AQUACULTURE RESEARCH AND ITS RELATION TO DEVELOPMENT IN CHINA

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ABSTRACT

China has a long history in aquaculture that goes back 2500 years. However, key advances followed the artificial breeding of carp in the 1950s. This chapter focuses on the development from the 1980s to the present, discussing the major issues in the developments, current and future trends and challenges, and the roles of Shanghai Fisheries University and the WorldFish Center in addressing these concerns.

STATUS

Dramatic development since 1980s

The history of fish farming in China goes back at least 2500 years, and it has long held prominence in the rich Chinese civilization. But it was only after the 1950s that aquaculture has been rapidly developed. The breakthrough in the artificial breeding of the silver carp, bighead carp and grass carp achieved from 1958 to 1960 changed the traditional practice of collecting wild fry from the rivers. Meanwhile, in the 1960s Chinese scientists summarized the experience of Chinese freshwater fish culture into "eight words"; "water, seed, feeds, density, polyculture, rotation, disease, and management". These two events ushered in a new era in which freshwater fish culture in China has shifted from empirical practices to a science-based technology. Aquaculture development has been dramatic from the 1980s, when the open-policy and economic reformations were adopted. In 2000, China's aquaculture reached 25.78 million tons, 60 per cent of the country's total output of fisheries

Pond culture is the most important practice contributing to total aquaculture production from freshwaters. Pond culture has an estimated share of 60 to 70 per cent of total freshwater aquaculture production, in which Taihu Lake area in the Yangtze River Delta and Zhong-Nan-Shuan area in the Pearl River Delta are the traditional centers of fish culture. Culture in open-waters (lakes, reservoirs, channels) and in paddies contributes most of the remaining output. The most commonly farmed species are silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Aristichthys nobilis*), grass carp (*Ctenopharyngodon idellus*), black carp (*Mylopharyngodon piceus*), common carp (*Cyprinus carpio*), crucian carp (*Carassius auratus*), blunt snout bream (*Megalobrama amblycephala*), mud carp (*Cirrhina molitrorella*), mandarin fish (*Siniperca chautsi*), Japanese eel (*Anguilla japonica*), river crab (*Eriocheir sinensis*), Japanese prawn (*Macrobrachium nipponensis*), and soft-shelled turtle (*Trionyx sinensis*). Species introduced from abroad are also cultured such as tilapias (*Oreochromis niloticus*), rainbow trout (*Onchorhynchus mykiss*), channel catfish (*Ictalurus*

Table 1. The share of total fisheries production provided by aquaculture in China.

Year	1960	1970	1975	1980	1985	1990	1995	2000
Share from aquaculture (%)	17.4	25.2	23	27	32	50	54	60

punctatus), largemouth bass (*Micropterus salmoides*), and giant prawn (*Macrobrachium rosenbergii*).

In marine and brackish waters, prior to 1980, the cultured species were mainly kelp (*Laminaria japonica*), porphyra (*Porphyra* spp.) and shellfish (*Ostrea* spp., *Mytilus* spp.) which accounted for 98 per cent of the total marine culture output. Since the 1980s, the Government has been giving full support to multi-species marine cultivation, ranging from shrimp (*Penaeus monodon*) to scallop (*Argopecten* spp.), to valuable species of fish. In 1992, China was the largest producer of cultured shrimp in the world (220 000 t) but experienced a major setback after 1993 due to the outbreak of disease. Ecological principles are now being introduced in marine culture. A successful example is polyculture of bivalves with seaweed, which is practiced successfully in north China. Water-based farming, such as sea-cage culture, is becoming popular in south China for big yellow croaker (*Pseudosciaena crocea*), grouper (*Epinephelus* spp.) and sea breams (*Pagrosomus* spp.), and land-based farming, such as tank culture for flounder (*Paralichthys olivaceus*), and turbot (*Psetta maxima*) is becoming popular in north China, since these systems are very profitable.

From 1949 to 1999, particularly from 1978, through the adoption of a smart open policy and scientific advancement, Chinese aquaculture has entered its most flourishing stage in history with impressive achievements and a dramatic increase of aquaculture production. Total aquaculture production increased from 1.60 million tons in 1978 to 25.78 million tons in 2000. The relative contribution (percentage) of aquaculture production in total fisheries production has also been increased concomitantly from 27 per cent in 1978 to 60 per cent in 2000 (Table 1).

Major issues for development

1. **Exploitation of waters and lands**
   Since 1978, the area of ponds, lakes, reservoirs, and marine areas used for aquaculture has steadily increased. In 1999, the farming area reached 7.75 million ha (Table 2), a threefold increase from 1978.

2. **Movement of labor to aquaculture from agriculture/capture fisheries**
   The development of aquaculture has become a part of the strategy for rural, social and economic

Table 2. Extent (area and percentage) of water resources used for aquaculture in China (1999).

Types	Total usable area (X 10^3 ha)	Used in 1999 (X 10^3 ha)	Percentage Used
Brackish/Marine	9 360	1 095	12
Mud flats	797	630	79
Bays	1 800	201	11
Shallow seas (Water depth <15m)	6 763	263	4
Inland	6 935	5 195	75
Ponds	2 145	2 145	100
Lakes	2 150	911	42
Reservoirs	1 884	1 610	85
Waterways	756	375	50
Others		154	
Paddy fields	6 867	1 464	21

Table 3. Changes in labor in culture and capture fisheries in China.

Year	Full time				Part time	Total
	Capture	Culture	(Service sector)	Sub-total		
1978	859 825	524 824		1 384 649	1 016 559	2 401 208
1980	861 276	718 317		1 579 593	1 370 751	2 950 344
1982	918 613	748 063		1 666 676	2 158 682	3 825 358
1984	1 031 279	805 177		1 836 456	3 277 354	5 113 810
1986	1 154 607	1 454 530		2 609 137	4 698 520	7 307 387
1988	1 253 556	1 572 009		2 825 565	5 715 158	8 540 723
1994	1 609 291	2 661,344		4 270 635	6 103 407	10 374 042
1996	1 776 016	3 074 418		4 850 434	6 779 822	11 630 256
1998	1 875 183	3 420 533	(634 886)	5 295 716	6 444 213	11 739 929
2000	1 861 942	3 722 349	(702 561)	5 584 291	6 648 837	12 233 128

Service sector labor is not included in sub-total and total

Table 4. Average yield of different types of aquaculture in China (kg/ha) from 1980 to 2000.

Types	1980	1985	1990	1995	2000	2000/1980 (fold increase)
Freshwater						
Pond	765	1 395	2 385	3 742	4 899	6.4
Lake	150	256	435	710	1 043	6.9
Reservoir	90	150	435	538	922	10.2
Channel	345	525	795	1 337	1 756	5.1
Paddy				265	487	
Brackish/Marine						
Finfish	150	315	915	1 188	5 507	36.7
Shrimp	285	690	1 275	343	986	3.5
Molluscs				3 773	10 600	
Seaweeds				17 224	21 464	

Table 5. A summary of the stages reached in the artificial reproduction and nursing of cultured freshwater species.

Groups	No of species	Artificial propagation level			Nursing level		
		Completed propagation*	Half completed propagation**	Not succeeded	In large scale***	In small scale****	Not succeeded
Fish	59	45	7	6	38	15	5
Crab, prawn	3	3			3		
Molluscs	2	2			2		
Turtle	1	1			1		

** Whole life cycle can be controlled artificially*
***Brooders are collected from wild population*
**** Production volume can be managed to provide as many as needed*
***** Production volume is restricted technically*

Table 6. A summary of the stages reached in the artificial reproduction and nursing of cultured brackish/marine water species.

Groups	No of species	Artificial propagation level			Nursing level		
		Completed propagation	Half completed propagation	Not succeeded	In large scale	In small scale	Not succeeded
Fish	21	21			7	14	
Crab, prawn	8	8			7	1	
Molluscs	9	9			9		
Seaweeds	8	8			8		
Others	2	2			1	1	

Table 7. Approximate numbers of fry produced by artificial propagation.

Species/groups	1995	1999	2000
Freshwater fish (billion fry)	278.00	592.00	602.00
Marine fish (billion fry)		2.00	3.90
River crab (billion larvae)	9.50	3.80	4.70
Shrimp (billion larvae)	33.00	51.90	58.30
Scallop (billion seeds)	6.90	100.00	175.30
Kelp (billion ind.)	9.00	6.90	15.50
Pophyra (billion shells)		0.28	0.22
Soft-shelled turtle (billion larvae)		0.60	0.30
Abalone (billion larvae)		0.90	1.00

development, for example, to provide employment and to absorb the laborers released following agriculture reformation and poverty alleviation. With more labor input, aquaculture expanded from the traditional aqua-farming provinces, such as the Pearl River Delta in the south and the Yangtze River Delta in the east, into north-eastern, western, and northern regions of China. By 1990, over 2 million people had been attracted to aquaculture from agriculture and other industries. In the 1990s, the trend increased still further. Total fishery (aquaculture and capture) labor in 2000 reached 18.6 million, in which full-time employment in the aquaculture sector reached 3.7 million, a seven-fold increase over 1978 levels (Table 3).

3. Improvement of techniques and yield

The yields from aquaculture have increased from 3.5 to 36 times from 1980 to 2000 depending upon the species and type of culture concerned (Table 4) through technological developments and their extension. For instance, the national average yield of fish ponds increased from 765 kg/ha in 1980 to 4899 kg/ha in 2000, i.e. some 6.4 times.

It is estimated that scientific advances have stimulated the growth of aquaculture by about 42 per cent. For instance, most of the species that are farmed now have been artificially reproduced (Tables 5 and 6) and huge amounts of fry and fingerlings have been nursed to meet the seed

Table 8. Increasing trends of farmed species in China.

	Fish	Molluscs	Crustaceans	Seaweeds
1960s	> 10	< 5	–	< 5
1990s	> 60	> 20	> 10	> 10

Table 9. High value species production in China (X 10^3 tons).

Species	1992	1993	1994	1995	1996	1997	1998	1999	2000
Eel	80.0	78.6			147.0	67.0	160.0	164.0	161.0
Shrimp	30.0	55.0	35.0	78.0	89.0	103.0	140.0	170.0	218.0
Giant prawn			14.5	25.7	37.4	42.8	61.8	79.0	97.0
Soft-shelled turtle		4.4	9.4	17.5	32.0	44.0	61.8	76.7	92.0
River crab		17.5	31.2	48.0	52.6	95.0	123.0	172.0	232.0
Mandarin fish		17.6	28.0	37.5	58.4	68.1	83.1	89.4	99.0
Scallop				920.0	1 000.0	1 001.0	630.0	712.0	919.0

Table 10. Growth in volume and value of popular species and high value species in China between 1995 and 2000.

	Popular species	High value species
1995		
Volume (%)	98	2
Value (%)	85-90	10-15
2000		
Volume (%)	90	10
Value (%)	70	30

Table 11. Change in the production and percentage composition of popular species/groups in freshwater aquaculture between 1978 and 2000.

Species (groups)	Production (X 10^4 tons)				Percentage (%)			
	1978	1998	1999	2000	1978	1998	1999	2000
Silver and bighead carp	53	470.0	477.0	484.0	70	36	33.5	23.7
Grass carp	12	281.0	306.0	316.0	16	21	21.5	13.8
Common carp	5	193.0	205.0	212.0	7	15	14.4	9.9
Crucian carp	2	103.0	124.0	136.0	3	8	8.7	5.3
Tilapia	1	52.6	56.2	62.9	1	4	4.0	2.6
Breams	4	44.9	47.6	51.1	5	3	3.4	2.0
Black carp	2	28.0	17.3	31.6	2	2	1.2	1.3

demand (Table 7). Aquafeeds have been improved greatly and produced in greater quantities to meet the growing needs of aquaculture.

4. Diversification of farmed species

The traditional culture species such as carps, and exotic species, such as tilapias, continue to dominate production. However, in the past ten years, there has been greater efforts to diversify products to other high value species, such as mandarin fish, freshwater crabs and prawns, soft-shelled turtle, and eel in freshwaters; and shrimp, scallops, croaker, and flounder in marine waters (Table 8 and 9). This trend has changed the aquaculture volume/value proportion remarkably (Table 10 and 11).

5. **Diversification in the modes of farming**

Compared to the state of aquaculture in the1960-1970s, the modes of farming in aquaculture have been greatly diversified. The major systems can be categorized as follows:

a. *Polyculture systems*

Polyculture has a long history in China. It is believed that towards the end of the Tang Dynasty (about 1000 years ago), mixed culture of the four major Chinese carps (grass carp, silver carp, bighead carp and black carp) was already developed. Later on, crucian carp, bream, mud carp, tilapia, eel, and prawns were also incorporated. Polyculture has the major advantages of using fully the space and food available in the pond and maximizing the beneficial interactions among compatible species with different feeding habits and ecology. Generally there are one or two principal species cultured in large populations in ponds, and four or more compatible species cultured with them.

In the 1980s the polyculture principle was introduced into seaweed-bivalve culture in coastal areas.

b. *Integrated farming system*

China also has a rather long history of integrated fish farming. The integration of aquatic plant cultivation and fish farming was recorded as early as the second century BCE. In the ninth century CE, fish were reared in paddy fields. By the 17th century, mulberry-dike fishponds and the integration of fish and livestock farming was developed. Now, fish culture is closely integrated on a wide scale with conventional agriculture, such as crops, vegetables, animal husbandry and the processing of agriculture products. These systems are managed in a comprehensive way according to the attributes of the contributing components, for example, fish-crop integration, mulberry-dike fishpond, fish-livestock integration, fish-duck integration, and the integration of fish with commercial industrial pratices.

c. *Intensive culture systems*

Intensive culture has become a trend coupled with technologies such as formulated feed, water quality management, disease control and hatchery techniques. Examples include cage culture in freshwaters (lakes, reservoirs, and ponds) and seawater (mostly in bays), and land-based facilitated culture (outdoor and indoor tanks with recirculation systems).

The flourishing aquafeed production can be seen as one of the indicators of the rapid development of intensive culture.

Trends

Challenges of aquaculture in the 21st century

The Chinese population is predicted to rise from the present 1.2 billion to 1.6 billion by 2026. This will reduce further the per capita share of land resources for food production. Agricultural land per capita has decreased steadily from 0.19 ha in 1949 to 0.09 ha in 1995. The city population has rapidly increased; in 1995, the urban population was 352 million (30 per cent of total population). By 2010, the urban population will increase to 450 million, and become 35 per cent of the total population. The per capita GNP in 2000 was US$ 830, and it is expected to increase to US$ 1 200 in 2010.

These considerations – the rapid changes in population structure (city/rural) and rising living standards – have presented China with several challenges and opportunities to meet the rising demand for both low and high quality animal products, particularly aquatic products.

Table 12. Predicted production of aquaculture for 2005 and 2010 in China (X 10^4 tons).

	2000	2005	2010
Freshwater	1 517	1 700	2 000
Brackish/Marine water	1 061	1 300	1 500
Total	2 578	3 000	3 500

The decrease in wild marine fish stocks from traditional fishing grounds has focused policies on expanding aquaculture as a key strategy for meeting changing national demand and consumer patterns. In 1999, the Chinese Government decided to maintain a "0" increase in the production of marine capture fisheries. This has resulted in an historic opportunity for the development of aquaculture (Table 12).

More diversity of species structure

The diversity of species cultured will be even further increased with guidelines for incremental and stable increases in total production, aiming at high productivity, high quality, and high efficiency.

Greater consideration for aquatic food safety and security

A target for the future will be the extension of the HACCP management system.

Science and technology development

Generally, the progress of aquatic science and technology in China cannot keep up with production activity. There is great scope for research to facilitate further aquaculture expansion. For instance, research could support seed production and the domestication of certain economically important species; genetic improvement by means of selective breeding; nutritional improvement and the search for non-conventional protein sources; and improving farm management for making aquaculture operations more environmental friendly and more sustainable.

Constraints

Environmental carrying capacity

China today feeds 22 per cent of the world's population from 9 per cent of the world's arable land, and produces 67 per cent of aquaculture products from 27 per cent of the fresh and marine waters. China is a country with a shortage of freshwater. Environmentally sustainable production systems are urgently needed, namely water-saving, land-saving, feed-saving, and low-waste culture systems.

Red tides in coastal areas, flooding in major river systems, and sandy wind in north-west China are three major events happening more frequently. The pollution of the aquatic environment has caused public and Government concern.

The development of methodologies for conducting environmental impact assessments (EIA) of coastal aquaculture is urgently needed, as are protocols and guidelines for aquaculture zoning and environmental standards for aquaculture effluent and water quality.

Conservation of aquatic biodiversity and genetic improvement

China has a history of studies on fish genetics and breeding of less than 30 years. The application of genetic principles to aquaculture is far behind that of agriculture or animal husbandry. As a result, the contribution of the genetic component to aquaculture in China is rather weak compared with inputs from labor and resources. Estimates show that scientific research in genetics contributed only 10 per cent to the phenomenal aquaculture growth. The major achievements were the breeding of common carp (such as red common carps, jing common carp) and crucian carp (such as allogynogenetic silver crucian carp) in the early part of the 1980s, the gene engineering in the late 1980s, and the genetic conservation efforts started in the 1990s. They play an increasing role in the development of aquaculture in China. Most of the species cultured are still wild stocks, without genetic improvement. New genetically improved strains and varieties will pour new energy into the development of aquaculture.

Aquatic biodiversity in China is under extreme stress due to the high demand for fish and the rapid development of the aquaculture industry. Loss of biodiversity will severely limit the sustainable development of aquaculture and fisheries. Conservation of genetic resources will bring long-term benefits to the development of aquaculture in China and globally.

Urgent study is needed of the diversity of cultured species, genetic improvement, and genetic conservation.

Disease control

The outbreak of new diseases must be prevented effectively to raise the efficiency of the aquaculture industry. It is recorded that there are 400-500 kinds of aquatic diseases in China, and it is estimated that the loss to diseases was 15-20 per cent of the total production and over US$ 1 billion annually. New disease outbreaks have been occurring with the rapid development of aquaculture.

New technologies for disease diagnosis and early prediction are required together with the development of non-conventional disease control strategies, such as the use of probiotics and vaccines, instead of antibiotics. Quarantine technology and management systems, and aquaculture health management must be developed simultaneously.

THE ROLE OF SHANGHAI FISHERIES UNIVERSITY (SFU)

General introduction to Shanghai Fisheries University

Shanghai Fisheries University is a comprehensive multi-disciplinary and multi-level teaching university in fishery science in China. The University evolved from Jiangsu Provincial Fishery School, which was founded in 1912. After the vicissitudes of over 80 years, the university ran as a priority construction project of education directly under the Ministry of Agriculture (MOA) until March 2000. Since 2001, it is jointly managed by Shanghai city and the central Government.

The university has seven colleges (Fishery, Food Science, Engineering and Technology, Economics and Trade, Humanities and Basic Sciences, Computer Science, Continuing Education, and Higher Professional Technology), one information centre, one key aquaculture discipline (certified by the Ministry of Education and Shanghai Education Commission) one key laboratory for ecology and physiology in aquaculture (certified by the MOA), and one Ichthyology Research Laboratory which stores samples of most of the fish species in the Asia Pacific region. Moreover, the university has 14 experimental laboratories separately affiliated to the respective colleges and departments, two field work bases for mariculture and aquaculture, three fishing boats for student training and practice, machinery workshop, food processing plant, and refrigeration and cold storage plants for student practice as well as for production.

Since 1949 and the foundation of the People's Republic of China, the university has rapidly developed and trained over 10 000 graduates in the area of fishery science and technology, who are practising in the fields of fisheries, foreign trade, commerce, light industry, transportation, sanitary organisation as well as administration nation-wide. Many of them are now responsible for important technical tasks and hold leading positions at various levels in education, research, production and administration.

The university comprises 17 specialities for undergraduate students with a four-year schooling period conferring bachelorship, and 16 specialities for two-year short-cycle courses. As authorized by the State Degree Commission, the university is qualified to offer Doctoral degrees in fisheries science, including aquaculture science, fishing science and fisheries resources subjects, as well as 14 subjects that confer Masters degrees.

In addition to teaching, the university undertakes a large amount of research tasks in the field of fisheries science and technology for the country and for enterprises. In recent years many achievements have been registered. Amongst these, 70 achievements have been awarded national or provincial prizes, and 10 items have gained patent licenses.

As a result of the policy of reform and opening, great successes have been attained in technical cooperation and academic exchange. The university has concluded academic exchange agreements in fisheries science and technology with many universities and scientific research institutes in the countries of Japan, USA, Canada, UK, Republic of Korea, and Russia, to promote teaching quality and raise the level of scientific research. The university has played an active role in cooperation with FAO, UNESCO, Canadian International Foundation of Science, and Asian Fisheries Society, and received a great deal of information materials and funds from them.

Table 13. Job distributions of students graduating from the four-year aquaculture program from Shanghai Fisheries University between 1953-1999.

Total number	Education	Research	Administration	Production	Others
2 811	349	476	931	244	811
Percentage (%)	12	17	33	9	29

Brief introduction to the fisheries college (aquaculture)

The fisheries college was the earliest established Department of Aquaculture. At present, it has three disciplines: aquaculture science, water and environmental science and biotechnology. They cover aquatic animal physiology, aquatic genetics, breeding and biotechnology, aquatic animal health science, aquatic animal nutrition and feeds, aquatic animal genetic resources, intensive culture systems, ichthyology and fish ecology, marine algae bio-technology, and associated research.

This faculty has about 70 staff, including 19 full professors, (of which 6 are doctoral supervisors), as well as 20 associate professors. The faculty undertakes 39 research projects in collaboration with national and international institutions. Since 1952, more than 7 000 students have been trained, and students graduating with specializing in aquaculture are spread over the whole country in major education, research, administration and extension activities as well as production activities (Table 13). Some of them became cadres in policy making.

Expected roles of The WorldFish Center in China

The WorldFish Center has been identified as "The World Fish Center". Its logo consists of a hand holding a fish encircled with the words "People, Science, Environment, Partners". The fish is a symbol of all aquatic resources, including finfish, molluscs, crustaceans and aquatic plants. The hand represents the concern for these resources and the people who depend on them. The circle represents our holistic ecosystems approach. The blue and green colors represent the aquatic and rural environments.

The commitment of The WorldFish Center is "to contribute to food security and poverty eradication in developing countries" through research, partnership, capacity building, and policy; and to promote sustainable development and use of living aquatic resources based on environmentally sound management. I appreciate the above goals and commitment.

Since 1994, I have been honored to be involved in two cooperative projects with the Center, "The Dissemination of Genetically Improved Tilapia in Asia" (1993-1996) and "Genetic improvement of carp species in Asia" (1997-2000). Under these two projects, one PhD and one MSc student were trained in Shanghai. About 30 papers were published. One research award on tilapia was made by the Ministry of Agriculture. One new strain (bream) was produced and certificated by the Government as a good strain for aquaculture. I have been China's active member of the International Network on Genetics in Aquaculture (INGA), and we have received a lot of valuable ideas from the network. The cooperation with the Center is fruitful and significant.

We should consider that China is the largest developing country, the largest fisheries country both in capture fisheries and aquaculture, and has the largest population in poverty. So far the activity of the Center in China has been limited to a few research projects and a very few meetings actually held in China (noting however the meeting in November of 2000 in Beijing, when the Center convened a meeting with senior Chinese scientists through the China Society of Fisheries, and, in the same month the Center held the final workshop on genetic improvement of carp species in Asia, in Wuxi). On the other side, Chinese scientists play a small role in the Center's international activities so far, as indicated by the fact that there is no research/ program site in China, and no staff from China are resident at the Center's research/program sites or headquarters.

In order to strengthen and broaden the collaboration between China and The WorldFish Center, I would like to outline a few key areas amongst the many areas where things are needed:

1. **West China exploitation – Poverty alleviation through fish culture, an effective rural development strategy.** The Bangkok Declaration and Strategy on Aquaculture Development Beyond 2000 (NACA/FAO 2000) recognized that:

   > The practice of aquaculture should be pursued as an integral component of development, contributing towards sustainable livelihoods for poor sectors of community, promoting human development and enhancing social well-being.

   Experience gained in China during the last decades shows that development of aquaculture can make a significant contribution to better livelihoods and to alleviate poverty, both as specific interventions and as a component of integrated rural development.

   The causes of poverty are diverse depending upon local conditions. For example, an area is poor because of geographical isolation, limitations in land area for rice cultivation, poor communication and transportation infrastructure, poor public and extension services including heath and education, difficult access to market and credit services. Government policies and programmes do not reach these areas. The people in poverty areas usually have very little arable land, a harsh climate with high risk of natural calamities such as typhoons, flooding, and sand storms and aquatic resources are overexploited.

   In west China, the economy is much behind that of east China, and the west has most of the areas of poverty in China. Aquaculture is also less developed in comparison to the rest of China. The total aquatic production from 12 provinces in west China in 2000 was 3.58 million t, comprising just 8.4 per cent of the national total production (42.79 million t) (Table 12).

Case I: Guizhou province is a mountainous area with few flat fields. Planted land per capita is only 0.8 mu (1 mu=1/15 ha). From years of survey, it is found that the rice-fish culture system is an effective strategy to develop the rural economy. In 2000, this province produced 62 400 t fish, of which 21 900 t was from rice-fish culture. According to a survey (Ma 2001) in 2000, of 153 villages of 26 counties, where rice-fish culture was carried out, the advantages of the rice-fish culture system can be summarized as follows:

- Improvement of the environment: This was exemplified by the increase in the water storage capacity. One mu of rice-fish field can store 150 m^3 of water. The total water storage in 10 000 mu rice-fish field equals that of one small reservoir, with 1.5 million m^3 water storage. When the fish capacity is 100 kg/mu, rice yield can be increased 5-15 per cent. One year after fish culture, the content of N, P, and K in earth can be increased 57.7, 82.1 and 34.8 per cent respectively, thus improving the circulation of matter and energy, which is important for the sustainable development of agriculture.
- Increase in yields and improvements in the structure of agriculture: The average yield was: fish 120 kg/mu, rice 515 kg/mu, and income increased by RMB 500/mu. The composition of income was, crop 26.8 per cent, animal husbandry 24.0 per cent, and fish 27.2 per cent.

Table 12. Basic condition of aquaculture in West China compared with China as a whole.

	Population (billion)	Aquaculture production (million tons)	Aquaculture area (ha)	Water resources (billion m^3)
West China	–	3.58	756 000	1 500
Whole country	1.29	42.79	5 053 630	2 700

Source: Ma 2001

- Decrease the risk of production activity: Fish and aquatic products provide daily sustenance. When crop production fails, fish provides food and helps to buffer the loss of income.
- Improve the market: Farmers consider their rice-fish fields as a reservoir, bank, cereal store and source of fertiliser.

Case II: In Yunnan province, the Government carried out a rice-fish culture project as a poverty eradication strategy. In 2001, rice-fish fields covered 1.40 million mu, average fish yield was 22 kg/mu. In on-farm testing covering a total area of 24 693 mu, average fish yield reached 71 kg/mu, from which 417 village, 12 114 families and 51 115 persons benefited, the average income increased by RMB 273/person (Guidan 2001).

Case III: Ertix River basin fish culture and conservation. The Ertix is the only river running into the Arctic Ocean in China's territory in which there are some fish species typical of European fauna. For a thousand years, there were only capture activities, which caused the fish resources to collapse. From 2000, SFU has helped the local people to breed tinca, pike and river perch and produced thousands of fry to assist the local farming and activities in east China. It is expected the local fish breeding and culture will bring the local people a new industry to increase income.

Case IV: Oujiang color (red) carp is an ideal fish for the rice-field system. Oujiang color common carp has been cultured in paddies and backyard ponds for about 1300 years in the Oujiang river basin of Zhejiang province. In some villages, almost every family cultivates this fish in their own paddies, backyard ponds or channels and forms the main source of protein and provides pocket money on some occasions. In recent years, the preliminary genetic evaluation study conducted by SFU showed that the Oujiang color carp is ideal for rice-fish culture system and backyard fishponds. For example, in Longquan county of Zhejiang province, there are over 4 000 ha paddies which have been reformed into the rice-fish system in the year 2000.

2. Costal water utilization – development of deep-sea cage culture on a large scale?

It is recognized that the fisheries along China's coastal areas (Bohai Sea, Yellow Sea, East China Sea and South China Sea) have been in an over-exploited condition for many years. Recently, following negotiations held with South Korea, Japan and Vietnam, about 32 000 Chinese fishing vessels will be withdrawn from fishing. This means the loss of about 100 000 fishing jobs and will affect 300 000 peoples' livelihoods. From 2002 to 2004, the Government will invest RMB 2 700 million annually to help the fishermen to shift to new jobs, mainly aquaculture. The relevant authorities believe that the development of deep-sea cage culture is one of the major options. In Zhejiang province alone, it is planned to develop 5 000 deep-sea cages by 2003, and 10 000 by 2005.

Amongst developed countries, Norway and Japan are major practitioners of marine aquaculture. Norway produces approximately 400 000 t fish, mainly Atlantic salmon. As a carnivorous species, salmon require high protein and lipid feeds derived mainly from fish meal and fish oil. It is estimated that to culture 1 t salmon needs 5 t of such fish products. On this basis, the maintainence of a 1 m^2 cage requires 50 000 m^2 of fishing ground. Japan produces around 800 000 t of scallop, oyster, and yellowtail. Yellowtail is also a typical carnivorous fish, similarly requiring fish meal. In Norway, the waste from the salmon cage culture industry equals the living sewage of 4 million Norwegians. To address this problem, and to maintain the high benefit from cage culture in Norway, the development of the industry is under strict control. The lesson provided by the worldwide over-development of shrimp culture, with large-scale destruction of mangroves, requires that in the future the proper evaluation of the balance between the benefit from shrimp culture, and the environmental losses over time, is first undertaken. In China, a large proportion of the coastal waters has been used for aquaculture, and there is not much room left to set more cages. China's coastal area has few deep bays and islands to locate many cages and storms, particularly typhoons, are frequent. It is suggested that as well as the geo-physical problems, identification of suitable target species, their feed sources, and the subsequent pollution etc. have not been considered properly. "Do not drink poison wine to stop a current thirst".

3. **The ecological principle of "culturing down the food web"**
   For more than a thousand years, the Chinese have been using polyculture technology. Different species of fish are raised at different levels of the food web, in such a way that they complement each other. China also created integrated fish farming systems, combining fish culture with agriculture and animal husbandry. These two technologies provide a strategy to produce animal protein at a low cost for low income people, to maintain the sustainability of the development through environment-friendly approaches, and to produce healthy or "green" food (or ecological food) without residuals of medicine or drugs.

   Ecological principles have also been introduced into marine culture, and the polyculture of bivalves and seaweed is practiced successfully in northern China.

   Globally, the production of animal protein from capture fisheries is near its limits and land availability constrains the further development of some forms of agriculture. However, an annual population increase of eighty million means that China needs to produce more animal protein. What approach is the most effective way? Certainly aquaculture is not the only key to resolve this problem, but it is an ideal one. For aquaculture, the ecologically-based culture systems may be time-consuming, labor-consuming and provide rather low output in the short term. With the improvement of living standards, a rich country and rich people need higher quality and more tasty food and they are more willing to pay higher costs. Many farmers want higher benefits through instant entry or conversion to the culture of high value species. Generally the conversion of energy between steps in a food chain is about 10 per cent each step. Managing a few farming products at the top of the food web in one country should be feasible. Similarly, managing products at the top of the world's food web for a few countries could be practical. But, for farming in one country (and most countries in the world), the products from the bottom and/or the median levels of the food web must represent the bulk of aquaculture, just as in animal husbandry, herbivorous cattle and sheep, as well as the omnivorous pig dominate the meat production. Tigers, for instance, as carnivores, could never dominate animal protein production. In aquaculture, carps, tilapias, molluscs, and seaweeds must continue to play a dominant role in aquatic protein supply and food security through low cost systems. Therefore, the ecologically-based culture systems, including polyculture and integrated farming system, have a great capacity to contribute to human development.

References

Fisheries Bureau. 1980-2000. Year Book of Fisheries.

Guidan. 2001. Sweat Rice and dumping fish: struggle to alleviate poverty village by village – rice-fish engineering, strategy for poverty alleviation in Yunan province. China Fisheries. 12:26-27.

Li, S.F. 2001. "Species" issue regarding present aquaculture in China. ***In*** H. Huang and R. Zhou (eds.) Theses collection of workshop on key techniques in aquatic products seeding production, facing problems of aquatic products and solutions after China's WTO entry. Bureau of Ocean and Fisheries, Guangdong Fisheries Society 42-53.

Ma, W.J. 2001. The hope of wealthy farmers in mountain areas. China Fisheries. 12:22-24.

NACA/FAO. 2000. Aquaculture Development Beyond 2000. The Bangkok Declaration and Strategy, 23 p. http://www.enace.org/publications.htm