the cages cannot withstand typhoons, so that the security of fishermen's lives and property is threatened by this annual disaster; and
- inshore cage farming causes severe environmental pollution through fish metabolites and residuals (e.g. trash fish), inducing outbreaks of disease and parasitic infections. Thus offshore cage culture promises to be a better option.

TABLE 1
Economically important fishes reproduced in hatcheries in China

Chinese name	English name	Scientific name	Origin
鲻[1]	Flathead mullet	*Mugil cephalus*	Native
梭鱼[1]	So-iuy mullet	*Mugil soiuy*	Native
鲈鱼[1]	Japanese seaperch	*Lateolabrax japonicus*	Native
遮目鱼/虱目鱼	Milkfish	*Chanos chanos*	Native
军曹鱼，海鲡	Cobia	*Rachycentron canadum*	Native
尖吻鲈[2]	Barramundi	*Lates calcarifer*	Native
赤点石斑鱼[1]	Hong Kong grouper	*Epinephelus akaara*	Native
青石斑鱼[1]	Yellow grouper	*E. awoara*	Native
锐首拟石斑鱼 (驼背鲈/老鼠斑)	Humpback grouper	*Cromileptes altivelis*	Native & introduced from Malaysia
大黄鱼[1]	Croceine croaker	*Lamichthys crocea*	Native
鮸状黄姑鱼	Amoy croaker	*Argosomus amoyensis*	Native
眼斑拟石首鱼 [1,2] (美国红鱼)	Red drum	*Sciaenops ocellatus*	Introduced from USA
真鲷[1]	Red seabream	*Pagrus major*	
黑鲷	Black seabream	*Acanthopagrus schlegelii schlegelii*	Native
平鲷	Goldlined seabream	*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 rockfish	*Sebastes pachycephalus nigricans*	Native
牙鲆[1]	Bastard halibut	*Paralichthys olivaceus*	Native
漠斑牙鲆[2] (南方鲆)	Southern flounder	*Paralichthys lethostigma*	Introduced from USA
夏鲆[2]	Summer flounder	*Paralichthys dentatus*	Introduced from USA
石鲽	Stone flounder	*Kareius bicoloratus*	Native
黄盖鲽	Marbled sole	*Pseudopleuronectes yokohamae*	Native
大菱鲆[1,2]	Turbot	*Psetta maxima*	Introduced
半滑舌鳎	Tongue sole	*Cynoglossus semilaevis*	Native
红鳍东方鲀[1]	Torafugu	*Takifugu rubripes*	Native & introduced from Japan

[1] Main cultured species raised on large commercial scale.
[2] Exotic species introduced from other countries & zones.

Developing offshore cage farming is a new way to provide employment for people switching from fishing to aquaculture. From 2003 to 2010, an estimated 300 000 fishers are expected to leave their boats and look for other jobs. Offshore cage farming creates an opportunity for them.

The Chinese government and relevant authorities strongly support the development of offshore cage farming, both in policy and financing. Since the beginning of the twenty-first century, six types of offshore cages have been developed and extended in coastal provinces. They are the HDPE circle cage, the metal frame cage, the floating rope cage, the dish-formed submersible cage, the PDW submersible cage and the SLW rotatable and submersible cage. Developing offshore cage farming can create significant socio-economic impacts. The short-term target of offshore cage culture is that marine fish farming will become a major sector in China's aquaculture industry. The projected output of cultured marine fishes is around 500 000 tonnes by 2010.

PRESENT STATUS OF MARINE CAGE CULTURE

Traditional cages

Configuration, model, quantity and distribution

Traditional cages still account for the majority of marine cages. The total quantity is about one million, distributed along the coastal provinces of China. These cages are at an artisanal level; the configuration and the design are small (normally 3x3 m to 5x5 m in size, with nets of 4–5 m in depth), simple (square in form) and rough (Figure 1). The materials used for these cages are collected from the local market and include bamboo, wooden boards, steel pipes and polyvinyl chloride (PVC) or nylon nets. Most inshore cages are made by the farmers themselves to save investment cost and are easy to manipulate. These cages, however, cannot withstand waves and winds caused by typhoons and swift sea-currents; they have to be installed in inshore waters and sheltered sites. In some locations, the cages are connected together to form a big floating raft and crowded into small inner bays (Figure 2).

FIGURE 1
Traditional cages, simple and roughly constructed

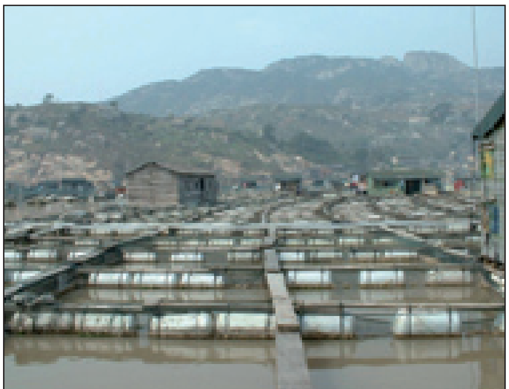


FIGURE 2
Shallow fish cages crowded in inshore waters

Most of the cages are distributed in Fujian, Guangdong and Zhejiang provinces, which account for 80 percent of total number of marine cages in China (Table 2).

TABLE 2
Number and distribution of traditional cages

Year	Location	Number of cages
1993	Guangdong, Fujian, Zhejiang	57 000
1998	All coastal provinces	200 000
2000	All coastal provinces	Over 700 000[1]
2004		1 000 000
Distribution:	Fujian	540 000
	Guangdong	150 000
	Zhejiang	100 000
	Shandong	70 000
	Hainan	50 000
	Other provinces & zones	100 000

[1] Of which 450 000 in Fujian Province

The reasons for rapid extension

Along with the Chinese open door policy, economic development has stimulated the demand for aquatic products, especially live marine fishes. The soaring price of marine fish in the 1990s further accelerated the extension of marine cage culture. Figures 1 and 2 show a farm located in Luoyuan Bay, Fujian Province. In 1990 there were less than 1 000 cages in the bay, but during the highest period (late 1990s), the number of cages in this area reached 60 000. At that time, the price of farmed live marine fish such as red seabream was about US$6 per kg with a production cost of only US$2 per kg and thus a profit margin of 200 percent. No doubt this high profit margin was one of the main factors expediting the expansion. It is a typical example showing the development of inshore cage farming in China.

Problems with traditional cages

As traditional cages cannot withstand high waves and winds caused by typhoons and fast currents, they have to be installed in inshore waters or sheltered sites. A lot of cages in inshore waters cause problems, the foremost of these being pollution caused by metabolites of fish and residual feed. With a series of cages blocking the inner bay, the reduced current and water exchange will lead to metabolites and residual feed accumulating on the seabed. One investigation showed that the accumulated waste in some severely affected locations was as high as one meter or more. Eutrophication, disease outbreaks and lower quality of farmed fish are the result, while poor seawater quality jeopardizes other farmed animals like oyster and scallop and may cause occurrences of red tide. The losses caused by diseases and red tides have been placed at US$10 million annually. In addition, the vulnerability to typhoons causes severe economic loss. For example, the direct financial losses caused by typhoon “Chebi” on Fujian Province in 2001 reached US$150 million.

Facing up to this severe situation, China’s government and relevant authorities have actively encouraged farmers and investors to develop offshore cages. Beginning in the late 1990s, offshore cages have been introduced from developed countries including Norway, the United States of America and Japan, while R&D of offshore cages has started in coastal provinces including Shandong, Zhejiang, Fujian and Guangdong. At present, there are about six types of offshore cages developed and installed in all coastal provinces and zones. The experiences suggest that some offshore cages can withstand typhoons, increase the output of fish with higher commercial value and minimize pollution, as well as gain higher income for fishermen.

The present direction in China is towards offshore cage culture becoming a main form of marine culture in the near future, while inshore cages will be used for nursing to supply large fingerlings for stocking into offshore cages or release into the open sea for sea ranching.

DEVELOPMENT OF OFFSHORE MARICULTURE CAGES

The development of offshore cages in China was initiated in the late 1990s. In 1998 the first offshore cages (four cages, 40 m and 50 m 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 the Chinese government and relevant authorities.

Importance of developing mariculture

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

In developing its oceanic fishing industry, China adheres to the principle of "speeding up the development of aquaculture, purposely conserving and rationally utilizing offshore resources" and is actively expanding offshore aquaculture. Since the mid-1980s, China's mariculture has 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 and made efforts to conserve and rationally utilize off-shore space, so as to make the mariculture industry constantly adapt to the changes in the marine fisheries structure.

Since the 1990s, the Chinese government has been carrying out a series of comprehensive reforms and new policies in the fishery sector, the following of which are relevant to mariculture:

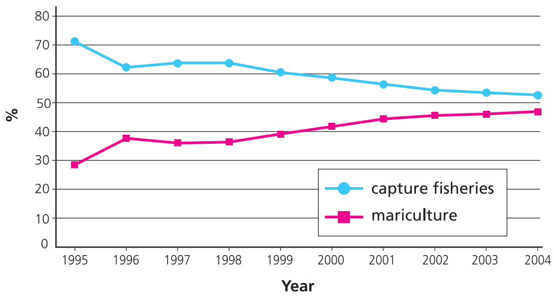
- Since 1995, China has practiced a midsummer moratorium system. Every year during July and August fishing is banned in the sea areas north of 27°N latitude. The new system has achieved encouraging economic, ecological and social results, and as of this year the midsummer moratorium area will be expanded to 26°N latitude and its duration will be lengthened to three months.
- A policy of carrying out "zero gain" of marine capture fisheries from 1999, and putting "minus gain" into practice in future years will be implemented.
- A total of 30 000 fishing vessels of various types will be removed from the fishery between 2003 and 2010; and more than 200 000 fishermen will have to leave their fishing vessels and obtain new jobs, including work in the mariculture subsector.

The purpose in implementing these new policies is to establish sustainable fisheries through protecting marine resources and by means of mariculture and sea ranching. The performance so far has been significant; for example, the landing volume from the sea was 2.356 million tonnes in 1995, among which the output from mariculture accounted for only 28.7 percent (4.1 million tonnes). However, this situation has been gradually changed; the proportion derived from marine culture has continuously increased such that the landing volume from mariculture reached 47.6 percent (13.1 million tonnes) in 2004 (Table 3 and Figure 3). It is believed that mariculture will become the major contributor to total marine output in the near future. The gain from the marine fishery will shift from marine capture to mariculture. Developing offshore cages has consequentially become a priority project of the Chinese government and investors.

TABLE 3
The proportion of mariculture and marine capture in the total output of marine fisheries in China, 1995–2004

Year	Total output of marine fisheries	Marine capture		Mariculture	
		Output	% of total marine fisheries output	Output	% of total marine fisheries output
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

Figure 3
Proportion change between marine capture fisheries and mariculture, 1995–2004



Government financial support

Developing offshore cage culture needs high investment and entails high financial risk. Individual farmers are hardly able to bear the expenses for developing offshore cages and the risk. The Chinese government and the provincial authorities therefore strongly support the project. It is estimated that the investments from different sources have reached more than US$10 million. For example, 20 projects dealing with offshore cages have been granted and have obtained as much as 20 million Yuan in financial support in the last five years. In addition, since 2001, Zhejiang, Fujian, Guangdong, and Shandong provinces have arranged special funds (more than 50 million Yuan) for developing offshore cages. The funds are partially for R&D, while directly supporting fishermen to buy offshore cages. This financial support and favourable policies promote the development and extension of offshore cage culture.

TABLE 4
Quantity and distribution of offshore cages in China[1]

Model	Zhejiang[2]	Shandong	Fujian	Guangdong	Other provinces	Total
HDPE circle	640	495	488	60	100	1 800
Floating rope	1 083	-	-	150	-	1 300
Dish-formed submersible	13	-	-	-	-	13
Other	51	110	-	-	100	180
Total	1 787	605	488	210	200	3 293

[1] Cage volume: >500 m^3.
[2] The figure for Zhejiang Province is from the first half of 2004; data for other provinces are the latest available.

According to incomplete survey data, about 3 300 offshore cages of different models have been installed in the coastal provinces, of which 1 800 are plastic hose (high-density polyethylene, HDPE) circle cages (floating and submersible) distributed in Zhejiang, Shandong, Fujian and Guangdong provinces and another 1 300 are floating rope cages installed in Zhejiang, Guangdong and Hainan provinces (Table 4).

Models and features of offshore cages

There are six offshore cage models developed. They are:

- HDPE floating circle cage (Figure 4a and 4b);
- Metal frame gravity cage (Figure 5);
- Floating rope cage (Figure 6);
- Dish-shape submersible cage (Figure 7);
- PDW submersible cage (Figure 8); and
- SLW submersible cage (Figure 9).

High-density polyethylene (HDPE) floating circle cage

The HDPE cage is based on the Norwegian design that was introduced into China (Figure 4). It is simple and easy to manufacture, and relatively low cost compared to others. The results indicate that although these cages cannot withstand typhoons, they are much better than traditional cages. The cage consists of net frame, nets, and anchoring system. The frame is made of high-density polyethylene (HDPE) and the nets are made of nylon. The cage performs well in the open sea with 20–40 m water depth. For example, in 2003 two cages were used to farm Japanese perch (*Lateolabrax japonicus*) and rockfish (*Sebastes schlegelii*). The stocking density of both species was 10 000 fingerlings (10 fingerlings per m^3) per cage. The survival rate was more than 80 percent after one-year grow out; the harvest reached 4–5 tonnes for each species. Although this is not high enough, the higher survival rate, the reduced use of chemicals and the lower energy costs meet the demands of farmers. The disadvantage of this type of cage is its lower ability to resist water currents. When the current velocity reaches 0.5 m/sec, the nets will swing up and down; at 1.0 m/sec, the effective volume of the cage will be reduced by 60 percent. This seriously influences the cage safety and causes stress to farmed fish. Technical parameters of the HDPE cage are listed in Table 5.

FIGURE 4a
HDPE floating circle cage

FIGURE 4b
Inauguration of a HDPE floating cage

The first kind of cage cannot withstand typhoons; therefore, submersible cages have been devised for installation at sites subject to typhoons. The basic structure is similar, except that before a typhoon arrives it can be submerged 4–10 m beneath the sea surface within 8–15 min, and it is easy to refloat it to the surface within 3–13 min after the typhoon has passed.

The cage can be installed in the open sea of 15 m depth and thus is suitable for China's shallow sea. Importantly its cost, which is about US$15 per m^3 (effective volume inside of cage), is about 40 percent that of imported cages.

TABLE 5
Technical parameters of the HDPE cage[1]

Model	Circumference (m)	Capacity against wind (km/hr)	Capacity against wave height	Capacity against sea current (m/sec)
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

[1] Diameter of HDPE pipe: φ200~φ315mm; density of HDPE: φ=0.95g/cm^3, intensity of HDPE: $φ_s$ = 24MPa.

Metal frame gravity cage

Metal frame gravity cages have various forms, such as rectangular or circular, and may be floating or submersible (Figure 5). Except for the cage material used, which is different from that used for the HDPE cage, the basic principle is the same. Between 2003 and 2004, two companies in Zhejiang Province introduced these cages from Japan. Their use in the open sea proved that the performance of the metal cage in swift currents is good, but that the metal nets are easily eroded by seawater. There are now about 30 metal cages (10x10x8 m) installed in the province.

FIGURE 5
Metal frame gravity cage

FIGURE 6
Floating rope cage

Floating rope cage

The floating rope cage was adopted from Japan in the 1970s and used by farmers in Taiwan Province of China. Since the 1990s, these cages have become widely used in Hainan, Guangdong and Zhejiang provinces (Figure 6).

It is a simple offshore cage that can also be used in inshore waters. It has a good capacity against strong winds (60–100 km/hr) and a lower cost that is welcomed by farmers. The size of a single cage is 6x6x6 m, and the total cage area can reach 1 000–2 400 m^3 when cages are linked together. The interval between two cages is 3 m.

The first attempt to farm cobia in Hainan Province was successful. A total of 11 871 fingerlings (0.75–1.0 kg/fish) were stocked in two cages. After four months, 8.6 tonnes of fish were harvested from the two cages. The largest fish to be harvested had gained 5.5 kg and was 80 cm in body length, while the smallest weighed 3.2 kg and measured 68 cm. The production cost was US$3.5/kg and the profit margin was US$2/kg.

Dish-shaped cage

The dish-shaped cage, which is similar to the “sea station” as it is called in the United States of America, was introduced from Ocean Spar Technologies in 2002 and installed in Shengsi County, Zhejiang Province (Figure 7). 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 it 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 years of practice indicates that the cage introduced from the United States of America is excellent against typhoons and high current velocities, but a crucial shortcoming is that its design makes it difficult to harvest the farmed fish. A new model of dish-formed cage that was devised by a Zhejiang company is welcomed by Chinese cage farmers in Zhejiang Province.

FIGURE 7
Dish-shaped cage
(made in Zhejiang Province, China)

PDW submersible cage

All cages mentioned above were introduced from other countries. However, the PDW cage was developed in China as independent intellectual property (Figure 8). The PDW submersible cage is specially designed for flatfish farming. Flatfishes such as flounder, sole, turbot and halibut have a high commercial value in international and domestic markets and are popular farmed fish in China. Normally they are cultured in indoor cement tanks and/or fiberglass containers with seawater that has to be pumped from the open sea. Hence, the production cost is much higher than that of cages. However, most of the cages mentioned above are not suited to the ecological habits of flatfishes, so the PDW submersible cage was designed for this special purpose.

In normal conditions it is submerged on the seabed. During maintenance, net exchange and harvesting, it can be floated to the surface; and it is thus easy for these operations. In order to provide a stable environment for farmed fish, the cage nets are held tight, providing a good habitat for flatfish. At the same time, the cage is separated into multiple-layers that increase the effective space for flatfish.

The experiences in Yantai Fisheries Research Institute, Shandong Province, have shown that the cage is good for farming flatfish (flounder and turbot). Founder fingerlings (*Paralichthys olivaceus* and *P. lethostigma*) of 50–100 g (live weight) were stocked; after six to eight months the body weight reached 800–1 000 g at a stocking density of 20 fish per m^2. During the experimental period, the cage withstood a typhoon attack with 90–100 km/hr wind velocity, 5 m wave height and 1 m/sec current velocity. The cage possesses strong ability against swift currents and waves due to being submerged on the seabed (Table 6).

TABLE 6
Technical parameters of the PDW submersible cage

Model	Effective surface range (m^2)	Diameter (m)	Ability against wave height (m)/ wind speed (km/hr)	Ability against seacurrent (m/sec)
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

FIGURE 8
PDW submersible cage, manufactured by Fishery Machinery and Instrument Research Institute (FMIRI), Shanghai, China

FIGURE 9
SLW submersible cage manufactured by Fishery Machinery and Instrument Research Institute (FMIRI), Shanghai, China

SLW cage

The SLW cage's special design is adaptable to the direction of current and to swift currents (Figure 9). Its technical parameters are given in Table 7. Its features include:

- one anchor fixed on the seabed always faces up to the current direction;
- easily moved to a new position for anchoring;
- strong capacity against current; when current speed reaches 1.5 m/sec, its effective volume is 95 percent or more; and
- a cage body that can run like a wheel, preventing bio-fouling and allowing easy exchange of nets.

TABLE 7
Technical parameters of the SLW submersible cage

Model	Effective surface (m^2)	Length x diameter (m)	Capacity against wave height (m)/wind speed) (km/hr)	Capacity against seacurrent (m/sec)
SLW 400	400	16 x 6.5	5/100	1.5
SLW 1000	1 000	20 x 10	5/100	1.5
SLW 2000	2 000	25 x 12.5	5–7/100	1.5

The characteristics of all offshore cages discussed above are shown below in Table 8.

TABLE 8
Summary of the characteristics of different offshore cages

Item	FRC[1]	HDPE	MFC	DSC	PDW	SLW
Anti-wind (grade)	12	12	12	12	12	12
Anti-wave (m)	7	5	5	7	6	7
Anti-current (m/sec)	≤0.5/0.5	≤1/0.5	≤1/0.8	≤1.5/1.7	≤1.0/1.2	≤1.5/1.7
Frame material	PP, PE	HDPE	steel	steel	steel	steel
Site installed	semi-open	semi-open	inshore	offshore	semi-open	offshore
Installation	easy	easy	easy	laboured	easy	laboured
Maintenance	laboured	easy	easy	laboured	easy	laboured
Harvesting	easy	easy	easy	laboured	easy	laboured
Suitable fishes	pelagic	pelagic	pelagic	pelagic	benthic	pelagic
Cost	low	medium	medium	high	medium	high

[1] FRC: floating rope cage, HDPE: HDPE circle cage, MFC: metal frame cage, DSC: dish-shaped cage, PDW: PDW submersible cage, SLW: SLW submersible cage.

Development of associated facilities

Offshore cage culture is a complex system that involves much equipment, such as that for grading, harvesting, feeding, net-cleaning and maintenance, live-fish transportation, auto-monitoring and others. China's offshore cage farming is in a fledgling stage so that many operations can be considered as pilot activities. It is expected that offshore cage farming will also develop the input supply and equipment industries. There will be a big market for fishery facility manufacturers.

Fish species farmed in cages

There are about 30 species (Table 9) of fish to be farmed both in traditional and in offshore cages, but the prices of farmed fish differ between those farmed in inshore cages and offshore cages. The quality of fish flesh from offshore cages is much better than that from inshore cages. For example, the price of croceine croaker farmed in offshore cages is about US$8 or more per kilogram, which is almost double the price of the fish farmed in inshore cages. Thus, the return from offshore cage farming is much better than that from inshore cages.

TABLE 9
Economically important fishes farmed in cages

Species	Farmed region	
	Northern	Southern
Croceine croaker *(Larmichthys crocea)*		√
Red drum *(Sciaenops ocellatus)*		√
Cobia *(Rachycentron canadum)*		√
Grouper *(Epinephelus* spp.*)*		√
Japanese seaperch *(Lateolabrax japonicus)*	√	√
Rock fish *(Sebastodes fuscescens)*	√	
Fat greenling *(Hexagrammos otakii)*	√	
Red seabream *(Pagrus major)*	√	√
Black porgy *(Acanthopagrus schlegelii schelgelii)*	√	√
Derbio *(Trachinotus ovatus)*		√
Torafugu *(Takifugu rubripes)*	√	
Bastard halibut *(Paralichthys olivaceus)*	√	
Southern flounder *(Paralichthys lethostigma)*	√	√
Tongue sole *(Cynoglossus semilaevis)*	√	√
Turbot *(Psetta maxima)*	√	

Among the species grown in offshore cages are the croceine croaker, which is mainly farmed in Zhejiang and Fujian provinces, cobia and grouper which are raised in Hainan and Guangdong provinces, and some other species (torafugu, red seabream, red drum, etc.) that are bred in Shandong Province in the north and Fujian Province in the south of China. Notwithstanding the large number of marine species, it is difficult to select one or two candidates suitable for growing in northern provinces like Shandong, Liaoning and Hebei year round because the seawater temperature of these provinces is quite low in winter (around 1–2 °C) and quite high in summer (26 °C or higher). The wide fluctuation in seawater temperature makes it difficult for certain species. For example, in the northern provinces most farmed fishes cannot be farmed over winter in the open sea and must be moved to indoor tanks if they cannot attain commercial size. In this case, genetic improvement is a priority project for developing cage farming.

TECHNICAL ISSUES IN DEVELOPING OFFSHORE CAGES

The history of developing offshore cages is less than ten years. As a young industry, there remain many technical issues to be resolved. These include:

- increasing the ability of cages to withstand strong seacurrents and retain their effective volume;
- developing cages that are better suited to the sea conditions in different regions and to different species, for example, in the north for flatfish and in the south for croceine croaker, cobia and grouper;
- producing associated facilities and equipment, including machines for feeding, grading, net-cleaning, auto-monitoring, antifouling, harvesting, etc.;
- studying new antifouling compounds to replace imported compounds for which the cost is too high to be accepted by farmers;
- developing stronger artificial fibers like super-high molecule polyethylene for stronger cage-nets;
- developing effective formulated feed to replace the trash fish that is still widely used in some cage-farming zones (Figure 10), causing water pollution and waste of aquatic animal protein (formulated feed has been used in aquaculture for 30 years, but is not widely used in marine cage culture);
- implementing healthy farming practices as a priority project in China, including the urgent development of vaccines; and
- breeding new varieties that are suitable to offshore cage farming.

FIGURE 10
Farmer carrying trash fish used for feeding farmed fish

GOVERNMENT POLICY FOR DEVELOPING CAGE CULTURE

It is a priority to develop offshore cage farming in Chinese mariculture. For example, Shandong, Zhejiang and Guangdong provinces have plans to install 10 000 offshore cages inside the 40m isobath; Fujian and Hainan will have 5 000 cages each by 2010; while Liaoning, Hebai, Jiangsu and Guangxi provinces are also planning to increase the number of offshore cages in the near future. By 2010 the total quantity of fish landed from offshore cages is projected to reach about 500 000 tonnes; and some 100 000 people will be employed in offshore cage farming.

Offshore cage farming is an important source of employment for fishermen who have been transferred from fishing to other jobs. China’s capture fisheries resources have been declining, and according to conventions between China and the Republic of Korea, China and Japan, and China and Viet Nam, about 30 000 fishing vessels have to leave their traditional fishing grounds. Therefore, about 300 000 fishermen will have to be gradually transferred to other jobs from 2003 to 2010.

Promoting sustainable development of the fishery industry is a strategic move. Rationally exploiting the offshore zone (inside the 40m isobath) is important because there is no room for further development in inshore waters.

It is necessary to meet the demand of an increasing population. In 2030 the Chinese population will reach 1.6 billion. In accordance with the consumption level of 38.7 kg per capita in 2004, the additional requirement for fisheries production will be 1.16 million tonnes. Furthermore, the world market needs more quality fish. Therefore, developing offshore cage farming is an effective way to achieve the two goals of maintaining per capita consumption and earning money from exports. Experts estimate that by 2035, the global output from aquaculture will reach only 62 million tonnes. If a 1 percent increase in consumption is assumed, the demand would be 124 million tonnes. FAO reports that the landed volume of marine fish from mariculture is only 4 percent of the total volume of fisheries. In this regard, there is an increasing demand for marine fish, not only in domestic markets but in the global market as well. Developing offshore cage farming is, therefore, an answer to meet this demand.

MANAGEMENT OF OFFSHORE CAGE CULTURE

Routine management starts from stocking and requires daily observation. Management includes feeding, grading, cleaning or exchanging fouled nets and routine recording. Paying attention to routine management guarantees a good result. Management of offshore cage culture should give attention to the following aspects.

Site selection for offshore cage farming

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

- a depth of more than 10 m and less than 30 m;
- a seabed that is plain, open tideway, mud-sandy substratum or rocky bottom;
- a current velocity of 50–100 cm/sec;
- a seawater surface temperature of 8–28 °C (optimum temperature is 18–26 °C);
- a pH of 7.8–8.6;
- DO of >5 mg/liter;
- transparency of >50 cm; and
- other conditions in accordance with seawater standards for fishery.

Cage layout

- The acreage of offshore cages should be less than 10 percent of the total farming area.
- The direction of cage layout should correspond to the direction of the sea-current.
- The arrangement of cages should be that two groups of cages are installed in parallel; the interval between the two groups is 80–100 m and the interval between the two lines of cages should be more than 50 m.

Species selection

- Candidate species for offshore cage farming should have basic requirements that match the conditions of the receiving environment (e.g. seawater temperature, salinity);
- Fingerlings should be quarantined before stocking (specific pathogen free (SPF) and healthy fingerlings are needed);
- The seed should come from qualified hatcheries and possess good genetic characteristics.

Stocking requirements for fingerlings

- The fingerlings should be healthy and vigorous.
- They should be free from parasites and other diseases.
- They should be graded for size and consistent weight (a weight per fingerling of more than 100 g will guarantee the survival rate and grow-out to commercial size during the culture season).
- The stocking density should be 30–50 individuals per m^3 or 20 fingerlings per m^2 for flatfishes (yield is about 20 kg/m^3 depending on species).

Feed and feeding

- Feed is a vital factor; trash fish has been used in large quantities because it is cheap and easy to buy in local markets; however, it is a source of disease. Normally, the food conversion ratio (FCR) is about 6 to 8 if using trashfish.

- It is a priority to develop high-quality formulated feeds.
- Automatic feeding systems are not widely adopted; judgment of feeding requirements based on visual observation is common at most farms. Normal feeding frequency is one to three times per day, the quantity fed depending on ambient conditions such as temperature, current, turbidity, waves, etc.

SOCIAL AND ECONOMIC IMPACTS OF OFFSHORE CAGE FARMING

Developing offshore cage farming has created social and economic impacts.

- There is a need to expand the space used for mariculture without occupying precious land and consuming freshwater.
- The eutrophication of seawater and the release of pollutants harmful to the environment and to the farmed fish themselves need to be reduced so that offshore cage farming is an environmental friendly system.
- The improvement of design and materials used in cages greatly increase their abilities to withstand typhoon and swift currents (Table 10). Hence the security of marine cage farming has reached a new level that brings improved benefits to farmers and investors.
- The development of offshore cage culture augments the employment for fishermen who have lost jobs in the capture fishery.
- Developing offshore cage culture brings new opportunities for the manufacture of offshore cages and equipment for monitoring, grading, feeding, etc.

TABLE 10
Comparison of economic effect between inshore and offshore cage culture

Items	Traditional cage culture	Offshore cage culture
Survival rate of fish (%)	70%	> 90%
Cage volume (m^3)	< 100	> 1000
Capacity against wind (km/hr)	< 100	> 110
Capacity against current (m/sec)	< 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)	about 5	> 20
Ratio of input vs output	1:1.3–1.5	1:1.5–2.0

This review finishes with the words published in the "White Paper on the Development of China's Marine Programmes" issued in 1998 by the Information Office of the State Council of the People's Republic of China:

"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."

Developing marine cage farming is a long-term strategy in terms of mariculture; therefore, the increased attention to its development will continue for many years. Its social effects and environmental impacts will be far-reaching. Beyond all doubt, it is indispensable to consider how to improve the existing situation to make rational layout and scientific decision-making that will ensure a sustainable mariculture in China as well as for the world's fisheries.

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