Agricultural Development and the Opportunities for Aquatic Resources Research in China

L.X. Zhang • J. Liu • S.F. Li • N.S. Yang • P.R. Gardiner

WorldFish CENTER

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Foreword

This brief volume documents an important early step in the collaboration between The WorldFish Center and the People's Republic of China.

This volume is a collection of papers that four Chinese scientists presented to the WorldFish Center in March 2002. The four scientists, Dr Zhang Linxiu, Professor Liu Jian, Professor Li Sifa, and Professor Yang Ningsheng, designed their papers so as to introduce and explain the background to the rapid changes that China is undergoing, the aquatic resource issues and development challenges that are confronting China and major Chinese institutions dealing with those issues and challenges.

We at the WorldFish Center are confident that this step will be a part of a continuing process that will enable the Center to direct its strategic research efforts to assist China and to provide benefits from the joint research to other regional partners in the future. WorldFish hopes that publication of these papers will also serve as a useful starting point for others interested in aquatic resources and development challenges in China as much of the information has not been assembled in English before.

WorldFish has a major focus on Asia because people in Asia are major producers and consumers of aquatic produce. The population in Asia also stands to suffer the greatest risk from damage to the environmental base that supports sustained productivity. The Center has a portfolio of research, partnership, capacity building and policy support to promote sustainable development and use of living aquatic resources based on environmentally sound management.

WorldFish has conducted productive collaborative research with institutes in China for many years. In the genetic improvement of tilapia and carp species, the Center has collaborated with the Shanghai Fisheries University and the Wuxi-based Freshwater Fisheries Research Centre (FFRC) of the Chinese Academy of Fishery Sciences (CAFS). WorldFish has also worked with the Information Center of CAFS and, more recently, has begun to collaborate with the Center for Chinese Agricultural Policy (CCAP) of the Chinese Academy of Sciences..

During the Third World Fisheries Congress in November 2000, WorldFish met representatives of Chinese universities and other national agencies concerned with the aquatic sector in China in order to broaden future collaboration. Professor Chen of FFRC, Dr. Zhang Linxiu of CCAP and a member of the Board of Trustees of the WorldFish Center, and Dr. M.V. Gupta, the Director of International Relations of the Center, convened and organized the meeting. The meeting raised two questions, namely identifying China's priority efforts which could best be augmented by international collaboration and determining ought the national and institutional context for collaborative research projects.

In March 2002, the Board of Trustees and senior staff of WorldFish invited Dr Zhang and Professors Li, Liu and Yang to a discussion focused on seeking answers to the two questions. The papers presented at that discussion are the basis for this volume.

We are very grateful to Dr. Zhang Linxiu and our other Chinese partners and speakers for helping us take this important step. We hope that their papers lead to ideas and the institutional knowledge necessary for further constructive collaboration.

Meryl Williams
Director General
WorldFish Center

Introduction

China is a large and rapidly developing country. The size of its human population, the extent of its agricultural and other resources, and its enormous actual and latent markets, particularly as the world adopts measures for the liberalization of trade, ensure that China will be increasingly influential in global affairs. However, the country could be said to be at a crossroads. Rapid economic and rural development has been achieved and agriculture has played an important role in this development. Fisheries and aquaculture have been prominent sectors in the contribution to GDP and the provision of food security, export revenue, and livelihoods for the poor. China is making important contributions to agricultural biotechnology (e.g. Huang et al. 2002; Sun and Liang 2002; Yu 2002) on the one hand, but is still faced with relatively large-scale poverty on the other. The development has been unbalanced, with generally increasing income disparities, and differences in agricultural research investment and the levels of poverty between the provinces of the Eastern sea-board and the more western and northern parts of the country. The rapid development has come at some cost to the environment and the sustainability of natural resources. Levels of marine fisheries catches are stagnant, or are actually lower than previously thought (Watson and Pauly 2001; FAO 2002; Yang 2002). Red tides are increasing both in frequency and extent, presumably due to the pollution of coastal areas. Some of the rivers and major lakes are similarly polluted and the restoration of the productivity of these lakes, which may well be on decadal time frames, is of key concern. Aquaculture has played a very significant role in the overall fisheries production (China is almost unique amongst countries with a sea board in that aquaculture is said to provide more than 60 per cent of total fisheries production). However, its further expansion requires appropriate planning and regulation to ensure its continued utility and to avoid it being a contributor to environmental degradation.

These Proceedings, made up of four papers that leading Chinese experts presented to WorldFish Center in 2002, review four aspects of these trends (namely agricultural development, environmental issues, and the contributions of aquaculture and fisheries to development in China). The authors represent China's institutional capacity for research and development. Dr Zhang Linxiu and Professor Liu Jian are at the Chinese Academy of Science (CAS), the peak science agency of the State Council, China's central government. Dr Zhang, who is also a member of the Board of Trustees of WorldFish Center, is at the Center for Chinese Agriculture Policy (CCAP) of CAS. Professor Li Sifa is at the Shanghai Fisheries University (SFU), which is currently managed by the Shanghai Municipal Government and the central government. Professor Yang Ningsheng is at the Chinese Academy of Fishery Sciences, the peak fisheries science agency of the Ministry of Agriculture. Three themes run through the papers in this volume. First is the current setting of aquaculture and fisheries within the overall context of agricultural development in China. Second, are market and environmental trends that define the opportunities and limits to production. Third is the current institutional capacity, and the general and specific opportunities for addressing several of the most pressing aquatic resource issues through international collaboration with WorldFish Center.

This introductory chapter deals with each of the three topics in turn and presents a synthesis of the contributions made by Dr Zhang and Professors Liu, Li and Yang.

Agriculture as a driver of development

As an introduction to the identification of major aquatic resource issues in China, Zhang LX (2002) has provided an historical review of agricultural and rural development in China. The well-known commune system in Chinese agriculture lasted nearly 30 years and was replaced by economic reforms only in the late 1970s. This shift from a planned, to a more market-oriented system and a more open economy, stimulated the annual growth rate in agricultural production from 2.7 per cent in the period 1970-1978 to 7.1 per cent during the period 1979-1984. However, the basic characteristics of agriculture still remain, with the production system based on small-scale farms and individual households. The land tenure system provides the rural households with a basic means of living, and so serves as a substitute for welfare and insurance systems in the rural area, although it may reduce production efficiency. Although reform has penetrated throughout the whole economy since the early 1980s, most of the successive transformations have, in some way, depended on growth in the agricultural sector. China's economy has grown substantially with an annual growth rate of GDP of 8.5 per cent in 1979-84 and 9.7 per cent in 1985-95. Moreover, despite the Asian financial crisis, China's economy continued to grow at 8.2 per cent annually between 1996 and 2000. Foreign trade has been expanding even more rapidly.

The effects of changes in agriculture

Although agricultural growth decelerated after 1985 after the one-off efficiency gains from the decollectivization, the country still enjoyed agricultural growth rates that have outpaced the rise in population. The even faster growth of the industrial and service sectors during the reform era has begun to transform the rural economy, from agriculture to industry and from rural to urban. During this process, the share of agriculture in the national economy has declined significantly - whereas agriculture contributed more than 30 per cent of GDP before 1980, it fell to 16 per cent in 2000. These structural changes in the economy have been accompanied by a large transfer of the labor force from the agricultural to the non-agricultural sector (from 80 per cent of the total labor force in agriculture in the early 1970s to 50 per cent in the year 2000).

The rapid economic growth, urbanization and food market development have boosted demand for meats, fruits and other non-staple foods, changes that have stimulated sharp shifts in the structure of agriculture. Opportunities have been provided for livestock (with output value more than doubling from 14 per cent in 1970 to 30 per cent in 2000) and aquatic produce (from around 2 per cent of GDP in 1970 to 11 per cent in 2000) at the expense of the grain sector.

Over the last two decades, the impressive rates of economic growth in China have helped dramatically to improve the standard of living of its people. Per capita income in rural China was extremely low prior to the reforms. This changed directly after the initiation of rural reforms in 1978, with peak growth rates as high as 15 per cent per annum by 1984. Although this subsequently slowed (to 3 percent per annum), non-farm income has made up an increasingly large proportion of rural income, and the increase in overall income started to accelerate from1990 and continued throughout the subsequent decade (Zhang LX 2002; Zhang XS 2002).

The improved economy brought significant reductions in rural poverty. In China, poverty is considered to be primarily a rural phenomenon. Estimated by China's official poverty criteria, China's rural poor has decreased dramatically in the past twenty years, from 260 million in 1978 to about 30 million in the year 2000. The incidence of rural poverty (poor as proportion of rural population) also decreased sharply during the period (to 3 percent in 2000). Similar trends are discerned with other poverty indicators although the exact numbers may differ (Zhang XS 2002). A major issue for the future, however, becomes the employment of excess rural labour. This will require diversification of opportunities for employment and income, and to support this diversification through strengthened rural institutions (Zhang LX 2002; Zhang XS 2002).

The contribution of fisheries

China's fishery output in 2000 is reported as 42.79 million t, making up one third of the world's total (Yang 2002). The total fishery production value was RMB 184 billion (US$ 22.17 billion). The country's aquaculture production has exceeded its capture fisheries, reaching 24 million t in 2000 and contributing two thirds of the world's aquaculture. The GDP of the fishery sector was RMB 280.8 billion (US$ 33.83 billion), accounting for 11.6 per cent of the country's agricultural GDP. Fishermen's average income has gone up to 4474 RBM (US$ 539), about double that of farmers in agriculture. The industry has provided 12.57 million job opportunities. In terms of international trade in 2000, China's fish exports were reported as 1.534 million t in volume and US$ 3.83 billion in value, and the imports as 2.52 million t in volume and US$ 1.85 billion in value. A key factor in the trade is the high importation of fish meal and the use of low value species for aquaculture feeds, and the tendency currently to export high value species.

Marine capture fisheries were previously the mainstay of China's important fishery industry. Between the 1950s and 1960s, China's annual marine fishing production was about 2 million t, mainly made up of commercially important demersal species. Subsequently, lower value pelagic species accounted for a larger share of production, making up 60 per cent of the total biomass by the mid-1980s. Total or spawning biomass declines have been widely reported or, as for the East China Sea, some species remained stable in amount but their populations tended to be younger and smaller. Such declines due to overfishing, coupled to the effects of pollution (discussed below), are also evident in the freshwater fisheries.

China's fishery, although very large, cannot yet be considered as industrial. Apart from a few modernized fishing fleets and fish farms, scattered artisanal fishermen and fish farmers dominate both capture fisheries and aquaculture. Only 30 per cent of landed fish are processed (compared to 70 per cent in developed countries), the majority is simply iced or refrigerated. Fresh water fish are almost always sold alive. To date few high-value added technologies have been developed and the industry may be vulnerable without modernization.

The natural resource base

As Liu (2002) has pointed out, the dilemma for China, as for other nations, is in balancing the rate of agricultural and industrial intensification with the capacity of the natural resource base and environmental objectives.
The new challenges for agriculture in China can be summarized as (i) food security for a projected 1.6 billion people under the pressure of resource depletion, (ii) rural economic safety for the 900 million majority rural people under the pressure of WTO entry, and (iii) sustainable use of natural resources and environment improvement under the pressure of agricultural intensification.

In terms of natural resources, China is large in total; but, with a current population of 1.3 billion people, its resource endowment is relatively small on a per capita basis. For example, China's water resources per capita are only one fourth of the world average. Northern provinces have less available water than the south, and water scarcity is becoming widespread and looms as a constraint to economic development. The shallow groundwater table has been declining because of over extraction and inefficient irrigation since the early 1970s in some areas. Similar declines in the deep water table have recently been detected in selected counties in the Fuyang River Basin.

Ecological and environmental degradation pose further constraints on agricultural production. Soil erosion, salinization and desertification are inherent problems in the west, and are spreading rapidly to the north and northeast China. Food safety is threatened by pollution from industry and urbanization, and also agriculture is becoming a new source of pollution, especially through the excessive use of fertilizers and pesticides, animal waste from big farms, and intensive aquaculture. Eutrophication is now severe in some large lakes such as Taihu Lake in Jiangsu Province and Dianchi Lake in Yunnan Province (Liu 2002).

Competing priorities in the use of water resources

The first priority for the aquatic ecosystem services in south China is the requirement to supply adequate safe drinking water. The portion of water for agriculture is decreasing because of its comparative disadvantage in economic terms. However, it will be necessary to sustain healthy aquatic ecosystems for a variety of services. As crop/livestock-dominated agriculture faces increasing challenges of resource depletion and environmental degradation, aquaculture (including mariculture) should be one of the important solutions to the questions of food security, land pressure, and low farmers' income. However, balances between production and environmental costs will have to be found. For example, improper aquaculture was deemed to be a contributory factor to the degradation of Dianchi Lake and has been banned locally by the State Council. The question of how to sustain healthy aquaculture/mariculture is thus a major issue for China and cuts across different administrative boundaries and potential goals. For instance, the Ministry of Agriculture may stress the augmentation of productivity and its role in income generation; whilst the State Environmental Protection Administration may put the control of the eutrophication of important water bodies on the top of their priority list. The more general mismatch between the aspirations of central and local governments in relation to environmental conservation and productivity, and even amongst different interest groups in the same area, is likely to be exacerbated at a time of rapid economic change and devolution or readjustment in authorities for governance and services.

Coastal and marine environments

The pollution of the aquatic environment has provoked public and government concern. As well as the effects of overfishing, pollution in coastal waters is increasingly severe (Information Office of the State Council of the People's Republic of China 1998; Lu 2001; Yang 2002). Over three hundred red tides were recorded during the 1990s along China's coastal areas affecting cage culture and cultivated mollusks. Individual and successive calamities of this sort are estimated to have caused losses of several hundred million RMB. In the East China sea harmful algal blooms (HABs) substantially increased in 2000 covering up to 12 446 km^2 (Lu 2001). Estuaries and bays have become increasingly eutrophic because of the discharge of land-based industrial and household pollutants (including inorganic nitrogen and phosphates which predispose to the growth of HABs). Aquaculture itself in some areas also results in pollution. For example, the feed residuals, fish wastes, dead fish, fertilizer and fish drugs are all considered as contributory sources of pollution.

In recognition of these problems the Chinese Government has, starting in the 1980s, established a comparatively integrated law and regulation system for marine and environmental protection (Information Office of the State Council of the People's Republic of China 1998; Lu 2001). Collaborative projects with international agencies have been carried out to enhance the management of coastal resources. Since 1998, the Government and the World Bank have been collaborating in a major "Sustainable Coastal Resources Project" in key municipalities of Fujian, Jiangsu, Shandong and Liaoning Provinces (Lu 2001). As well as inter-sectoral and inter-administration management, 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 (Yang 2002).

Future food requirements and challenges

According to the projections by the Center for Chinese Agricultural Policy (CCAP), China would need to increase food supply by 40 per cent to meet demand in the year 2030. However, challenges associated with these targets are: (i) declining arable land, (ii) water shortages, (iii) the relatively limited comparative advantage of grain production, and, (iv) the increasing regional disparity in incomes. China's entry into the World Trade Organization (WTO) also poses substantial questions for the Chinese economy.

Technology-led development

China has a strong agriculture research system and agricultural technology development has been regarded as the primary engine for economic development, as well as the major factor for poverty reduction. Despite this past record, China faces considerable challenges as the expenditures of the publicly funded agricultural research system are tied to public budgets. Falling fiscal support has taken its toll. Currently, there is much concern that the intensity of investment in agricultural research (measured as the percentage share of total agricultural GDP) has declined since the early 1980s and reached a dangerously low level, only 0.44, in 1999 (Zhang LX 2002). At the same time, the increasing evidence of overlapping remits, inefficiency, over-staffing, and inappropriate technology make fundamental reform of the current research system an essential task.

Studies have revealed that public investments by the government still play significant roles in promoting the overall economic development. This is especially true for investments in agricultural research and development (Huang et al. 2002) and rural education. Prioritization of these investments is clearly an issue for the Chinese government. Also, various studies conclude that although grains, as a land-intensive commodity, do not have a comparative advantage in the world market; other commodities that are more labor-intensive do have comparative advantages. These commodities include livestock products, horticultural products, as well as aquatic products.

The role of aquaculture

Aquaculture in China accounts for 26 per cent of world total fish production, and supplies 44 per cent of China's meat production. The favorable conditions for aquaculture development include its contribution to food security, the resource potential (especially from mariculture with a coastline ranging for 18 000 km), and policy and technological advancement. These considerations, the rapid changes in population structure (between rural and urban), and rising living standards, have presented China with several opportunities to meet the rising demand for both low and high quality animal products, particularly aquatic products. The eroded status of wild marine fish stocks and the decrease of traditional fishing grounds have focused policies for the development of Chinese fisheries on expanding aquaculture as a key strategy for meeting changing national demand and consumer patterns. In 1999, the Chinese government implemented "a zero increase" policy in the production from marine capture fisheries. This has resulted in an historic opportunity for the development of aquaculture. Challenges to aquaculture come from market competition, (with other meat products and imported fishery products); limitation of resources in the case of shrinking fresh water areas; and the external and autogenous pollution.

The paper by Li (2002) outlines the history of aquaculture in China, current aquaculture research and its relation to development in China. Descriptions of aquaculture in China are 2 500 years old. However, in line with the rapid economic transformation, more recently aquaculture yields have grown by 13 per cent annually. Its growth potential has been augmented since 1985 when it was declared as a central part of China's fisheries policy. The breakthrough of artificial propagation of Chinese carps around 1960 changed the traditional practice of collecting the wild fry from the rivers, and formed a strong basis for seed supply, which was essential to the subsequent rapid development of aquaculture in the 1960-1970s. Further research increased the number of fish species that could be artificially bred and farmed (Li 2002; Tables 5 & 6: 19-20). In the freshwater aquaculture sector, fish farming in ponds provides an estimated 60-70 per cent of total freshwater aquaculture production. Over time, there has been a greater recruitment of other water bodies and resources (Li 2002; Tables 2, 4 & 6: 18-19, 20) so that culture in open waters (lakes, reservoirs, channels) contributes most of the remaining output. Current practices encompass both traditional species (native carps, mandarin fish, river crab) and exotic species (such as tilapias, rainbow trout, channel catfish, largemouth bass etc). The traditional polyculture and integrated fish farming systems are well known, but these are now challenged by the culture of high value species in more intensive systems characterized by monoculture and higher mechanization.

In the marine aquaculture sector, the representative principal species have shifted from seaweeds (kelp and porphyra etc.) in the 1960s, through mollusks to higher valued finfish and crustaceans in the 1980-2000s. Ecological principles have been introduced successfully into the polyculture of shellfish and seaweed systems. On the other hand, water-based farming, such as sea-cage culture, is popular in southeast China for big yellow croaker, grouper and sea breams. Land-based farming, such as tank culture for flounder, turbot, etc. is popular in northeast China. By 2000, the total output of aquaculture reached 25.78 million t, 60 per cent of the total, national aquatic production. The significance of science and technology in delivering people from poverty and supplying high quality protein is clear. While the political-economic settings provided the conditions for growth, Zhang LX (2002) credits technology for the majority of the rise in total agricultural factor productivity and Li (2002) estimates that 42 per cent of the increased aquaculture harvest can be credited to technology. The flourishing aquafeed production can be seen as one of the indicators of the rapid development of intensive culture. Because of the rather higher profit from aquaculture than agriculture, more and more farmers have moved to take up aquaculture. Aquaculture also provides market and labor opportunities in contrast to the decline in the capture fisheries sector.

Future requirements for the appropriate development of aquaculture

Maintaining, or even raising, the contribution of aquaculture beyond its current share in total fisheries production will depend not only upon the rate of scientific progress but attention to the requirement for sustainability. Several key issues need to be considered properly: (i) Environmental carrying capacity – an urgent requirement is the development of environmentally sustainable production systems, namely water saving, land saving, feed saving as well as low waste culture systems, within the carrying capacity. (ii) Genetic improvement - most species that are cultured are still virtually wild stock, without genetic improvement. New strains or varieties genetically improved to withstand biotic and abiotic stresses, or for product quality, will enhance possibilities for the development of aquaculture. Observers to the Third World Fisheries Congress, held in Beijing, noted the relatively large number of exotic species introduced into Chinese aquaculture, and the numerous attempts in Chinese institutes to improve strains through genetic engineering methods (New 2001) rather than traditional selection approaches. (iii) Disease control and the implementation of product safety standards will be required as over RMB 12 billion is lost annually in China's aquaculture as the result of rampant disease issues. Generally, the progress of aquatic science and technology in China is deemed to be rather behind the production activity.

The institutional setting

China has a strong institutional capacity for research and development and is making significant contributions to the fund of world science, including agricultural science and biotechnology. Peak institutions, such as CAS and CAFS, are associated with the State Council, China's central government, or the ministries and other agencies of the State Council. The peak institutions have links with relevant central government ministries and have field stations and institutes throughout the country (for CAS, see Liu in this volume: 12-15; for CAFS, see Yang in this volume: 30, 33-5).

The current challenges have generated new demands on the institutions. As noted above, this includes demands to reform to avoid inefficiency in the face of modest budgets, to encourage new investment in research and development, and to gain capacity to prioritize use of available resources. Institutional reform has been one response. Liu (this volume: 3) notes recent reforms in CAS and Li (this volume: 24) notes the recent changes bringing SFU under the guidance of the Shanghai Municipal Government and the central government.

International collaboration, seeking technology transfer and economies of scale, is another institutional response to the new demands. Agencies of CAS have extensive links with national, regional, international and multilateral institutions (Liu in this volume: 13). SFU and CAFS similarly have cooperated with national, international, and multilateral bodies, including WorldFish Center (Li in this volume: 25; Yang in this volume: 35).

The discussion session amongst the Chinese experts and WorldFish Center in March 2002 (Appendix 1: 37), was a further step in international collaboration and helped raise mutual awareness about the aquatic resources research context and capacities of the several institutes.

Conclusion

Arising from the presentations contained in this volume, and the discussions they stimulated, several research themes were identified where international and national Chinese requirements for research, monitoring and evaluation coincide and opportunities for future collaboration might occur. Without therefore prejudicing the further dialogue that is required to establish the focus and means for such an enhanced collaboration in the future, the themes would include the following:

The CAFS identifies the major general issues for China's fisheries are to (i) further raise the income of fishermen and fish farmers, as most are still living in poverty; (ii) improve the quality and varieties of fish products in order to promote international trade, and; (iii) restructure China's fishery industry in accordance with the new international marine management regime (Information Office of the State Council of the People's Republic of China 1998; Lu 2001) and to encourage sustainable fishery development. Professor Yang (this volume: 36) provided a list of key research areas for collaboration in the broader areas affecting fisheries and aquaculture, including disease; resource and environmental management; post-harvest technology; information exchange; and training.

Research to understand the context for future supply and demand from fish and aquatic produce would build on current collaborative initiatives between WorldFish Center and the CCAP, and would examine a) the interaction between production in China and regional supply and demand, and also b) the opportunities for aquaculture and fisheries to meet more effectively the food and other needs of the poorer sections of Asian societies. Research is required not only into product safety but into other factors potentially affecting access to international markets such as the effects of certification and ecolabelling.

Noting the Chinese wish to exploit aquaculture, as well as its obligations through international agreements to reduce fishing capacity (and therefore the number of fishers) in some coastal regions, three related themes to explore collaboratively would be a) the contribution of aquatic produce and industries to sustainable livelihoods, especially the absorptive capacity for new labor of aquaculture and mariculture industries, b) the role that integrated aquaculture-agriculture practices can play in poverty alleviation in Western China, and c) identifying the carrying capacity for aquaculture, particularly in coastal zones, taking into account technical improvements, the availability of feeds, and ecological principles. Collaborative work on genetic improvement, and means to control or resist diseases in aquaculture should be encompassed as a priority.

Noting the issues of pollution of water and aquatic habitats, research on the restoration of aquatic resources, and environmental and biodiversity management are of high importance. Urgent study is needed of the diversity of indigenous wild and cultured species, and their genetic characterization and conservation.

Sharing knowledge and experiences in coastal zone management between China, the Center and other partner countries is expected to be mutually advantageous. Excess capacity in (particularly coastal) fisheries is a global problem, but of particular concern to China and other Asian countries. Noting the difficulties in establishing research baselines (Watson and Pauly 2001; FAO 2002; Yang 2002) in a country as large and as swiftly changing as China, collaboration on the establishment of resource and economic baselines will also be helpful.

The key for the individual sectors is how to improve the quality or the standards of the products to ensure health and competitiveness. However, the ultimate, overriding question is how to balance trade-offs between growth, poverty and environment in the development process. Socio-economic and biophysical modeling procedures will be needed to assist in this optimization of competing demands for better management.

Subsequent to the discussion session, the Center identified seven research areas that could be tackled in the near future and circulated the list to Chinese institutes for further development and dialogue (Appendix 2: 38-40).

It is clear that collaboration between Chinese institutes and international partners such as WorldFish Center can provide “strong-strong” links, in which Chinese institutes would not only be a research partner, but have the means to share technologies and experiences of their own to channel for the wider benefit of the aquatic sector in developing countries.

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AGRICULTURAL AND RURAL DEVELOPMENT IN CHINA

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Abstract

This chapter looks at the various reforms in China since the 1950s and their impacts on agricultural and rural development. Among other things, this chapter discusses the major achievements of economic developments and the changing role of agriculture in the country. In the last section, major challenges and opportunities are identified for the further development of the agricultural sector in China.

Historical overview of agricultural and rural development in China

For a long time after the founding of the People's Republic of China in 1949, China adopted the formal Soviet model. This process of the adoption has gone through several stages.

Before 1949, China's economy was no different from that of any other developing country, with respect to private ownership of properties and private run businesses. However, large disparities in living standards and access to resources pervaded society. This was especially true in rural areas. Agrarian reform in the early 1950s enabled more than 80 per cent of the rural poor households to gain access to land resources, which had been previously controlled by less than 20 per cent of the wealthy. Until then, agricultural production had been carried out by individuals in rural China.

The collective movements started in the 1950s. The basic argument for the move was that small farms and individual households would not be able to cope with natural disasters or other kind of shocks. Thus, a certain level of collective management in production would be a way to compensate for the weakness. The initial idea was to run some kind of cooperative services in production in which small households were formed to help each other during busy seasons. This kind of arrangement can be categorized as "labor exchange".

The second phase of the collective movement was the concentration of all the medium and large sized farm production tolls. Individual households were provided with collective services for certain farm work. Not long after this, an even larger scale of merging took place in the rural areas. All lands owned by individual households were merged under a collective land ownership. All means of production also became collective. The commune system was established, under which the production team was the smallest production unit. The production brigade was at a level above and the commune was at a higher level still. Such a system existed for nearly 30 years, until the late 1970s, when the economic reforms started. Although there was not much change in the institutional setting in rural areas, major changes in agricultural policies did take place. The following table is a summary of the major political as well as agricultural policy changes before the reform.

Table 1. Major political events and agricultural policies in China since 1949.

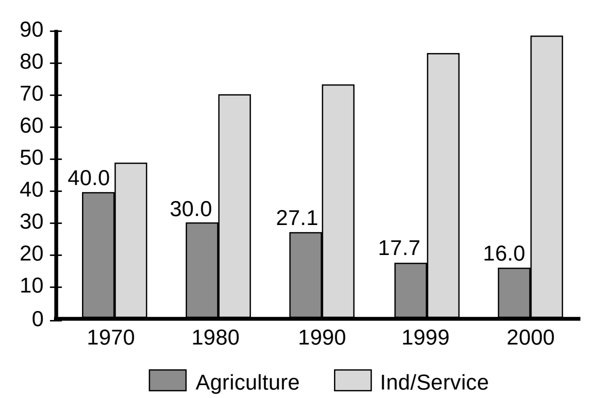
Period	Political events	Major agricultural policies
1949-52	Socialist land reform (Agrarian reform)	Specialized production
1953-57	Cooperative movement	Free market allowed
1958-62	"Great Leap Forward" movement	Compulsory commandism for demand and supply No free market Grain self-sufficiency for major agricultural products
1963-65	Readjustment period	Very low prices for agricultural products Commune system Policies during 1963-65 similar to those in the early reform period
1966-78	Cultural revolution	
1979-	Economic reforms	Relatively higher prices for agricultural produce Free market encouraged Specialized production encouraged Abolition of the Commune system Various kinds of production responsibility, especially household responsibility systems

Source: Adapted from Yao and Colman 1990

Economic reforms were introduced in China in the late 1970s. In rural areas, the reform process started with the introduction of the household responsibility system. The initial aims of the reforms were to expand agricultural production, to diversify the rural economy, to improve the rural standard of living and to promote the innovation and diffusion of new technologies. The major contents of the reform included: a) institutional reform by the introduction of the household responsibility system; b) marketing reform that freed most agricultural commodities from Government control, and brought about huge increases in the prices of major agricultural commodities; and c) encouragement of rural sidelines, or other non-farming activities, and allowing for labor mobility between regions and between rural and urban areas. This was accompanied by changes in the political system in rural areas.

The reform shifted the Chinese economy from a planned system, to a market-oriented system and towards a more open economy. Consequently, there was an overall improvement of the economy, which is reflected in various indicators as shown in Table 2 and Fig. 1.

Fig. 1. Changes in structure of economy – GDP Percentage.



However, the basic characteristics of agriculture still remains namely farms are all small scale with individual households operating the production system. An important structural difference between China's agriculture sector and those from developed countries and many other developing countries is that the agriculture sector in China is characterized by an equitable distribution of cultivated land among households. In essence, such a land tenure system provides rural households with a basic means of

Table 2. The annual growth rates (%) of China's economy, 1970-2000.

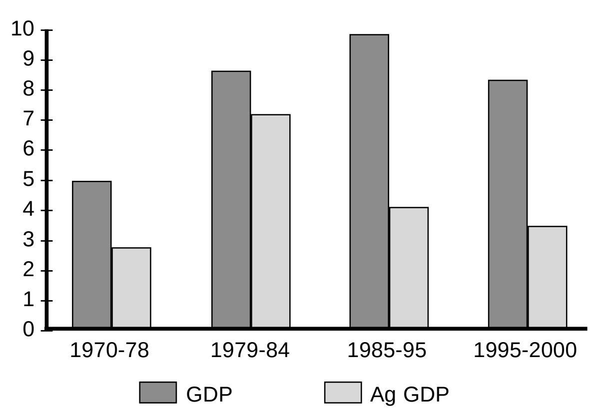
	Pre-reform	Reform period		
	1970-78	1979-84	1985-95	1996-2000
Gross domestic product (GDP)	4.9	8.5	9.7	8.2
Agriculture	2.7	7.1	4.0	3.4
Industry	6.8	8.2	12.8	9.6
Service	Na	11.6	9.7	8.2
Foreign Trade	20.5	14.3	15.2	9.8
Import	21.7	12.7	13.4	9.5
Export	19.4	15.9	17.2	10.0
Grain production	2.8	4.7	1.7	0.03
Oil crops	2.1	14.9	4.4	5.6
Fruits	6.6	7.2	12.7	8.6
Red meats	4.4	9.1	8.8	6.5
Fishery	5.0	7.9	13.7	10.2
Rural enterprises output value	Na	12.3	24.1	14.0
Population	1.80	1.40	1.37	0.90
Per capita GDP	3.1	7.1	8.3	7.1

Note: Figure for GDP in 1970-78 is the growth rate of national income in real term. Growth rates are computed using regression method. Growth rates of individual and groups of commodities are based on production data; sectoral growth rates refer to value added in real terms.

Source: Adapted from CCAP working paper (Huang and Rozelle 2001).

living, and so serves as a substitute for welfare and insurance systems in the rural areas. While such an arrangement may reduce production efficiency, it is an important factor contributing to rural welfare and social stability.

Fig. 2. Growth of GDP and Aggregate GDP percentage.



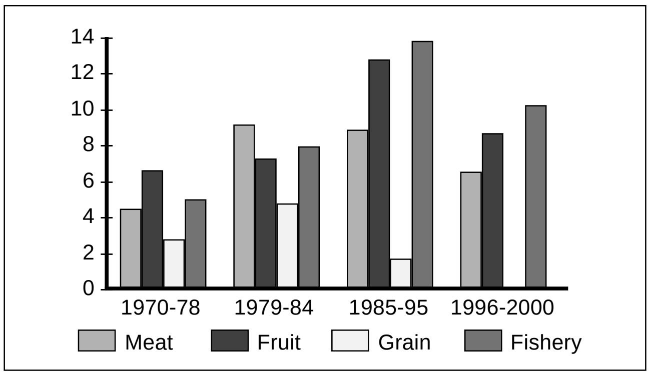
The majority of rural farmers are semi-subsistence. Although the performance in the agricultural sector has been well recorded, the relative role of agriculture in the national economy is changing. This is discussed in the next section.

Changing role of agriculture

China's economic liberalization and structural change have operated for several decades. Since the economic reforms were initiated in 1978, China's economy has grown substantially. For example, the annual growth rate of GDP was 8.5 per cent in 1979-84 and 9.7 per cent in 1985-95 (Table 2 and Fig. 2). Moreover, despite the Asian financial crisis, China's economy continued to grow at 8.2 per cent annually between 1996 and 2000. Foreign trade has been expanding even more rapidly. China's trade to GDP ratio increased from 13 per cent in 1980 to 44 per cent in 2000 (NSBC 2001).

Although reform has penetrated the entire economy since the early 1980s, most of the successive transformations began and in some way depended on growth in the agricultural sector. After 1978, decollectivization, price increases, and the relaxation of local trade restrictions on most agricultural products accompanied the take-off of China's agricultural economy noted for 1978-84. Grain production increased by 4.7 per cent per year. Even higher growth was enjoyed in horticulture, livestock and aquatic products (Table 2 and Fig. 3). Although agricultural growth decelerated after 1985 and the one-off efficiency gains from the decollectivization, the country still enjoyed agricultural growth rates that have outpaced the rise in population (Table 2).

Fig. 3. Growth of agriculture percentage.



Despite the healthy expansion of agriculture, the even faster growth of the industrial and service sectors during the reform era has begun to transform the rural economy, from agriculture to industry and from rural to urban. During this process, the share of agriculture in the national economy declined significantly. Agriculture contributed more than 30 per cent of GDP before 1980, but fell to 16 per cent in 2000 (Table 3 and Fig. 2). Employment in agriculture fell from 81 per cent in 1970 to only 50 per cent in 2000.

The rapid economic growth, urbanization and food market development have boosted demand for meats, fruits and other non-staple foods, changes that have stimulated sharp shifts in the structure of agriculture. For example, the share of livestock output value more than doubled from 14 per cent to 30 per cent in 1970 to 2000 (Table 3). Aquatic products rose at an even more rapid rate. One of the most significant signs of structural changes in the agricultural sector is that the share of cropping in total agricultural output fell from 82 per cent to 56 per cent. Moreover, the most significant declines in crop-specific growth rates are in the grain sector (Table 2 and Fig. 3).

The structural changes of the economy can also be revealed through employment data (Table 3 and Fig. 4). The transfer of the labor force (previously employed in the agricultural sector) to the non-agricultural sector has continued to the present.

In the early 1970s for example, employment in the agricultural sector accounted for more than 80 per cent but this number declined to 50 per cent in the year 2000. The same trends are true for the agricultural GDP and the export sector (Table 3).

Major achievements of the economic development

Over the past two decades, China has maintained impressive rates of economic growth. Rapid economic growth has helped to improve dramatically the standard of living of its people. This can be shown by the trend of rural per capita income increase (Fig. 5). Per capita income in rural China was extremely low prior to the reforms. In 1978, average income per rural resident was only about RMB 220 a year (US$ 150). For 29 years from 1949 to 1978, per capita income increased by only 95 per cent, or 2.3 per cent a year. This changed dramatically directly after the initiation of rural reforms in 1978. Per capita income increased to RMB 522 in 1984 from RMB 220 in 1978, a growth rate of 15 per cent a year. In the mid-1980s, rural income continued

Fig. 4. Change in structure of economy – employment percentage.

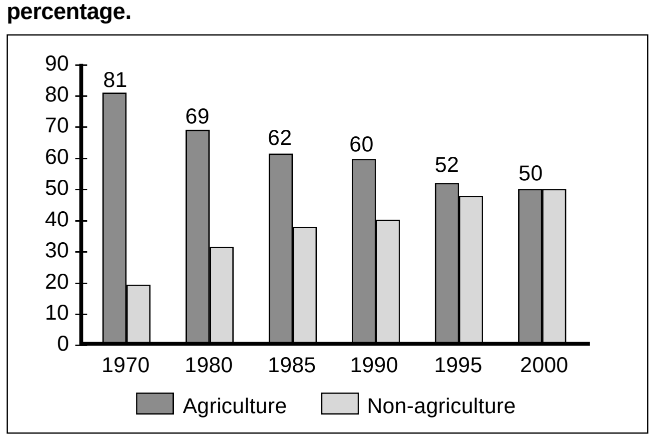


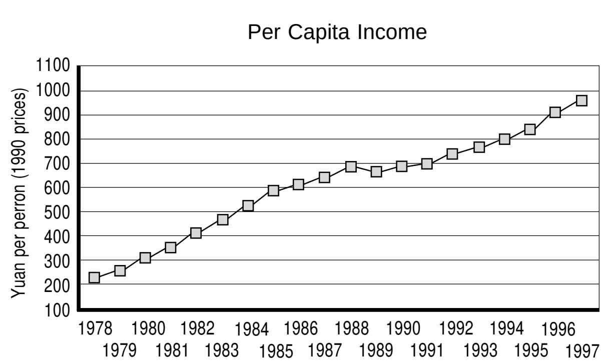
Table 3. Changes in structure percentage of China's economy, 1970-2000.

	1970	1980	1985	1990	1995	2000
Share in GDP						
Agriculture	40	30	28	27	20	16
Industry	46	49	43	42	49	51
Services	13	21	29	31	31	33
Share in employment						
Agriculture	81	69	62	60	52	50
Industry	10	18	21	21	23	22.5
Services	9	13	17	19	25	27.5
Share in Export						
Primary Products	Na	50	51	26	14	10
Foods	Na	17	14	11	7	5
Share in Import						
Primary Products	Na	35	13	19	18	21
Foods	Na	15	4	6	5	2
Share in agricultural output						
Crop	82	76	69	65	58	56
Livestock	14	18	22	26	30	30
Fishery	2	2	3	5	8	11
Forestry	2	4	5	4	3	4
Share of rural population	83	81	76	74	71	64

Source: Adapted from a CCAP working paper by Jikun Huang and Scott Rozelle, 2001.

to increase, but at the much slower pace of 3 per cent a year. This was due mainly to the stagnation of agricultural production after the reforms. With non-farm income as an increasingly large proportion of rural income, the increase in overall income started to accelerate from 1990 and continued throughout the subsequent decade.

Fig. 5. Per capita rural income change.



The overall achievement in the economy brought significant reduction in rural poverty. The significant reduction in the number of poor people, especially during the first decade, was a fact widely recognized both at home and abroad. In China, poverty is considered to be primarily a rural phenomenon (Fig. 6). According to China's official poverty lines, China's rural poor decreased dramatically in the past 20 years, from 260 million in 1978 to 128 million in 1984 (Fig. 7). After slowing down in the late 1980s, the rapid fall in the poverty head count continued in the 1990s, declining to 42 million in 1998 and about 30 million in 2000. The incidence of rural poverty (poor as proportion of rural population) also decreased sharply during the period. The incidence of poverty fell from 32.9 per cent in 1978 to 15.1 per cent in 1984, and then to 3 per cent in 2000.

Fig. 6. Rural poor as a percentage of rural population.

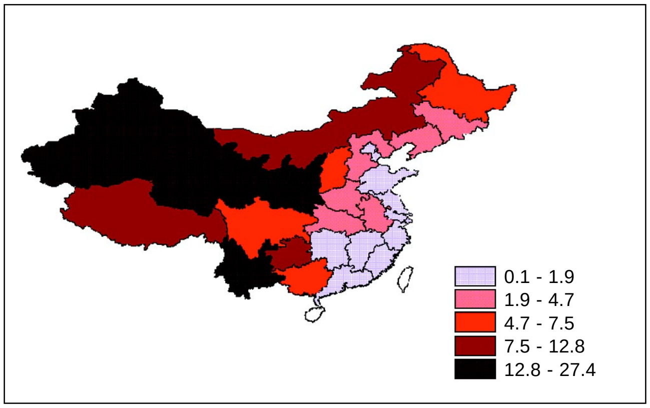


Fig. 8. Per capita cultivated land (ha).

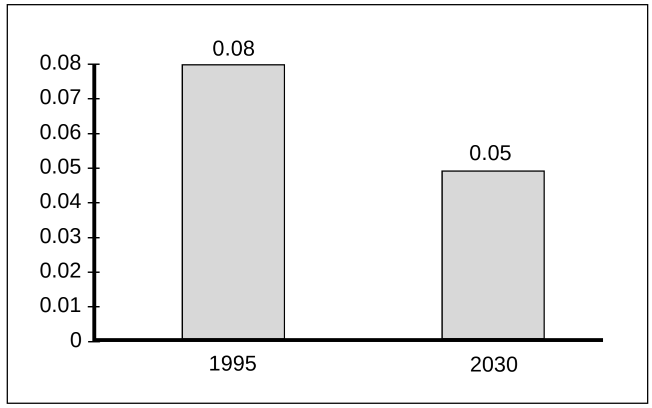


Fig. 7. Rural poor as a percentage of rural population.

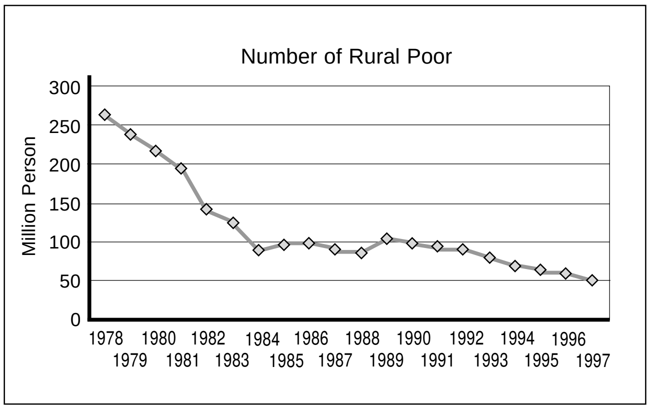
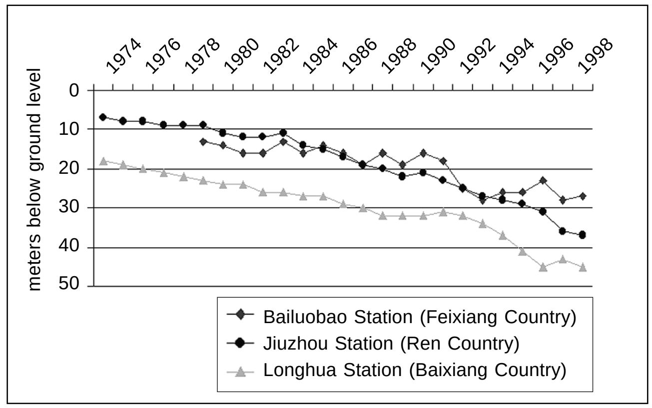


Fig. 9. Trend of the fall in shallow groundwater tables.



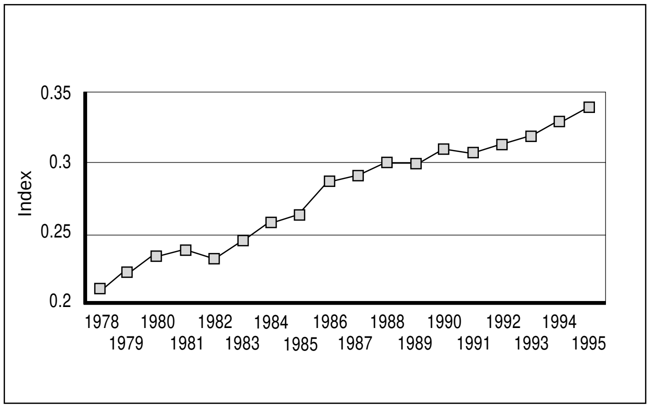
Challenges/opportunities and concluding remarks

According to projections made by CCAP, China would need to increase food supply by 40 per cent to meet increases in demand in the year 2030. This means that the Government still needs to make continued efforts to promote further development of agriculture and to maintain the growth of the economy. However, challenges associated with these targets are: 1) declining arable land – in 1995, per capita land area was 0.08ha while this number is expected to reduce to 0.05 ha by the year 2030 (Fig. 8); 2) water shortage will be one of the most constraining factor for the further development of the economy. According to a recent empirical survey by the CCAP, the shallow groundwater table has been declining over time since early 1974 (Fig. 9) in the sample areas. This is also true for the deep water table in selected counties in the Fuyang River Basin between 1980 and 1998 (Table 4). 3) the relatively limited comparative advantage of grain production, and 4) the increasing regional disparity in incomes (as reflected by the Gini coefficient) is also a course of concern (Fig. 10). All these, coupled with China's entry into the World Trade Organisation (WTO), pose many questions to the Government.

Table 4. Decline of deep water table in the selected Counties in the Fuyang River Basin (1980-98).

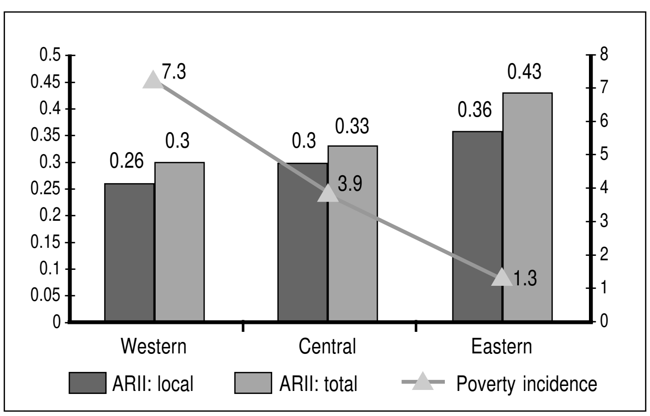
Country/City	Fall Rate (m/year)
Longrao County	2.24
Pingxiang County	2.18
Xingtai City	1.97
Jiuzhou County	1.86
Wuyi County	2.18
Wuqiang County	2.20

Fig. 10. Gini coefficient.



Agricultural technology development has been regarded as the primary engine for economic development and the major factor for poverty reduction. China has a strong agricultural research system that has generated technologies adopted by millions of farmers to meet the increasing demand of food and agricultural products in the most populous country in the world. All previous studies consistently show that research-led technological change is the main engine of agricultural growth. Technology produced by China's agricultural research system accounts for most of the rise in the total factor productivity of the cropping sector between 1980 and the late-1990s. Despite this past record, China faces considerable challenges. Although, as a publicly funded agricultural research system, it functioned well and addressed many important problems, its expenditures have been tied to public budgets. Falling fiscal support has taken its toll. Currently, there is much concern that the intensity of investment in agricultural research has declined since the early 1980s and reached the dangerously low level of 0.44 in 1999. At the same time, the increasing evidence of overlapping remits, inefficiency, over-staffing, and inappropriate technology make fundamental reform of the current research system an essential task.

Fig. 11. Agricultural research investment intensity and poverty by region in 1999.



Having discussed some issues and challenges above, there are also opportunities associated with the WTO entry and development potentials with Government efforts. Studies have revealed that investment by the Government still plays significant roles in promoting the overall economic development. This is especially true for investments in agricultural R&D and rural education (Fig. 11). The questions related to it are how to prioritize investment and how to encourage further investment in agricultural R&D and rural education. Also, various studies conclude that although grains, as a land-intensive commodity, do not have a comparative advantage in the world market, other commodities that are more labor-intensive do. These commodities include livestock, horticultural as well as aquatic products. The key for all of these sectors is to improve the quality or the standards of the products. And the ultimate, overriding question is how to balance trade-offs between growth, poverty and environment in the development process.

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ENHANCING LINKAGES BETWEEN CHINA AND THE WORLDFISH CENTER: SCIENCE, ENVIRONMENT AND AGRICULTURE

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Abstract

The chapter analyzes the dilemma for natural resources, environment and agriculture, and discusses the challenge of sustaining healthy aquaculture in China. The paper also describes the role of science and technology in environmental management and agricultural development, focusing on the experience of the Chinese Academy of Sciences (CAS). The interaction between research agencies and the implications for Government policy setting and local authority implementation is explained. The last section of the paper explores the complementary collaborative approach between CAS and the Consultative Group on International Agricultural Research (CGIAR), with special recommendations for the WorldFish Center and relevant CAS institutes.

The dilemma: resources, environment and agriculture

Food security has long been a priority in both the scientific and political agenda. The FAO estimates that 800 million people currently do not have adequate food. We will have to provide food for an extra 3 billion by 2025. Many continue to suffer hidden hunger, especially malnutrition due to protein and micro-nutrient deficiency in women and children. Borlaug believes that all food crops must increase by 50 per cent by 2025 to meet future requirements (MTM 1998).

Global agriculture is increasingly threatened by natural resource depletion and environmental degradation. The FAO predicts that two-thirds of the food production growth will be through intensified use of cultivated land. In addition, Brown (1997) has suggested that the slower rise in grain yields since 1990 reflects systemic difficulty in sustaining the gains (World Watch 1997).

A recent study by the International Food Policy Research Institute (IFPRI) and the World Resources Institute (WRI) reveals that world food production is degrading soils, parching aquifers, polluting waters, and causing the reduction of biodiversity (World Bank 2001). One can easily find soil degradation, deforestation, falls in ground water tables, and water pollution due to excessive use of fertilizers and pesticides.

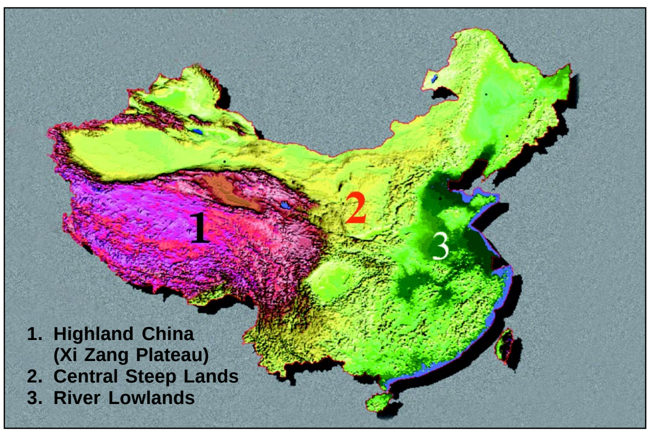
Confronted with two fundamental dilemmas – a) increasing demand and depleting natural resources; and b) accelerating economy and degrading environment – the situation in China is even more challenging!

The new challenges for agriculture in China can be summarized as:

- food security for 1.6 billion people under the pressure of resource depletion;
- rural economic safety for the 900 million majority rural people under the pressure of WTO entry; and
- sustainable use of natural resources and environment improvement under the pressure of agricultural intensification.

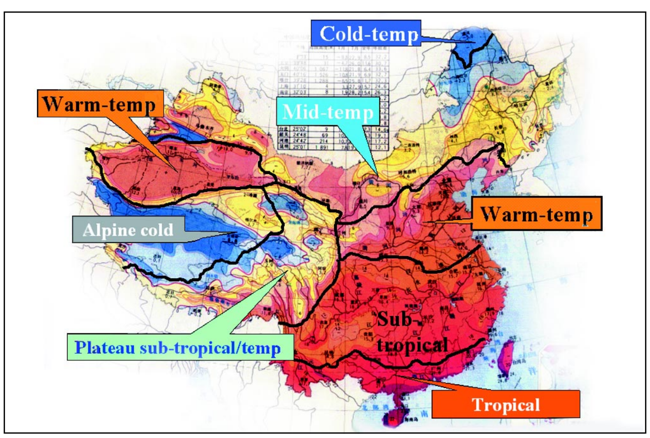
China has a vast amount of natural resources but they are small in per capita terms (Figs. 1- 4). The cropland per capita in China is only one third, water resources one-fourth, mineral resources one half, and energy two fifths of the world average, respectively. Prime farmland has been lost rapidly in the processes of urbanization and industrialization. Water scarcity is widespread, and the portion for agriculture is decreasing because of economic comparative disadvantage. Land and water, the basic resources for agriculture, are unevenly distributed. If we draw a line along the Yangtze River, it becomes evident that 64 per cent of the total cropland north of the river has access to only 17 per cent of the water while 36 per cent of cropland to the south enjoys 83 per cent of the total water (Hu and Wang 1992) (Fig. 5).

Fig. 1. Landform: three terraces.



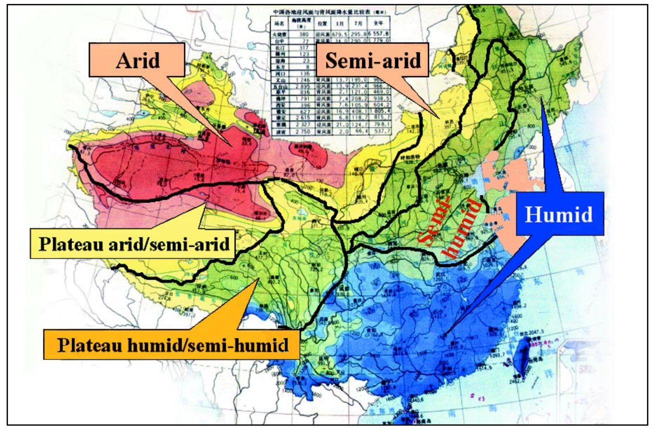
Source: Institute of Geographical Science and Natural Resource Research, Chinese Academy of Sciences (CAS)

Fig. 2. China's temperature.



Source: Institute of Geographical Science and Natural Resource Research, Chinese Academy of Sciences (CAS)

Fig. 3. China's precipitation.



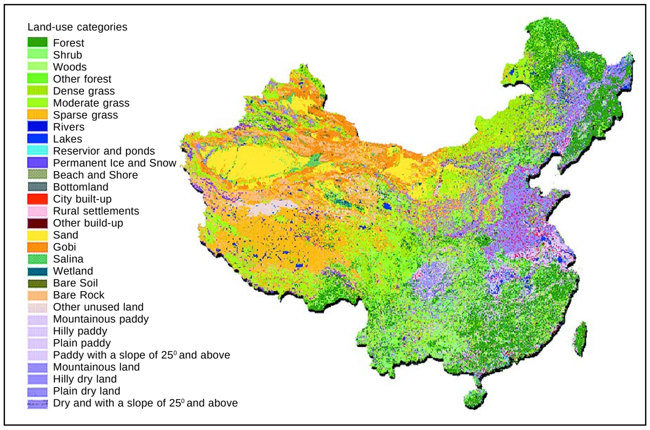
Source: Institute of Geographical Science and Natural Resource Research, Chinese Academy of Sciences (CAS)

Ecological and environmental constraints have posed even more impacts on agriculture. Soil erosion, salinization and desertification are inherent problems in the west, and are spreading rapidly to the north and northeast China. Food safety is threatened by pollution from the industry and cities. Agriculture is also becoming a new source of pollution, due to the excessive use of fertilizers and pesticides, animal waste from big farms, and intensive aquaculture. Eutrophication is now regarded as a "cancer" of the aquatic ecosystem in big lakes such as Taihu Lake in Jiangsu Province and Dianchi Lake in Yunnan Province.

The challenge: sustaining a healthy aquatic ecosystem

As crop/livestock-dominated agriculture faces increasing challenges of resource depletion and environmental degradation, aquaculture/mariculture remain an important solution to food security, employment and

Fig. 4. The land use map of China.



Source: Institute of Geographical Science and Natural Resource Research, Chinese Academy of Sciences (CAS)

revenue. Therefore, the way to sustain healthy aquaculture/mariculture in China is an important concern, which relates to the mandate of the WorldFish Center.

Aquaculture is a very important source of food, providing protein for 1 billion people, and the fisheries industry worldwide provides employment opportunities for 150 million people. In addition, aquaculture could assist in ecosystem services, including the conservation or replenishment of wild stocks, and for other uses such as recreation (Bert 2001). Xiang (2001) regards aquaculture as an essential supplement to land-based production in China (ICAST 2001).

Sorgeloos (2001), however, claims that both the food and aquaculture businesses pose serious threats to sustainability (ICAST 2001). Bert (2001) further explains that aquaculture can compromise habitats and biodiversity, and disrupt food webs. The Institute of Hydrobiology (CAS) has re-orientated its research foci from aquaculture productivity to lake eutrophication control (Nie 2002). Xie et al. (2001) observed that the introductions of bighead and silver carp pose a great threat to local fish communities. Xiang (2001) holds improper mariculture responsible for red tides in the sea (ICAST 2001).

A healthy aquatic ecosystem should provide animal protein and good water quality, rich biodiversity and many other services. This, in turn, will promote the sustainability of aquaculture in the long run. This approach is in line with the mission of the WorldFish Center.

Aquaculture in China accounts for 26 per cent of total world fish production, and supplies 44 per cent of China's meat production. In 1998, per capita fish products were 31.3 kg on an average, and net income was approximately US$ 1 000 per fisher (MOA 1998). In addition, China's aquaculture has been ranking number 1 in the world for about 10 consecutive years (FAO).

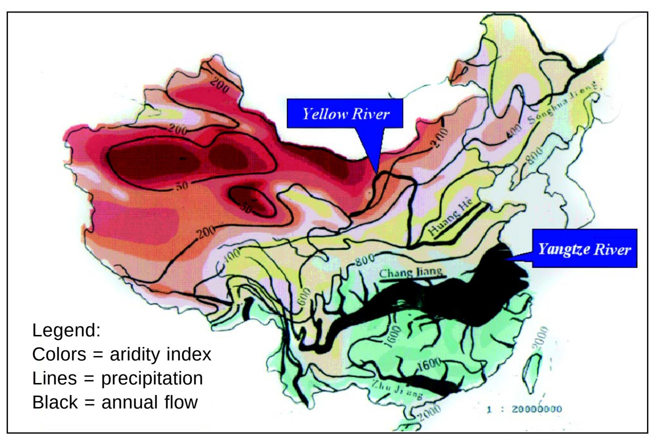
The favorable conditions for aquaculture development include its contribution to food security and changing patterns of nutrition, economic returns, resource potential, especially from mariculture with a coastline ranging for 18 000 km, and policy and technological advancement. However, aquaculture also faces great challenges such as:

- market competition, with other meat products as well as imported fishery products;
- limited resources, particularly, degradation of fresh water areas;
- pollution from dominantly non-point sources such as fertilizer and pesticide; rural living waste and waste from big animal farms – the main causes of the eutrophication of lakes.

As with the benefits from aquaculture, the negative consequences are also obvious. Aquaculture is also seen as:

- a source of pollution
- a cause of biodiversity reduction
- a factor in the degradation of aquatic ecosystems, which, in some cases have degraded to the lowest level: blue algal blooms.

Fig. 5. Unevenness of China's fresh water resources.



Source: Prof. Changming Liu

These factors, in return, could jeopardize the whole business. The deterioration process of Dianchi Lake in the last 20 years proves the statement. Prior to 1978, the lake was a clean and clear water body supplying drinking water and other water uses to the whole city of Kunming. From 1978, point pollution from the industry and the city were discharged to the lake, aggravated later by non-point pollution from agriculture and in a relatively corresponding period, the rapid growth of aquaculture. Until the early 1990s, the lake was grossly polluted with blue algae. As a result, aquaculture was totally banned by the State Council (Liu 2000).

It should be recognized that there is a conflict between different priorities, yet the priorities should be set in order. Sun et al. (2001) ranks the first priority for the aquatic ecosystem service in south China as supplying adequate safe drinking water, and the second priority as having a sound environment. Aquaculture comes in third, but it is not comparable to the first two priorities (CCICED-SAWG 2001). Accordingly, we have to find ways to sustain a healthy aquatic ecosystem for various services, in which aquaculture can be included if the approach is sustainable.

There are also institutional problems. Scientists may be far-sighted, but there is a long way to go before the research findings are brought to policy-makers. As aquaculture and related environmental issues are cross-cutting issues, different administrations dealing with these issues have different priorities. For instance, the Ministry of Agriculture may stress the augmentation of productivity and its role in income generation while the State Environmental Protection Administration puts the control of eutrophication on the top of their priority list. In addition, there are also conflict between central and local Governments, and even among different interest groups in the same area.

The options: the role of science and technology

The role of science and technology in developing environmentally sound agriculture is obvious, yet limited to some extent. The interaction of science and environment is a dynamic, multi-faceted process because science plays different roles at different stages and within different contexts. The contribution of science to the increase of agricultural productivity has been great, similarly for industry. Yet as "science creates pollution, so science creates solutions".

The consultation on environmental management provided by academicians of the Chinese Academy of Sciences is quite unique and significant. Based on the recommendations and widespread consultation, the Government of China took environmental protection as one of the two most important national policies. Consequently, the Committee of Environment and Resources in the National Peoples' Congress was established in the late 1980s, followed by the formulation of environmental laws, and establishment of the State Environmental Protection Agency and EPAs at different levels of local authorities. The China Council for International Cooperation on Environment and Development (CCICED) was established in 1992 to tackle the most important issues of environment and development, utilizing advice from Chinese and international expertise. This creative approach bridges the gap between the scientific community and high level policy-makers and, likewise, research and policy-setting (Liu 1994; 1997).

The Chinese Academy of Sciences was established in 1949 and is a ministerial-level research institution directly under the State Council. It targets basic, strategic and pilot research and high-technology R&D at the national level. There are 5 academic divisions for Government consultation and advice, 87 institutes nationwide, 50 national laboratories, and 107 field research stations. The total number of staff is about 60 000. Since 1998, under the auspices of the central Government, the Chinese Academy of Sciences has been undertaking the Knowledge Innovation Program (possibly its greatest reform since 1950). Between 1998 and 2005, staff numbers will be reduced from 70 000 to 30 000 plus 30 000 graduate students, post-doctoral students and visiting scholars. The number of institutes will be reduced from 123 to approximately 80. It is an incremental reform with an extra investment of some RMB 20 billion (US$ 2.5 billion) during the eight-year period, after which the funding will become fixed core-funding from the Government.

The academy's new policy began to operate in 2002 and includes as its objectives:

- to meet the national strategic need;
- to catch up the frontline of science and technology advancement;

- to strengthen the creation of new knowledge;
- to strengthen the breakthrough and synthesis of key technologies; and
- to make basic, strategic and pilot contributions to national economic development, social progress and national security.

There are five professional bureaus within the headquarters of the Chinese Academy of Sciences; these include the Bureau of Basic Research, Bureau of High-technology, Bureau of Life Science and Bio-technology, Bureau of Research and Development, and Bureau of Science and Technology for Resources and Environment (BRE).

The mission of BRE is:
- to promote the advancement of science and technology for resources and environment management;
- to strengthen the competitiveness of research teams in key disciplines within CAS; and
- to make use of such knowledge to contribute to sustainable development.

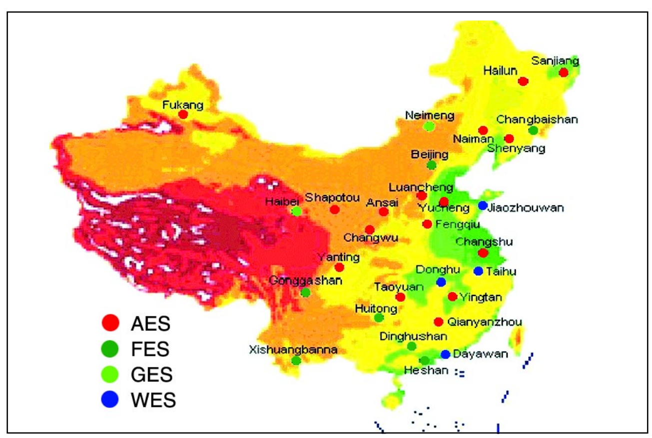
The mandate of BRE is as follows:
- to formulate strategies for studies on resources, environment, ecology and agriculture within CAS,
- to be responsible for the Knowledge Innovation Program of administered institutes, and
- to set policies and plans for R&D programs to guide research activities in such disciplines
- to organize and supervise project implementation
- to coordinate inter-institutional relations and develop collaborative partnerships.

BRE has official links with 18 of the total 27 ministries in China. The Ministry of Agriculture, the State Environmental Protection Agency and the State Development Planning Commission are among those important users of the Bureau's research work. BRE also has links with 25 of the 34 provinces, municipalities, and autonomous regions. The Bureau's links to the International arena are widespread, through international programs such as International Geosphere-Biosphere Programme (IGBP), World Climate Research Programme (WCRP), International Human Dimensions Programme or Global Environmental Change (IHDP), World Data Centers for Space Science (Beijing Astronomical Observatory, CAS) (WDC-D), Global Terrestrial Observation System (GTOS), Global Environment Facility (GEF), Intergovernmental Panel on Climate Change (IPCC), United Nations Educational, Scientific and Cultural Organisation (UNESCO), Man and the Biosphere Programme, UNESCO (MAB), International Council of Scientific Unions (ICSU), Institute of Applied Physics (IAP), United Nations Environment Programme (UNEP), United Nations Development Programme (UNDP), International Centre for Integrated Mountain Development (ICIMOD), Food and Agriculture Organisation of the UN (FAO), World Bank (WB), World Wildlife Fund (WWF), Consultative Group on International Agricultural Research (CGIAR), European Union (EU), Asia Pacific Economic Cooperation (APEC), Australian Council for International Agricultural Research (ACIAR), Canadian International Development Administration (CIDA), Japan International Cooperation Agency (JICA), and National Science Foundation (NSF).

The China Ecosystem Research Network (CERN), as a founding member of the International Long Term Ecosystem Research Network (ILTER) and Global Terrestrial Observation System (GTOS), shows how research is translated to regional development (Fig. 6).

The mission of CERN is:
- to promote ecosystem conservation and improvement, environmental quality enhancement and agricultural development; and
- to promote the advancement of ecology and related inter-disciplinary studies. Its mandate includes monitoring, research and demonstration on typical ecosystems in China. It consists of 29 field research stations of various ecosystems, agriculture, forestry,

Fig. 6. Distribution of CERN's Field Stations.



Source: Chinese Ecosystem Research Network

Fig. 7. CAS institutes concerned with aquatic ecosystems.

grassland and waterbodies, five disciplinary centers and a synthesis center. For several years, it has been serving as an important facility to control desertification, soil erosion, salinization, and eutrophication, through its long-term monitoring, research and experimentation, demonstration and extension.

At this point, the CAS institutes involved in aquatic ecosystem research are (See Fig. 7):

- Institute of Hydrobiology (Wuhan, 1930)
- Institute of Oceanology (Qingdao, 1950)
- South China Sea Institute of Oceanology (Guangzhou, 1950)
- Nanjing Institute of Limnology and Geography (Nanjing, 1940)

The Institute of Hydrobiology is regarded as the pioneer of freshwater aquaculture and related research in China. The focus of the institute is to understand the interaction between freshwater organisms and the environment. Recently, the institute has re-oriented its research to focus on eutrophication, water pollution and sustainable development of lake fisheries, as well as aquaculture-related sciences. In line with the re-orientation, the institute has been restructured into the following centers and laboratories:

- Center for Freshwater Biodiversity and Resource Protection
- Center for Freshwater Ecology (including the Donghu Station)
- Center for Aquacultural Biotechnology
- Center for Water Environment Engineering
- Freshwater Ecology and Biotechnology Laboratory (FEBL)
- National Engineering and Technology Research Center for Freshwater Fishery.

The Institute of Oceanology is recognized as the pioneer of mariculture in China. Its new research foci are concentrated on:

- theory and key technology for "blue agriculture"
- dynamic processes of the marine environment and ecosystems
- dynamic process of ocean circulation
- evolution of the continental shelf and its effect on resources and environment
- key Laboratory of experimental marine biology and bio-technology
- marine ecology and environment
- ocean circulation
- marine geological process and paleo-environment
- marine bio-technology application and development
- marine environmental engineering and technology development.

The South China Sea Institute of Oceanology concerns itself with the South China Sea, a vast area in southern China encompassing subtropical and tropical areas alike. Their research foci include:

- dynamic environmental process of tropical ocean: physical, chemical and biological coupling processes.
- sustainable use of living aquatic resources in the tropical ocean
- geological evolution of continental shelf.

The Nanjing Institute of Limnology and Geography is the national center for lake studies with its foci on modern lake process, big river basin management and past lake evolution related to paleo-environmental change. The key area under study is mainly the Yangtze River, especially Taihu Lake. The structure of the institute includes:

- Key Laboratory of Lake Sediment and Environment
- Laboratory of Lake Resources and Environment
- Taihu Lake Ecosystem Research Station
- Laboratory of Basin Management and Simulation
- Laboratory of GIS and Mapping.

The way forward: a collaborative approach

We recognized that:

- the range of the CGIAR's partnerships are being broadened to include other organizations with a

shared commitment to the mission and goals of CGIAR (MTM 1998). The mission of the CGIAR is to contribute, through its research, to promoting sustainable agriculture for food security in the developing countries; and
- the CGIAR conducts strategic and applied research on increasing productivity, protecting the environment, saving biodiversity, improving policies, and strengthening agricultural research in developing countries.

The Chinese Academy of Sciences, with its overall policy change and shift of research foci in the domain of ecology, agricultural science, environmental science, related disciplines and interdisciplinary studies, has both the commitment and capacity to collaborate with many of the CGIAR centers.

Further, we recognize that the mission of the WorldFish Center is to promote sustainable development and use of living aquatic resources based on environmentally sound management with the following five mandates (which match those of our concerned institutes):
- raise and sustain the productivity of fisheries and aquaculture systems;
- protect the aquatic environment;
- save aquatic biodiversity;
- improve policies for sustainable development of aquatic resources;
- strengthen the capacity of national programs to support sustainable development.

We believe that the appropriate CAS institutes anticipate and are capable of, collaboration with all the research programs of the WorldFish Center including work on:
- biodiversity and genetic resources,
- coastal and marine resources, freshwater resources,
- policy research, and impact assessment, and in extending,
- partnerships, information and training.

Finally, we are confident that the collaboration between CGIAR and CAS, and/or between the Center and CAS concerned institutes are both complementary and will strengthen links between the institutes. CAS will not only be a recipient partner of CGIAR's technologies, but a donor and comrade as well.

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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.

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RESEARCH PRIORITIES OF THE CHINESE ACADEMY OF FISHERY SCIENCES (CAFS)

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Abstract

China has made outstanding progress in the fisheries industry since 1978 when the open policy and economic reforms were adopted. This chapter looks at the performance of the fisheries industry and the major problems it faces. The final section examines the role and scope of CAFS in addressing some of the concerns in the fisheries industry.

China's Fishery Industry

China has made outstanding progress in the fisheries industry since 1978 when the open policy and economic reforms were adopted. As a top fish producer in the world, China's fisheries output in 2000 was 42.79 million t, making up one third of the world's total. The total fisheries production value was RMB 184 billion (US$ 22.17 billion). The country's aquaculture production has exceeded its capture fisheries, reaching 24 million t in 2000 and contributing to two third of the world's aquaculture. The GDP of the fishery sector was RMB 280.8 billion (US$ 33.83 billion), accounting for 11.6% of the country's agricultural GDP. Fishers' average income has gone up to RMB 4474 (US$539), about double that of agriculture farmers. The industry has provided 12.57 million job opportunities. In terms of international trade in 2000, China's fish exports were reported as 1.534 million tons in volume and US$ 3.83 billion in value, and the imports as 2.52 million tons in volume and US$ 1.85 billion in value. The following figures and tables (Tables 1-7) illustrate the recent development of China's fisheries industry.

Major Problems of China's Fisheries Industry

China has made great achievements in its fisheries industry, but it is also faced with a number of problems.

Decline of natural fish resources

Marine capture fisheries used to be important to China's fisheries industry. Between the 1950s and 1960s, China's annual marine fishing production was about 2 million t, and the products mainly comprised commercially important bottom species such as great yellow croakers, small yellow croakers, hairtails, flounders, cods and squids. However, from the mid 1970s, low valued species gradually took over from the above species. It was reported that since the 1980s, pelagic species accounted for a larger share of production. For example, survey statistics between 1982 and 1988 showed that small pelagic fishes such as anchovy, black scraper, and pacific herring accounted for 60 per cent of the total biomass. From 1992 to 1993, marine invertebrates declined by 39 per cent and fish

Table 1. Import and export of China fish products.

Year	Export Volume (1 000 t)	Export Value (billion US$)	Import Volume (1,000 t)	Import Value (billion US$)
1996	802	3.297	1 387	1.204
1997	922	3.140	1 513	1.220
1998	1 003	2.840	1 141	1.020
1999	1 348	3.140	1 305	1.290
2000	1 534	3.830	2 520	1.850

spawning biomass fell to only 30 per cent compared to that of 10 years earlier. Biomass of commercially important species like perch, Chinese herring, sea bream, flounder, sole, shrimp and crab decreased to 29 per cent while anchovies increased by 2.4 times. Data from 1998 again revealed that biomass in the Bohai Sea was down to 11 per cent of that in 1992. A similar situation took place in the East China Sea, where although some species stayed stable in biomass (such as hairtail, chub mackerel and some shrimps), their populations tended to be younger and smaller.

Fish resources in inland waters are in an even worse state than those in marine waters. Most places have been over-developed by improper production modes, which have threatened China's fresh water ecosystems and biodiversity.

Deterioration of water environment

With the rapid development of China's economy, it is inevitable that pollution becomes more and more serious. It is reported that among the 1 200 rivers in China, 850 have been more or less polluted, and 61 per cent of the lakes are estimated to be eutrophic. Pollution in coastal waters is increasingly severe. Three hundred and ten red tides were recorded during the 1990s along China's coastal areas. Cage fish farmers in Guangdong and Hongkong lost about RMB 350 million between October 1997 and April 1998 due to successive red tides. Not long after that, an area of 50 million mu in the northern China Sea was invaded by red tide, killing a great number of molluscs and resulting in RMB 500 million losses. Most pollutants are from industrial and household discharges such as petroleum, paint, detergent, textile, plastics, pesticides and herbicides. Aquaculture itself in some areas also results in pollution. For example, the feed residuals, fish wastes, dead fish, fertilizer and fish drugs are all considered sources of pollution.

Lack of advanced technologies

China's fishery, in general, is still a less industrialized industry although its production takes first place in the world. The production modes in most areas are still backward. Apart from a few modernized fishing fleets and fish farms, scattered artisanal fishers and fish farmers dominate both capture fisheries and aquaculture. The industry is considered vulnerable and has a long way to go in terms of modernization.

Lack of good breeding stocks

China has a long history in aquaculture. However, only a few breeding stocks have been strictly selected for aquaculture so far. Most breeding stocks, even 70 per cent of that of Chinese Carps that are the major aquaculture species in China, are simply taken from the wild. As a result, it impacts negatively on the aquaculture of many species and this is exemplified by degeneration, low growth rate, weak anti-disease resistance, and bad quality.

Lack of control in the management of diseases

Disease is one of the major obstacles to China's aquaculture. Up to now, few effective measures have been worked out to control diseases. So, China's aquaculture still suffers severe economic loss due to widespread diseases. It is reported that over RMB 12 billion is lost annually in China's aquaculture as a result of the lack of control in the management of diseases.

Fig. 1. Fishery production as a share of agricultural production.

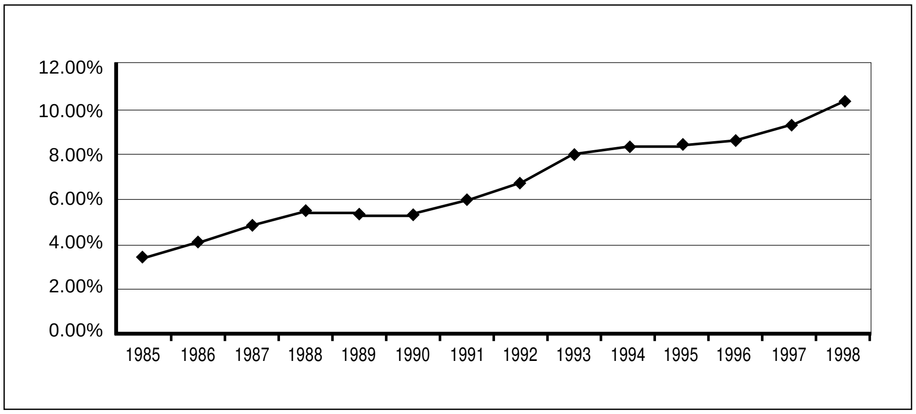


Fig. 2. Per capita availability of some animal products (kg) 1985-1998.

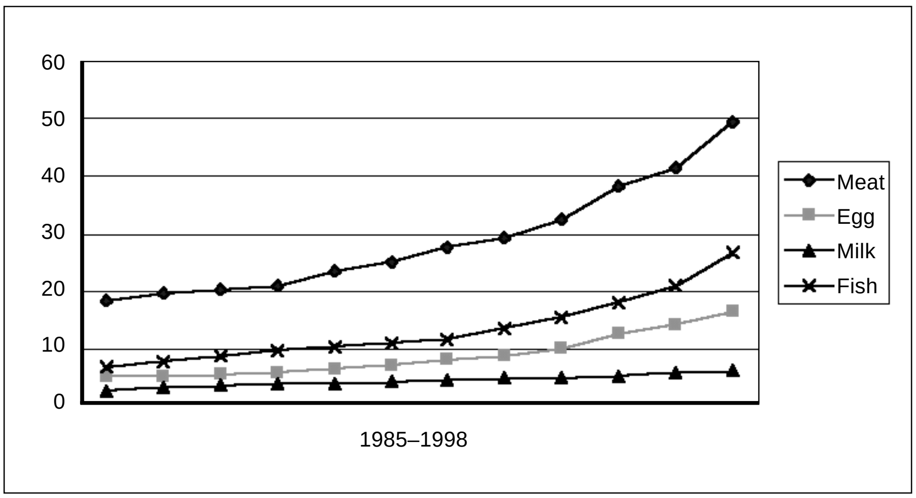


Fig. 3. China fishery production (10 000 t) 1978-2000.

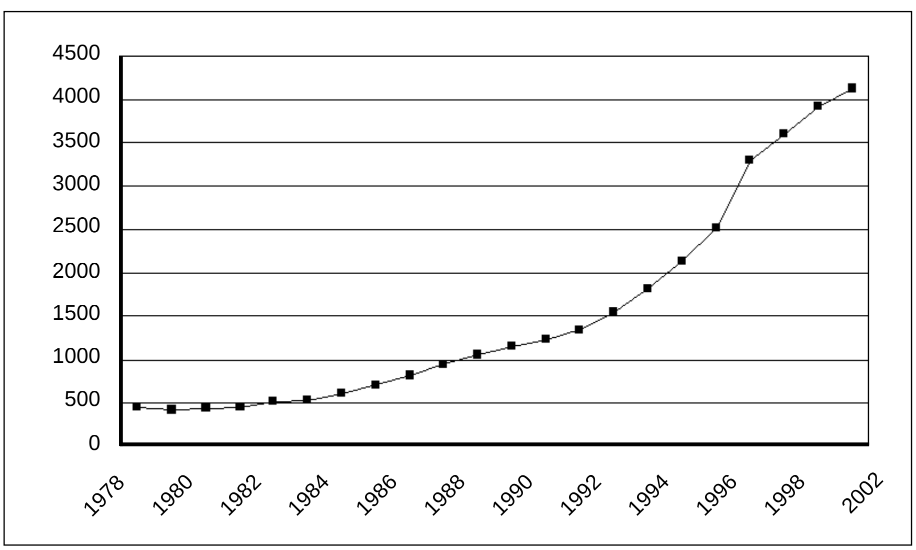


Fig. 4. Production share of aquaculture and capture fisheries.

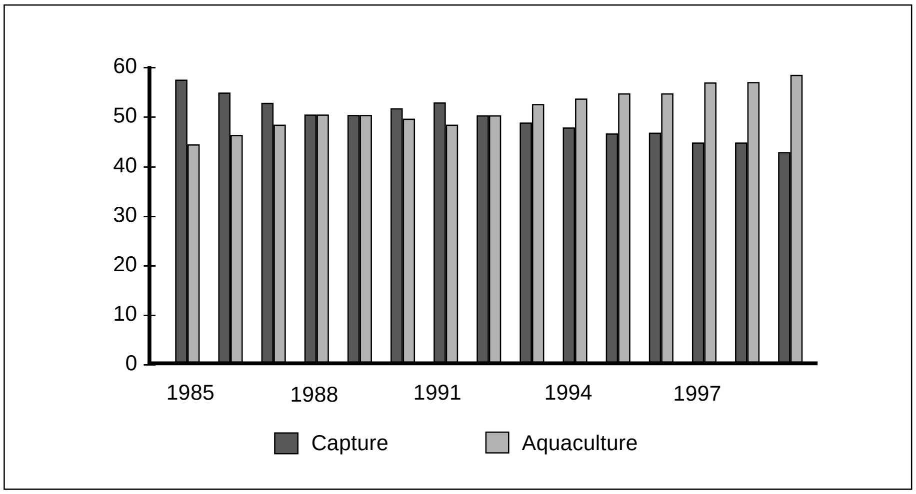


Fig. 5. Production share between marine and inland waters.

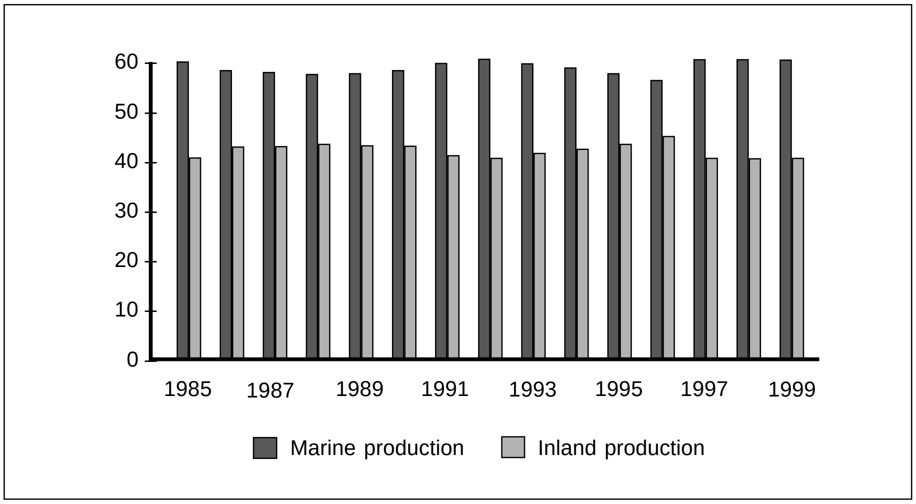
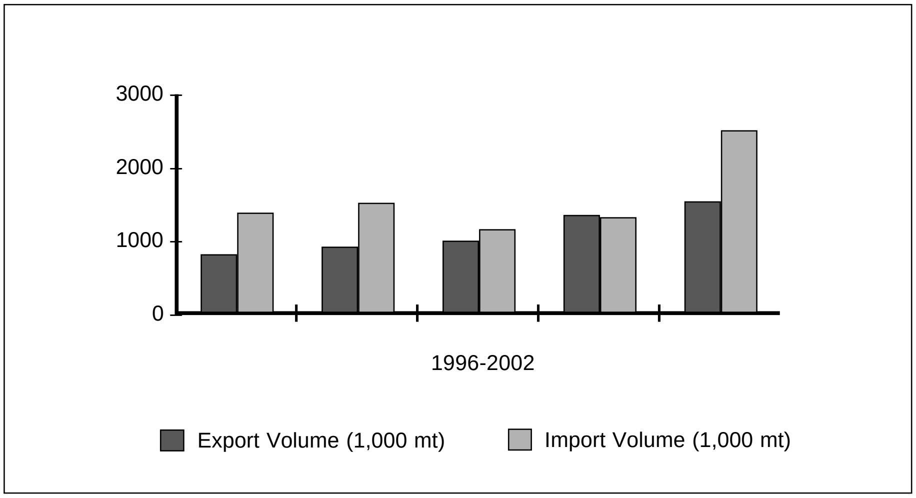


Fig. 6. Comparison of export and import in volume.



Backward fish processing technologies

China's fish processing technologies are relatively backward in the world. Only 30 per cent of landed fish are processed compared to 70 per cent in developed countries. The majority is simply iced or refrigerated. Few high value added technologies have been developed. Fresh water fish are almost always sold alive.

THE OFFICIAL ROLE AND SCOPE OF ACTIVITIES OF CAFS

CAFS, which operates directly under the Ministry of Agriculture, has a total of 2 343 staff currently, of whom about 340 are senior research fellows including three academicians of the China Engineering Academy. With its headquarters in Beijing, the capital of the country, CAFS has 15 branches located in different parts of China (Fig. 8). Among them, three are engaged in marine fisheries and aquaculture, four are focused on inland water fisheries and aquaculture, four are specialized in aquatic resource-related areas and four are responsible for fishery resource enhancement.

As a national fishery research institution, CAFS aims to conduct various and comprehensive applied research to help fishery and aquaculture production in China. Its research scope covers almost everything in terms of fishery and aquaculture such as fish breeding, disease control, fish nutrition, fish processing, fishing technology, resource assessment and conservation, environment protection, fishery criteria, policy and development strategy, and information dissemination.

Over the last decades, CAFS has achieved a number of research results, of which 35 were given awards by the central Government and 335 by the Ministries or Provincial Governments.

RESEARCH PRIORITIES FOR CAFS

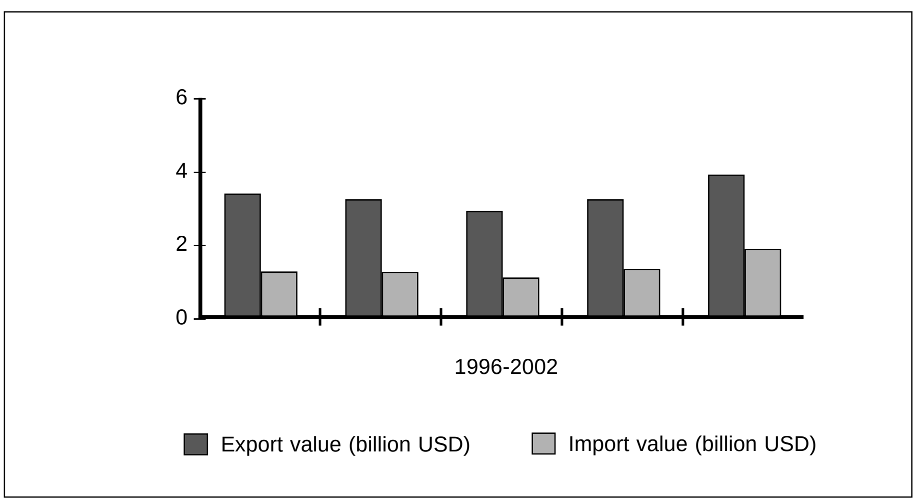
Marching into the 21st century, China's fisheries will encounter many new challenges. The main challenges are:

- increasing the income of fishers and fish farmers as most fishers and fish farmers are still living in poverty
- improving the quality and varieties of fish products in order to promote international trade
- restructuring China's fisheries industry in accordance with the new international marine management regime
- encouraging sustainable fishery development so as to save limited resources and protect the environment

According to the mandates above, CAFS as a national fishery research institution will focus its research interests in the following areas in the near future.

1. Marine fishery resource assessment and sustainable utilization
    - resource monitoring and assessment
    - evaluation for fishing quotas

Fig. 7. Comparison of export and import in value.



- selective fishing gears
- evaluation of resource enhancement with artificial reefs

2. Protection of fishery ecosystem
   - evaluation of fishery environment and ecosystem
   - bio-restore and optimize ecosystem technologies
   - evaluation of technology for increasing aquaculture capacity in natural waters
   - aquaculture technologies in shallow sea, mud field and lake
   - pollution control in aquaculture

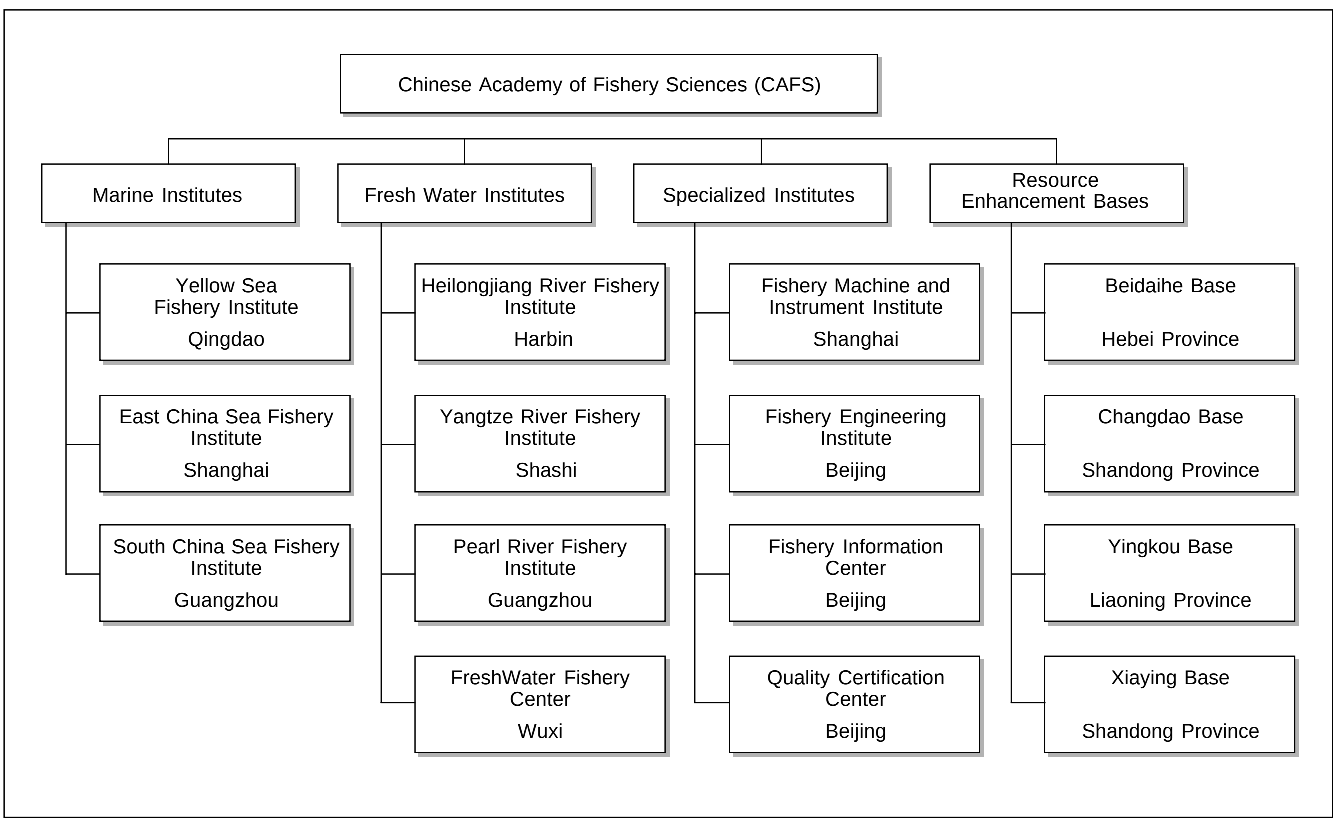
3. Conservation of aquatic biodiversity and fish germplasm
   - fish germplasm identification and characterisation
   - fish genetics and gene mapping
   - conservation technology for fish germplasm
   - conservation technology for endangered species

4. Selection of improved varieties and fish breeding
   - identification of new varieties
   - combination of conventional selection with biotechnology
   - artificial breeding of fish and shrimp on a large scale

5. Disease control
   - healthy aquaculture
   - prediction for hazard disease in aquaculture
   - fast detection and diagnosis of aquaculture pathogens
   - vaccine preparation and technology for improved immunity
   - creation of low residual fish drugs, non-hazardous to the public

6. Technology aquaculture
   - high density culture technology
   - water processing technology
   - anti-wave technology for inshore aquaculture
   - aquaculture engineering

Fig. 8. The organisational structure of Chinese Academy of Fishery Sciences (CAFS).



7. Distant water fishing
   - fishing technology for tuna and squid
   - high technology fishing vessels

8. Fish processing and food safety
   - improvement of fish quality and flavor
   - fish processing technology
   - healthy fish products

9. Information technology
   - fishery management information system
   - networking and development
   - information and publication
   - Geographical Information System (GIS), Global Positioning System (GPS) and Remote Sensing (RS) technologies

10. Fishery policy
    - market economy reform
    - fishery development strategy
    - international trade
    - WTO and China's fishery policy

Current Research Projects of CAFS

"973" National Significant Basic Research Program

- Ecological dynamics of the East China Sea and Yellow Sea and sustainable utilization of the biological resources, *Yellow Sea Fishery Research Institute, Qingdao*

"863" National High-Tech Research Program

- Development of new Marine enzyme, *Yellow Sea Fishery Research Institute, Qingdao*
- Engineering optimization for breeding facilities of molluscs, *Yellow Sea Fishery Research Institute, Qingdao*
- Genetic improvement of *Penaeus chinensis, Yellow Sea Fishery Research Institute, Qingdao*
- Engineering optimization for industrial high density aquaculture, *Yellow Sea Fishery Research Institute, Qingdao*
- Comprehensive disease control and demonstration of industrial culture of Turbot (*Scophthalmus maximus*), *Yellow Sea Fishery Research Institute*, *Qingdao*
- Immunity mechanism and factors analysis on triploid *Chlamys farreri, Yellow Sea Fishery Research Institute*
- Large scale artificial breeding of *Peneaus monodon, South China Sea Fishery Institute, Guangzhou*
- Development of major vaccines for some cultured marine fishes, *Pearl River Fishery Institute, Guangzhou*
- Industrialized breeding of high rate male Tilapia with gene engineering, *Fresh Water Fishery Research Center, Wuxi*
- Establishment of pure and ecologically secured gene transferred Common Carp, *Heilongjiang River Fishery Institute, Harbin*

National Key Research and Development Program

- Key technologies and facilities on plant and fish culture
- Anti-wave technology and facilities for deep sea net cage fish culture
- Ecological aquaculture technologies in inland waters
- Technologies for healthy marine aquaculture
- Selection of improved aquaculture varieties and the artificial breeding technology
- Manufacturing of high value fish feed

Internal cooperation within China

In addition to the strong linkages among its internal institutes, CAFS also seeks collaboration with other institutes in China such as the Oceanic Institute of CAS; the Institute of Hydro-Biology, CAS; the institutes from the State Oceanic Administration (SOA), universities like Qingdao Oceanic University, Shanghai Fishery University, and Dalian Fishery University and local fishery research institutes and extension stations.

Ongoing International Collaborations of CAFS

Currently CAFS has extensive international collaboration. Over the last decade, it has developed a number of international projects with countries including the United States, Japan, Norway, Korea, and EU, and such international organizations as FAO, UNDP, The WorldFish Center, and NACA (see the project list of international collaboration). Examples are as follows:

China-US Marine and Fishery S&T Agreement

- Shrimp virus
- Specified Pathogen Free (SPF)/Specified Pathogen Resistance (SPR)
- Effect of sex hormone on fish reproduction physiology and behavior
- Ecology of marine virus
- Analysis of harmful algae bloom
- Analysis of mollusk toxin (PSP)
- Biological decomposition of organic pollutant in marine environment
- China information web page

China-Norway Project

- Utilization of liquid protein

China-EU Project

- Marine aquaculture capacity and sustainable resource management

China-Korea Projects

- Prevention of fish diseases with natural medicines
- Analysis of harmful red tide organisms along the China and Korea coasts
- Comparison of mollusk germplasm and aquaculture ecosystems in different areas

Responding to National Priorities

Most of the priorities are based on the requirements of the State Council. CCAFS applies to conduct national research projects according to the guidelines released from various agencies of the State Council, especially from the Ministry of Science and Technology and the Ministry of Agriculture. The State Council research bidding system has only started in recent years, and most projects are now subjected to public bids. Some projects are conducted with support from local Governments and the industries in line with their demands.

The Chinese Government has paid great attention to the issues of environment protection and sustainable development. So, a number of research projects from the Government are concerned about production and also concerned about the environment and ecosystem protection. For example, CAFS is conducting such projects as:

- marine fishery resource assessment and sustainable utilization, resource monitoring and assessment
- evaluation for fishing quotas, selective fishing gears
- evaluation of resource enhancement with artificial reefs
- evaluation of fishery environments and ecosystems
- bio-restoration and optimization of ecosystem technologies
- evaluation technology for aquaculture capacity in natural waters
- aquaculture technologies in shallow sea, mud field and lakes
- pollution control in aquaculture.

For all areas of research, the research results are basically provided to the Government as advice for policy making. They are also provided to the industry to alert them to the problems faced by the national agency so as to influence and adapt the behavior of the fishery and aquaculture sectors.

Opportunities For Collaboration

Noting The WorldFish Center's focus on the poor, livelihoods, and environmental management it may, in the future, play a significant role in collaborative approaches to the following key areas:

- health in aquaculture
- the introduction of new varieties for aquaculture
- disease control
- facilitating the practices of aquaculture
- resource and environmental management
- post-harvesting technologies
- information exchange, and seminars
- personnel training.

APPENDIX 1
PROGRAM

21ST BOARD OF TRUSTEES MEETING ON "ENHANCING LINKAGES BETWEEN CHINA AND THE WORLD FISH CENTER"

5 March 2002 (Tuesday)
The WorldFish Center, Penang, Malaysia

Time	Speaker	Topic
0830 – 0840	Dr Meryl J. Williams *Director General* *WorldFish Center*	Welcoming remarks
0840 – 0850	Dr Peter R. Gardiner *Deputy Director General – Science Quality Assurance and Project Development* *WorldFish Center*	The WorldFish Center's current activities in China
0850 – 0920	Dr Zhang Linxiu *Deputy Director* *Center for Chinese Agricultural Policy* *Chinese Academy of Sciences*	Agricultural and rural development in the New China
0920 – 0950	Professor Liu Jian *Director Division of Ecology, Environment and Agriculture* *Bureau for Science and Technology for Resources and Environment* *Chinese Academy of Sciences*	Natural resource and environmental management in China
0950 – 1000	Discussion	
1000 – 1030	Coffee Break	
1030 – 1100	Professor Li Sifa *Key Laboratory of Ecology and Physiology* *Laboratory of Aquatic Genetic Resources* *Shanghai Fisheries University*	Aquaculture research and its relation to development in China
1100 - 1110	Discussion	
1110 – 1140	Professor Yang Ningsheng *Director of Information Center* *Chinese Academy of Fisheries Sciences*	National priorities for fisheries research in China
1140 - 1230	Discussion	

APPENDIX 2
PROPOSED AREAS FOR COLLABORATION WITH CHINESE INSTITUTIONS

RESEARCH AREA 1
Determination of high-potential aquaculture development areas and impact in eastern and western China

***Research focus*:** Identification of factors responsible for successful development of rural and commercial aquaculture and extrapolation of the domains for aquaculture development in eastern and western China with high potential benefit.

A multidisciplinary project that will start with an analysis of historic successes and failures in aquaculture development in eastern and western China, with a particular focus on tangible impacts for the poor on one side, and economic and supply successes on the other. Subsequently, using information on agroecological conditions, farming systems, aquacultural potential, institutional capability for diffusion, socioeconomic conditions, market demand, input-output delivery systems, and policy environment, the potential for aquaculture development and its impact on different groups of the society will be estimated under alternative scenarios. These will be formulated as model relationships that will be incorporated into geographic information systems (GIS) to produce spatial and temporal estimates. The system will be installed on an Internet website and can be accessed by external users to produce estimates, based on own entries of enabling factors (for example, technology interventions and improvements, training and advisory services, cost). The resulting scenario maps will provide an important decision making tool to identify where support for promoting aquaculture for small and marginal farmers can give maximum impact. Scientists can use the tool to estimate what technology innovation steps they need to invent in order to achieve targeted gains under given scenarios.

The WorldFish Center is just commencing a project funded by Germany, which will conduct the above-described studies in two countries in Africa (Cameroon and Malawi) and two countries in Asia (Bangladesh and Thailand). It will establish a network of cooperators applying the same methodologies and hold regular project workshops, the first of which is planned for October of November 2002. In case there is interest from colleagues and institutions in China to participate in this activity at their own cost, they could be invited to our workshops and materials and methods will be shared with them. FAO has already expressed interest to be a cooperating partner in this activity.

RESEARCH AREA 2
Genetic Characterization, Conservation and Use of Common Carp

***Research focus*:** Common carp is the fourth most important freshwater fish in Chinese aquaculture. Both the farmed and wild stocks of Common carp constitute an extremely valuable resource both from a biodiversity point of view and due to their potential for enhancement for food production purposes.

Common carps are widely distributed and highly adaptable. There are various carp strains, and they exhibit a wide range of morphological variability that has been achieved through breeding and crossbreeding. There has been no systematic evaluation of the potential of the various strains of common carp that are found in China and how effectively they could be utilized for genetic up gradation. Many of the traits that are being targeted for genetic enhancement like disease resistance, environmental tolerance, flesh quality and reproductive parameters could be already found in these domesticated strains.

The objectives of the study would be:

(i) to evaluate the variance in disease resistance, environmental tolerance, flesh quality and reproductive parameters in the different domesticated strains of common carp;

(ii) to evaluate the genetic variability of different strains;

(iii) based on phenotypic variance of important traits and genetic variability, to identify potential stocks that could be utilized: a) more extensively in aquaculture across various regions of China;

b) initiate steps for conservation of these strains; and c) evaluate and implement a program of cross breeding combined with selection to combine the better strains.

The objectives (i) and (iii) could be carried out by institutes having the quantitative genetics expertise and facilities for carrying out breeding and objective (ii) by those working on molecular markers. In both these areas, the Center can contribute and facilitate research programs utilizing its existing INGA network.

Research Area 3
Carp Genomic Library and Marker Assisted Selection

***Research focus*:** Common carp is one of the important cultivable species in China and many parts of the world. It is also representative of the carp group of species, which contribute to overall fresh water fish production. But unlike salmonids and tilapias the work on carp genomic is comparatively less. Many laboratories have been working on the molecular genetics of salmonids and tilapias and the results of these studies are being presently applied in marker assisted selection programs. There is considerable molecular genetic information on the carp, *Danio rerio* that has been used as a model species. By combining the molecular genetic information in model species with the emerging technique of marker-assisted selection, it is possible to initiate such programs in common carp.

The objectives of the study would be:
(i) to construct marker maps of carp genome;
(ii) cloning and characterization of specific genes;
(iii) to screen specific strains of common carp with these markers;
(iv) to utilize these markers in marker assisted selection programs.

The institutes with a strong background in molecular genetics with links to those organizations working on common carp selection programs can undertake this work. In many of the countries which participated in the Center's Carp genetics research project Phase I, carp genomic work is being initiated in many carp species like rohu (*Labeo rohita*). The WorldFish Center would be able to link these institutes as well as advanced institutes to achieve the required synergy for the work on carp genomic.

Research Area 4
Strategies and Options for Increasing and Sustaining Fisheries and Aquaculture production in China

***Research focus*:** The specific objectives of the study are to:
i) analyze policies, institutional environments, and support services in the fisheries and aquaculture sector;
ii) analyze factors determining demand for fish and aquatic products by fish species and income groups;
iii) analyze factors determining supply of fish and aquatic products by categories;
iv) make projection on future demand, supply, and trade of fish in China;
v) analyze the impact of technological change and policy intervention on poverty reduction; and
vi) identification of appropriate policies and options for sustainable fisheries development of the country.

Background: Since the economic reform initiated in the late 1978, China's economy has been growing substantially. The average annual growth rate of China's GDP reached 9 per cent in 1990s. Successful transformation of China's economy is based on economic growth in the agricultural sector. Agriculture has made important, but declining contributions to national economic development in terms of gross value added, employment, capital accumulation, urban welfare, and foreign exchange earnings.

In contrast to the declining role of the general agricultural sector in the national economy, China's fishery sub-sector keeps up with the overall economic growth, meeting the needs created due to the change in consumption pattern, and contributing to the improvement of the living standard of Chinese people. With the rapid growth of the economy in China, people's living standards have continued rising and demand for aquatic products has been growing. Per capita consumption of aquatic products rose by 6.5 per cent per year during the last decade.

With the rapid growth of national economy and changing trade regimes, many questions emerge in fishery sub-sector. What are the main sources of growth in China's fisheries and aquaculture production? What are the impacts of policies such as "zero growth in marine captured fishery regulation" on fishery sector? What are the factors that affected aquaculture production in the past? What will be China's demand for aquatic products? What are the impacts of market liberalization on fisheries and aquaculture production? What will be the impact of China's entry to WTO on its fisheries and aquaculture sector? And what are the determinants of increasing and sustaining aquaculture production in the future?

Research Area 5
Excess Capacity in Chinese fisheries

***Research Focus*:** The study would involve assessing fishing capacity in different regions of China by gear type and policies in vogue to reduce excess capacity, success and constraints in implementation of existing policies if any and come up with suggestions for the policies needed for reducing excess capacity and the strategies for implementation of these policies.

Research Area 6
Certification and ecolabelling of Chinese fisheries

***Research focus*:** The study will look at issues surrounding certification and ecolabelling of fisheries. The extent to which the Government. is willing/can buy in to certification. How the Government sees and needs to see the certification schemes as an approach to sustainable management of fisheries; impact of certification on small-scale fisheries.

Research Area 7
China FishBase

***Research focus*:** To achieve sustainable management requires structured resource management information, appropriate tools and capacity development including training of scientists and resource managers. Towards these ends, over the past 12 years, The WorldFish Center has developed and significantly invested in FishBase, the world's premier database and information system on fishes in cooperation with FAO and over 750 (institutional and individual) collaborators. However there has been limited involvement of China in development, application and use of FishBase. The information available in FishBase for China is important to understand the fish biodiversity of China. For countries like China with a large geographic area, the aggregated information cannot be utilized for managing the aquatic resources region wise. Therefore utilizing the knowledge foundation developed in FishBase, it would be useful to prioritize and focus on in addressing specific challenges of China. This will necessitate focusing on customized FishBase products and developing applications for situations within China and within regions, and by thematic content (for example, focused on fish trade, aquatic protected areas, ecosystems). These can exist as stand-alone products owned by China but also can be integrated into and enriched by the global FishBase. The scale of these customized databases will vary depending on the geographic scale and the objective. Through such an initiative, the needs for capacity strengthening and training in China to utilize information to analyse fisheries and biodiversity trends at national and regional levels can also be met. These programs would also provide the institutional and scientific base for developing appropriate national policies on fisheries management and related biodiversity conservation in China.

The objectives of the project would be:

1. To develop customized China Fishbase with customized theme based modules on aquaculture and analytical tools so that the database can be used as decision-making tool.
2. To train scientist from China's in developing such databases and for utilizing them.

The organizations to be involved are those who have access to published and unpublished data sources region wise and with strong expertise in database and GIS. The WorldFish Center can transfer its rich experience in building FishBase to these organizations in China and facilitate building China FishBase.