‘The future of mariculture; a regional approach for responsible development of marine farming in the Asia-Pacific Region’

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Dr. Liu Yingjie

Background

The Chinese population is predicted to rise from the present 1.2 to 1.6 billion by 2026, reducing further the per capita share of land resources for food production. Per capita agricultural land has steadily decreased from 0.19 hectares (ha) in 1949 to 0.076 (ha) in 2005. These considerations and the rapid changes in population structure, and rising living standards, have presented the Chinese with several challenges and opportunities to meet the rising demand for high quality animal products, in particular aquatic products. Between 1991 and 2020 the national per capita consumption of fish is projected to increase annually by 5.6 percent (Huang et al. 1997). The acknowledgement of stagnating wild fish stocks has focused Chinese fishery development policies on expanding inland, brackish and in particular marine aquaculture as a key strategy for meeting changing national demand and consumer patterns.

To meet these rising demands, China has formulated and refined its aquaculture development policies targeting specific national, provincial and farm level issues aimed at transforming the aquaculture sector from a centrally-based to a market-based activity. At the national level, the development of inland aquaculture production was part of the strategy for rural industrial development. Freshwater aquaculture expanded from the traditional provinces south of the Huai river, into north eastern, western, and northern regions of China.

To increase fish production and employment in the Provinces, the area allocated for culture was increased and the types of water bodies approved for aquaculture broadened, attracting hitherto uninterested households, State-owned farms and water conservation departments in many villages and towns into taking up aquaculture as an additional viable economic activity. Total fishery (aquaculture and capture) labor in 2004 reached 13 million. The total number of people who were employed full-time in mariculture and marine capture in 2004 reached 5.4 million. This increased opportunity played an important role in alleviating rural poverty and increasing the income of farmers.

To address key issues such as pollution, the government has introduced legislation to control water quality in order to protect aquaculture and capture fisheries. Since 1979 more than 500 laws and regulations were issued by the State Council. For farmers producing high value species, including small shrimp, eel, mandarin fish etc., fluctuations in fry cost, supply and quality, increased feed and medication and other input costs, price fluctuations of end products and high quality standards for export products, have all increased investment risk. To promote sustained production of high valued species, the State is promoting private investment and the formation of joint ventures with foreign companies which should continue to improve technology transfer and reduce some of the investment risk.

There are more tasks facing China: restructuring of the whole fisheries sector to improve quality and increase income (not only increase production) to add value to the sector; preferential loans, fiscal conditions and improved technical support to operators; extension of the use of manufactured feed pellets to reduce eutrophication, transformation into a professional industry with producers associations; upgrading of the national technological base; strengthening of scientific research, education and training to improve research capability; preparedness for emergencies.

1. Marine Aquaculture Products Demand, Trade and Markets:

1) The AsiaFish model for fish product

A. Introduction of the model and its operative mechanism

Quantitative modeling of supply, demand, and trade for fish becomes very useful for evaluating development strategies and options if done for disaggregated fish types, production categories, and regions. With detailed analysis, one can identify priorities in terms of technologies for dissemination, research problems to address, regions on which to focus investments, and fish groups that contribute most to food security of the poor. Recently a quantitative tool called the AsiaFish model (Dey et. al., 2004a) has been developed for this purpose. This model is currently being applied to nine major fish producers in Asia (namely, Bangladesh, China, India, Indonesia, Malaysia, Philippines, Sri Lanka, Thailand and Vietnam). The AsiaFish model is a quantitative tool for analyzing the supply and demand outlook and impact of policies, at a disaggregated level, to provide detailed guidance on the design of development strategies for the fish sector. The model has been applied to nine major fish producers in Asia to generate projections to 2020. Our results indicate that, with rising population and income, fish demand will continue to grow. Supply will also rise, with the bulk of the increase coming from aquaculture.

Generating an outlook for fish in these countries is useful for at least three reasons. First, these countries account for a significant proportion of global production and consumption, contributing over 51% of output while absorbing 40% of consumption (FAO, 2003; Delgado et.al, 2003). Second, the growth performance of the fisheries sectors in these countries has been impressive: between 1991 and 2001, production in these countries grew at an average annual rate of 7.8%, more than twice the growth rate of the world fish production. Fish consumption in these countries has also been rising rapidly; for example, the growth rates of consumption for 1985-1997 of China is 11.8% – over triple the global average of 3.3%. As argued in Dey et. al. (2004a), existing food sector models are ill-suited for the task of making fish sector projections for these countries. With few exceptions, these models typically gloss over the heterogeneity of fish types, the presence of alternative production sources (i.e. capture vs. culture), and the diversity of consumption demand across income groups or regions. The AsiaFish model addresses all these difficulties, as well as assorted data problems such as jointness of production, and the mismatch of fish type definitions in country-level data on the production and consumption.

The AsiaFish model is a multi-market equilibrium model for evaluating the effects of technology and policy changes on the prices, demand, supply and trade of various fish types. It is divided into producer, consumer and trade cores. The consumer and producer cores are essentially two sets of demand and supply equations systems. The producer core distinguishes between fresh and processed fish, with the assumption that a fixed ratio of fresh fish output is allocated to processed fish. Supply of fresh fish is also distinguished by domestic production source. The consumer core of the model describes the behavior of households, which can be disaggregated by region and/or income class. The demand functions are derived from a three-stage budgeting framework. The first stage divides consumption expenditure into food and nonfood spending. The second stage determines the representative household's demand for fish as a whole. The final stage captures the demands for different types of fish, using the quadratic form of the Almost Ideal Demand System (AIDS). The trade core of the model is composed of a series of export supply and import demand equations. In the tradition of Applied General Equilibrium (AGE) models, domestic and foreign goods are treated as differentiated products, which is the Armington assumption. One advantage of this formulation is that it allows a fish type to be exported and imported at the same time ("cross-hauling" in the trade data). The aggregation follows a functional form characterized by constant elasticity of transformation (in the case of exports) or constant elasticity of substitution (in the case of imports). Model closure is attained at simultaneous equilibrium among the three cores. The closure condition is however considerably complicated by the presence of mismatched fish type definitions in the production and consumption data. To complete the matching, the model identifies demand or supply composites. That is, a demand (supply) composite is one that is matched to several fish types on the supply (demand) side. The model then disaggregates the demand (supply) composite based on a constant elasticity function (in imitation of the Armington technique).

B. Preliminary results of China from the AsiaFish model

Table I: Projected Growth of the Output of Fresh Fish, 2005-2020

Value (%)	Quantity (%)	Aquaculture (%)	Capture (%)
6.22	3.04	4.69	-

Table II: Projected Growth of Fish Consumption and Consumption Per capita, 2005-2020

Consumption			Consumption per capita	
Total (%)	Rural (%)	Urban (%)	Rural (%)	Urban (%)
2.53	(2.00)	3.62	0.30	0.98

Table III: Projected Growth of Fish Export and Import, 2005-2020

Quantities		Values	
Exports (%)	Imports (%)	Exports (%)	Imports (%)
2.92	1.82	6.69	4.10

2) A forecasting support system (APPFSS) for aquatic products price in China

In China, aquaculture has been the fastest growing sub sector within the agricultural economy over the past two decades, enjoying an average annual growth rate of about 10%. The growth in the aquaculture sector has also been accompanied by significant structural change. The share of cultivated fish in total production has increased substantially from 25% in 1970 to 60% in 2000. On the demand side, per capita consumptions of fish were only 1.2 kg in rural and 3.7 kg in urban areas in 1980, but had reached 5.8 and 18 kg, respectively, by 2000 (Jikun Huang, 2003). So the aquaculture sector had become more prominent in the process of agricultural structure adjustment both in generating an alternative source of income for farmers and in enhancing food security in China. But the technological advancement in the production and storage of fishery products has exceeded the development of efficient market demand over the past one-decade.

China has a wealth of data about fishery market produced by municipal, county, province, state agency, academy, university and market. Unfortunately the data are scattered among a multitude of producers with dissimilar formats, resolutions. Recently work had done by Ministry of Agriculture and Ministry of Science and Technology to develop a common database had yielded some usable consistent results (www.uast.com.cn). To this end a forecasting support system for aquatics product price (APPFSS) had been developed (Zhang Xiaoshuan et al, 2004; 2005). This is an intelligence computer-based information system, which combines models, data, expert knowledge and a user interface and support participants of aquaculture industry to predict market price and related information.

3) The Strategy Options for Trade and Market Access

The reformed and open environment in China has provided easier conditions for the development of fisheries, a circumstance that included two main policies. The first was the liberalization of right for land use and farm management. An aquaculture farm management system was adopted based on the household responsibility system as the key element, combined with a diversified operating system. In order to encourage the people to reclaim and exploit low-lying or saline-alkali land suited for aquaculture, the local governments actively established preferential policies and provided support and privileged fiscal and investment measures. These were extremely successful, arousing enthusiasm for involvement in developing aquaculture both within the population and industry. The second policy was the liberalization of price control by government, which allowed the price of fish products to adjust to the market, permitting the full range of advantages of unified production and sales. All policies have given a great impetus to the development of aquaculture in the country. To be able to assure a constant, year-round supply of fresh and live fish, aquaculture methodology was also reformed, including the policy of “take turns in fishing and stocking, catch the bigger and leave the smaller”. This approach lessened seasonal peaks and troughs concerning supplies, thus improving the market situation and reducing overstocking as well as fluctuating prices. It is evident that aquaculture outputs and benefits have been improved with these reforms and operational changes.

A. Cooperation among individual farmers.

Most farms in China are small which makes it difficult and costly to individually fulfill requirements to ensure product quality. Collectively however, the speedy delivery of products to processing plant could be assured. It is important that buyers’ requirements of safe, clean and quality products are fulfilled and for producers to establish the capability, and therefore reputation, of reliability. Establishing mutually beneficial relations with buyers depends on reliability and trust

B. Cooperation among producers would enable the delivery of the required quantity.

It would also avoid or minimize the risk of a member providing products tainted with banned substances. Lessons could be learned from the experiences of some countries in promoting country-label products and integration between producers and buyers. It was advised that producers should actively promote their products to potential buyers and initiate and sustain dialogue between buyers and producers. The risk or tendency of buyers using food safety as a pretext to take advantage of seller could be minimized with timely information on prices and knowledge of pricing mechanisms.

C. Capacity building for quality assurance

Governments usually invest in the improvement of facilities and develop regulations but need assistance in training in quality control. Training in HACCP and application of HACCP not only at the plant but also at the farm level would be extremely helpful. Likewise assistance in the development of codes of practices, and guidelines for good management and manufacturing practices is needed.

D. Cooperation among governments.

A common and cohesive stand among Asian governments on issues that impact in their aquaculture sector is needed. It would enable the region to maintain its position as a major producer and exporter of aquatic products. Cooperation would enhance competitiveness in the global market. It would also facilitate and expand intra-regional trade.

E. Improving the domestic marketing system is just as important as improving foreign trade in national development.

An efficient domestic marketing system would have a strong impact on social objectives including poverty reduction and food security assurance. A good market infrastructure, better facilities, and easier access to information would facilitate domestic trade that would impact positively on rural development by raising technical efficiencies, farmers' incomes and supply of affordable and nutritious aquatic products. Governments usually invest on market infrastructure although municipal governments now involve the private sector in the management of the markets. An expanding population, the growing affluence in populations as well as changing population structures are important factors that should be considered in the development of the domestic market.

4) The demand for fisheries and aquaculture products

Both fish species and fish products will develop in different and diversified directions according to consumers' buying power, consumption habits and perceptions. According to present trends, the consumer appreciates and welcomes nutritious and safe fish products, with a particular appreciation for the highly rated species, which represent a considerable development opportunity. These include freshwater species like mandarin fish, snakehead, perch, catfish, shrimp, softshell turtle and tortoise, while marine species of interest include fish, shrimp, molluscs and seaweed.

The diversity of food preferences gives a wide range of consumption patterns, which is good for both the exploitation and the utilization of natural resources. This contributes to the avoidance of the irrational exploitation of the food chain and environmental destruction and is, therefore, good for the sustainable development of fisheries.

Due consideration has been given to ensure basic fish supplies and improve the food security situation in rural areas. Fish farming is considered as the quickest and most effective way to increase fish supplies, and it has been given high priority in the national fisheries development plan in the context of rural development. The government has been extremely supportive to rural aquaculture development through its technical extension service, particularly for production of species that are low in the food chain and with a wide adaptability and high productivity.

2. Livelihood Opportunities related to Mariculture Development

Trade figures in aquatic products from FAO-Globefish show the importance of aquatic products trade to developing economies. In 2001 the value of global fish exports was US$ 56 billion, 50% of this from developing countries. More significantly the net export revenues from fisheries for developing countries were US$18 billion. The developed countries imported more than 80 percent of world imports in value. The EU, USA, and Japan together imported 77 percent of the total.

China government seeks to find ways to improve the ability of aquatic farming area and their fisheries and aquaculture sectors to access markets. The pathways are greater competitiveness through technical efficiency in production, processing and marketing, compliance to market requirements including standards, responsibility to consumers, the environment and society, and better capacity to transact with buyers and negotiate in world forums. There is general agreement that fair trade and a well developed domestic marketing system are a powerful means to reduce poverty and improve food security, reduce dependence on aid, and even serve to attract direct investments particularly in a technically efficient and competitive seafood production and marketing sector.

Between 1980 and 1998, the additional number of people employed in the fisheries sector was 10 million; the average new entry or job creation is half a million people a year, with 70 percent going into aquaculture. To meet the demands of another 100 million people that are expected to be added to the population in the next 20 years, the fisheries development plan aims to promote the transformation of the fisheries economic system to fit the basic requirements of a market economy, and to promote science, education and sustainable fisheries development. The goal is to increase aquaculture contribution to improve the welfare of farmers and develop the rural economy.

3. Existing and Potential Mechanisms for Technology Transfer

In order to bring fishery technical extension into full play, it is necessary to develop different types of services for the benefit of the production sector. These include technical associations, mutual insurance aid and other nongovernmental service organizations that can serve the fisheries and aquaculture sectors. It is also necessary to improve the abilities for self-protection and self-development of the labor force under the conditions of a market economy.

The aspirations for aquaculture development for the period 2005-2020

In the next 15 years, the emphasis of fisheries and aquaculture development in China will be to:

- meet the needs of social and economic development;
- increase the efficiency of fisheries production;
- develop and promote aquaculture, agriculture and the rural economy;
- expand and diversify production so as to meet the demand for fish and fishery products; and
- make the best use of market potential.

To realize these goals, the state will primarily support the development of six core systems and six areas of concern. The systems to be developed are:

- original and fine species diversification system;
- fishery scientific and standardization system;
- fishery technology extension system;
- disease control system;
- fishery marketing system; and
- fishery management and environmental protection system.

The six fields to be developed are the:

- vertical integration of aquaculture production in the fish culture bases;
- development of offshore and distant water fishing;
- processing of fish products and comprehensive utilization of materials;
- building of fish ports;
- building of fishing vessels and
- manufacture of fishery machinery and new technical exploitation.

Present training activities and likely future requirements

- In order to transfer the technology of environmental monitoring to promote socio-econimic progress and environmental improvements in the aquaculture sector in Shandong province and further in China, five training courses and workshops had been hold from 2003 to 2005, which were holded in Beijing, Qingdao and Rizhao cities respectively. The five training courses and workshops, which were major organized by Yellow Sea Fisheries Research Institute, CAFS, were focused on the introduction of HACCP management system and EU Food Safety and Sanitation Regulations and Directives on the mariculture of shellfish, especially on the assessing water quality and safety, the implementation of harvesting area classification systems and the implementation of a marine biotoxin/harmful algal blooms monitoring regime and the information about EU markets and how to entry into EU markets for Chinese maricultural shellfish products. Nearly 240 relatively technicians and managers and governmental officials joined the meetings.

- Another three training courses will be hold in Shandong province in 2006. The topics will focus on the depuration centres and technique, traceability of shellfish products and the enforcement of EU hygiene legislations, so as to improve environmental and products quality and foster long term sustainable development of shellfish in China and then find a gateway for Chinese shellfish products into EU markets.

4. Existing Major Mariculture Species and Farming Technologies

1) Existing Major Mariculture Species

Table IV: Existing Major Mariculture Species and its total product in 2004 (T)

Finfish	Flounder(Paralichthys olivaceus)	57,270.0
	Sea Bass(Lateolabrax latus)	80,625.0
	Sevenband grouper(*Epinephelus septemfasciatus*)	33,033.0
	Black Sea Bream(Acanthopagrus schlegelii)	46,248.0
	Parrot fish(Oplegnathus fasciatus)	
	Red sea bream(Pagrus major)	
	Other sea breams	
	Brown croaker(*Miichthys miiuy*)	
	Red drum(*Sciaenops ocellatus*)	43,506.0
	Yellowtail(*Seriola quinqueradiata*)	12,572.0
	Puffers	14,861.0
	Korean rock fish(Sebastes schlegeli)	
	Other rock fishes	
	Mullets(*Muguil* spp.)	
	Okhostk Atka mackerel(*Pleurogrammus azonus*)	
	Dotted Gizzard shad(*Konosirus punctatus*)	
	File fishes (Stephanolepis sp.; Thamnaconus sp.)	
	Other finfish	
	subtotal	582566
Crustaceans	*Fenneropenaeus chinensis*	54,380.0
	Penaeus japonicus	45,173.0
	subtotal	722172
Shellfish	*Crassostrea gigas*	3,750,910.0
	Rapana venosa	202,452.0
	Haliotis discus hannai	
	Chlamys farreri nipponensis	
	Cyclina sinensis	2,799,004.0
	Mactra chinensis	
	Scapharca subcrenata	323,225.0
	Solen spp.	676,391.0
	Ruditapes philippinarum	
	Meretrix lusoria	
	Atrina pectinata	
	Scapharca broughtonii	
	Mactra veneriformis	
	Mytilus coruscus	717,368.0
	Other shellfish	
	subtotal	10247151

Seaweeds	*Porphyra spp.*	81,017.0
	Laminaria japonica	801,128.0
	Undaria pinnatifida	219,607.0
	Gelidium amansii	115.0
	Gigartina spp.	
	Codium fragile	
	Hijika fusiforme	
	Enteromorpha spp.	
	Other seaweed	
	subtotal	1467545

2) Farming Technologies

Table V: Aquaculture methods used in China

Kind		Habitat(methods)
Finfish		Land-based tank culture
		Pond culture
		Cage culture
		Other methods
Crustacean		Pond culture
Shellfish		Hanging culture(scallop, oyester, abalone, mussel etc)
		Bottom culture(clam, oyster, abalone etc)
		Land-based tank culture(abalone)
Seaweed		Floating net method
		Long-lined method
		Other methods
Others	Sea cucumber	Pond culture
	Polychaetes	Pond culture
	Jellyfish	Pond culture
	sea urchin	Bottome culture
	Others	
Collective farms		Bottom culture
		Seaweed
		Others

A. Polyculture

One possible solution to avoid and lessen aquaculture impacts on the environment, isextensive and balanced 'polyculture' - an integrated fish farming practice adopted over 4000 years ago in China, and over 1500 years ago in Hawaii. Polyculture techniques mix fed species (e.g. finfish, shrimp), herbivorous species and extractive species (filter feeders, such as shellfish, and seaweeds) in a more balanced ecosystem-approach aquaculture. While polyculture has not been implementedto any great extent, it may offer opportunities for reducing or transferring nutrient loads. Ecosystems are inherent recyclers of energy, and can provide the resources humans need as long as critical processes are left undisturbed. Ecosystems, although frequently described as "fragile", have remarkable powers of resiliency. As long as basic processes are not irretrievably upset, ecosystems will continue to recycle and distribute energy. A healthy functioning ecosystem not only sustains itself, it also sustains local communities, regional economies and resource based industries, in this case aquaculture. This suggests that strategies and guidelines for sustainable management should focus on maintaining resilience and healthy functioning of coastal and marine ecosystems.

Integrated Culture Examples:

Israel: Sea bream + *Ulva*; abalone + fish + *Ulva*; abalone + fish + mollusc + *Ulva*

China: Shrimp + crab + seaweeds (pond culture); mussel + scallop + *Laminaria*/*Undaria*(longline culture); fish + *Gracilaria*; fish + seagrass+ *Kappaphycus*, scallops and crab (Lantern nets culture), Seaweeds+sea urchin+sea cucumber+abalone (bottom culture).

Japan: shrimp + *Ulva*

Norway: salmon + mussel + seaweed

Maine (USA): salmon + *Porphyra* (Fig. 3)

Hawaii (USA): shrimp + *Gracilaria*

Chile: seaweed biofilter - *Gracilaria* + turbot

Philippine (with Norway): sea urchin/sea cucumber + *Eucheuma*/*Gracilaria*France: sewage treatment system-*Ulva*

South Africa: finfish aquaculture effluent + *Gracilaria*

Southeast Asia: shrimp + seaweeds (primarily *Gracilaria*)

Australia: shrimp + oyster + *Gracilaria*

B. Offshore farming

Offshore farming is seen as a means to overcome such difficulties, and as a way toincrease production in areas where it would otherwise not be possible. Indeed, a number of offshore farms have already been established and have operated with varying degrees of success for a number of years. Offshore aquaculture of sea bass and bream is well developed in Malta, Cyprus, Spain and Italy, while mussel offshore aquaculture is developed in France (CIHEAM/FAO/INRH, 1999; CIHEAM, 2000). Offshore farming is particularly well developed in Cyprus (840 t/yr; 87% of the total national aquaculture production) and Malta (about 2,000 t/yr; which is almost the total aquaculture production of the country), where no sheltered areas exist. It is also becoming more of an aquaculture option for Italy, Spain, and France where conflicts with the tourism industry or scarcity of appropriate sites are already forcing the producers to move far from the coast. In addition, the Black Sea countries reported interest in developing offshore aquaculture, and some activities are already carried out by Turkey involving the farming of salmon and large-size trout (FAO, 1999). However, the offshore environment continues to present many challenges, not only to systems design and installation, but also to stock management. Also, if marine offshore aquaculture moves offshore there will be more business opportunities for fishermen!. Another emerging aquaculture is fattening of bluefin tuna (*Thunnus thynnus*). During the last 5 years there has been a very important development of tuna farms in Mediterranean, with approximately 20 farms (most of them in Croatia 9 and Spain 7). It is estimated that more than 70% of the Mediterranean recommended catch quota is already being used for this production, which is mainly exported to the Japanese market (one bluefin tuna can reach price of 30,000 US$). This year, the researchers from seven countries (Spain, Israel, France, Germany, Italy, Greece, and Malta) started a three year project REPRO-DORR, "Reproduction of the Bluefin Tuna in captivity: Domestification of *Thunnus Thynnus* (Fish Farming International, 2003). Japanese researchers have closed the bluefin tuna life cycle, and the current goal is to improve incubation, hatching and larval rearing of tuna and to release juveniles into oceans to replenish natural stocks (bluefin tuna).

C. Phytoremediation

Phytoremediation is considered as the most efficient and prospective approach in removing of the contaminations. Many works have been conducted in order to identify plant species capable of accumulating undesirable toxic compounds such as heavy metals, and numerous plants to be known to accumulate metals from their environment. Phytoremediation used in removing aquatic heavy metals is a newly developed environmental-protective technique. Studies concerning freshwater resources decontamination are extensive, and some freshwater plants have been found to have the capability of accumulating heavy metals, among which water hyacinth is the most noteworthy because it arrests considerable attentions of scientists. Other fresh water plant species, such as *Hydroxotyle umbellate*, *Lemna minor* and *Chlorella vulgaris* are also used in studies of phytoremediation.

Few studies have been conducted on marine macroalgae. Brown marine algae, such as *Ascophyllum nodosum* and *Sargassum aquifolium*, can accumulate metals that occupy more than 30% of the biomass dry weight. Being unicell marine algae, *Tatraselmis suecica* and *Chlorella* spp. NKG16014 are used in heavy metal bioremediation. Some experiments showed that gametophytes of *L. japonica* played a remarkable role as a heavy metal decontaminator, especially to Cd (Naihao Ye, 2005). Stagnant and clean seawater is usually required in the breeding of algae and marine animals in the aquafarm. The gametophytes adhering to some objects are preferable, which can be easily cultured in the stagnant seawater and can act as an efficient heavy metal decontaminator.

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