SECTION 2

Country experiences

Bangladesh

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AN OVERVIEW OF THE FISHERIES SECTOR

Bangladesh has extensive water resources in the form of numerous small ponds, ditches, lakes, canals, small and large rivers, and estuaries covering approximately 4.34 million ha. The culture fisheries include freshwater ponds of 0.15 million ha and coastal shrimp farms of 0.14 million ha. The country has a coastal area of 2.30 million ha and a coastline of 714 km along the Bay of Bengal supporting a large artisanal and coastal fisheries (Figure 1). In addition, it has a 166 000 km2 of Exclusive Economic Zone (EEZ) in the Bay of Bengal. The fisheries sector of Bangladesh is highly diverse in resource types and species. There are 795 species of fish (including 12 exotic species) and shrimp in fresh and marine waters. Exports were valued at US$307 million in 2003. In 2000 the fisheries sector contributed approximately 6 percent of the national gross domestic product (GDP), including full-time employment equivalent to at least 5.2 million people or 9 percent of the labour force. Moreover, the sector provides a safety net for income and food for the rural poor.

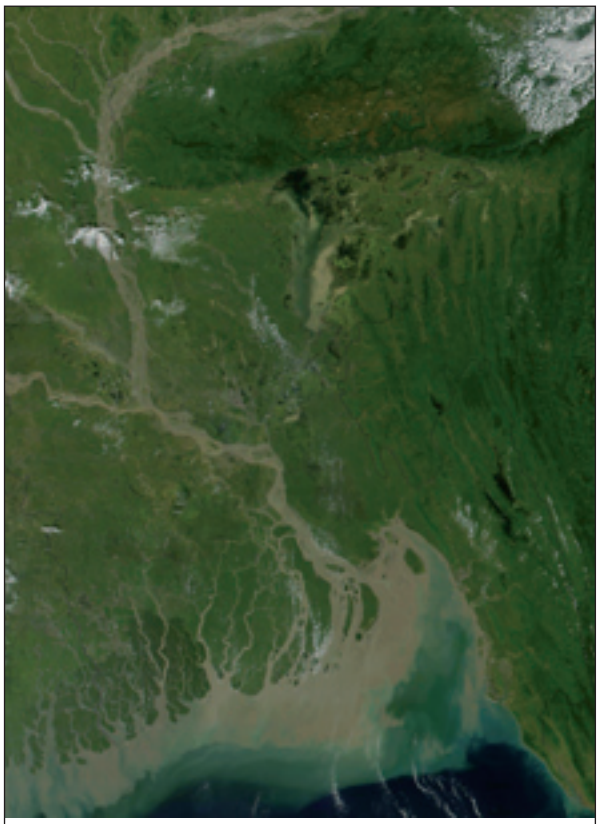

FIGURE 1
Aerial view of the coastal area of Bangladesh

Total production is estimated at 750 000 tonnes from inland capture fisheries, 850 000 tonnes from inland aquaculture and 95 000 tonnes from coastal aquaculture (on-shore aquaculture; the major species include shrimp and a few finfish) and 589 000 tonnes from marine fisheries. Inland and marine capture fisheries are declining annually by approximately 5 and 1 percent, respectively. The current levels of marine fisheries production are being maintained by a significant increase in fishing effort. On the other hand, aquaculture has grown by about 14 percent per annum over the decade. Areas of growth include carp (20 percent per annum) and shrimp (3 percent per annum). Mariculture in the Bay of Bengal is is considered as one area for future development of the production of aquatic animal products.

MARINE RESOURCES

Bangladesh has wide ranging marine biodiversity. There are some 1 093 marine aquatic species recorded in the waters of Bangladesh, of which 44.4 percent are finfish, 32.2 percent shellfish, 15.1 percent seaweeds and 8.32 percent other organisms, including shrimps. Details on the number of species are provided in Table 1.

TABLE 1
Marine aquatic biodiversity in Bangladesh

Aquatic groups	No. of species	Percentage (%)
Finfish	486	44.4
Sharks, Rays, Skates and Dolphin	21	1.9
Shrimps	36	3.3
Lobster	6	2.0
Crabs	16	
Sea turtles	3	0.3
Crocodiles	3	0.3
Squid and Cuttlefish	7	0.6
Shellfish (univalves and bivalves)	350	32.2
Seaweeds	165	15.1
Total	1 093	100

MARINE AQUACULTURE

Bangladesh does not have any marine farming, only land-based coastal aquaculture.

Coastal aquaculture

Coastal aquaculture has developed significantly in the last decade, particularly the culture of shrimp *(Penaeus monodon* and *Litopenaeus indicus*) in medium to high-saline water and prawn (*Macrobrachium* sp.) culture in less saline areas. In addition, there is a small production of mangrove crabs (*Scylla* spp.) and varied quantities of brackishwater and marine fish species such as seabass and mullet, most of which are produced as by-products or during fallow periods in shrimp ponds. Shrimp farming constitutes the major export-oriented subsector of aquaculture. Its relatively high value places considerable importance on upstream inputs such as seed and feeds, and downstream services such as transport and processing.

Seed supply

This subsector comprises both capture and culture elements, supplying both finfish and shrimp seed. Both groups still depend to varying degrees on wild-caught stocks, although fish (carp) culture is increasingly dominated by hatchery supply, and shrimp/prawn culture is steadily increasing its demand for hatchery-bred seed. The supply of wild seed has important interactions with artisanal fishing in coastal areas. Whatever the source of seed, considerable national (and cross-border) networks have been set up to distribute seed. The government has banned the collecting of wild postlarvae from the coastal zone to conserve its biodiversity. This has caused more demand and hence an increasing supply of hatchery-produced seed over the past four years. The transportation systems have been modernized as well. Farmers still depend upon wild-caught seed for finfish such as seabass and mullet.

Post-harvest and market

The gradual shift from local consumption within rural areas, and the growth in urban markets and their service infrastructures, has increased the role of market intermediaries and service suppliers in coastal aquaculture. However, as many markets are still based on wetfish sale, the scope for value addition has been limited. More particularly, the production of shrimp and its export in frozen tailed form have created

a significant production subsector, with large commercial investments and notable employment impacts.

In 2001, Bangladesh achieved its highest ever export earnings of US$32 million by exporting 29 719 tonnes of shrimp. The growth in exports has been consistent since the early 1970s, but it was set back by problems associated with health and food safety in 1997–2000.

General support to the subsector

A range of products and services support coastal aquaculture. However, most of the input supply services are relatively under- or undeveloped, such as production of seed, feed, equipment, maintenance and other post-harvest supplies. Positive changes have occurred in the more commercialized subsector of shrimp farming. The provision of research and extension and of financial and management services needs to be further developed and modernized.

Offshore mariculture

Bangladesh has approximately 714 km of coastline and 166 000 km^2 of Exclusive Economic Zone (EEZ) with 1 093 species of aquatic marine organisms including finfish, shellfish, shrimps, seaweeds etc. The marine capture fishery is declining at about 5 percent per annum, so it is the right time to think about how to increase marine production. This situation points to the need to develop mariculture. In the strict sense of the concept, there is no mariculture in Bangladesh. Among the marine species, only shrimp is cultured in on-shore ponds. Other species such as seabass, mullet and mud crab have begun to be cultured in saline-water ponds on a limited scale, and have shown potential for mariculture.

Constraints

The following constraints need to be addressed for the development of mariculture in Bangladesh. The resolution of these constraints would increase marine fish production in a sustainable manner, reduce pressure on wild stocks and have a tremendous and long-term impact on the livelihoods of coastal people. Regional cooperation will be

- essential to deal effectively with the constraints, which include:
- lack of awareness about mariculture techniques, such as cage culture;
- lack of appropriate technology for mariculture;
  inadequate infrastructure in relation to information, communication, transportation,
- hatcheries, markets, etc.;
- lack of skilled manpower;
- areas for mariculture not demarcated by the government; and
  lack of financing to the sector.

THE WAY FORWARD

Initiatives have to be taken by both the government and the private sector to develop mariculture and the market for mariculture products in a more coordinated way and in collaboration with regional and international organizations. These are geared to:

- Capacity building, including:
  - developing appropriate technologies for mariculture suitable to the climatic, market and socio-economic conditions of Bangladesh;
  - developing knowledge and appropriate technical and management skills for mariculture; and
  - demarcating areas for mariculture (zoning).
- Development of infrastructure, including:
  - roads;
  - educational and training infrastructure and programmes;

  - information and communication systems for rapid access to information; and
  - modernization of market infrastructure, including landing centers and the marketing channels for both inputs and outputs.
- Development of networks, including:
  - producers' organizations and networks for information, better management and access to finance; and
  - coordination with regional and international organizations for updating and accessing technology, markets and other support.

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BACKGROUND

The Chinese population, currently at 1.2 billion people, is predicted to rise 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 ha in 1949 to 0.076 ha in 2005. These considerations, 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, Rozelle and Rosegrant, 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, the People's Republic of 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 the northeastern, 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. In 2004 the total fishery (aquaculture and capture) labour force reached 13 million, while the total number of people employed full-time in mariculture and marine capture fisheries was 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 have been 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, 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-value species, the Chinese government is

promoting private investment and the formation of joint ventures with foreign companies that should continue to improve technology transfer and reduce some of the investment risk.

There are more tasks facing China, including:

- restructuring of the entire 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 producer associations;
- upgrading of the national technological base; and
- strengthening of scientific research, education and training to improve research capability and preparedness for emergencies.

MARINE AQUACULTURE PRODUCTS DEMAND, TRADE AND MARKETS

The AsiaFish Model for fish product

Quantitative modelling 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, Briones and Ahmed, 2004) has been developed for this purpose. This model is currently being applied to nine major fish producers in Asia (Bangladesh, China, India, Indonesia, Malaysia, the Philippines, Sri Lanka, Thailand and Viet Nam). The AsiaFish model is a quantitative tool for analyzing the supply and demand outlook and impact of policies, at a disaggregated level, in order 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 with the aim of generating projections to 2020. Our results indicate that, with the 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. Firstly, these countries account for a significant proportion of global production and consumption, contributing over 51 percent of output while absorbing 40 percent of consumption (Delgado *et al.*, 2003). Secondly, 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 percent, more than twice the growth rate of world fish production. Fish consumption in these countries has also been rising rapidly; for example, the growth rate of consumption for China during the period 1985–1997 was 11.8 percent – over triple the global average of 3.3 percent. As argued in Dey, Briones and Ahmed (2004), 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 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 behaviour of households, which can be disaggregated by region and/or

income class. The demand functions derive from a three-stage budgeting framework. The first stage divides consumption expenditure into food and non-food 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 through 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).

The preliminary results of China from the AsiaFish model are shown in Tables 1–3 below where the cumulative yearly growth rates for a 15-year period are indicated.

TABLE 1
Projected growth of the output of fresh fish, 2005–2020

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

TABLE 2
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 3
Projected growth of fish export and import, 2005–2020

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

A forecasting support system for aquatic products price in China

In China, aquaculture has been the fastest growing subsector within the agricultural economy over the past two decades, enjoying an average annual growth rate of about 10 percent. The growth in the aquaculture subsector has also been accompanied by a significant structural change. The share of cultivated fish in total production has increased substantially, from 25 percent in 1970 to 60 percent in 2000. On the demand side, per capita consumption of fish, which was only 1.2 kg in rural and 3.7 kg in urban areas in 1980, reached 5.8 and 18 kg, respectively, by 2000 (Huang, 2003). In the light of such growth, the aquaculture subsector 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. However, the technological advancement in the production and storage of fishery products has exceeded the development of efficient market demand over the past decade.

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

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 the right to 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 the government, which allowed the price of fish products to adjust to the market, permitting a full range of advantages of unified production and sales. These policies have given 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 in 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.

Cooperation among individual farmers

Most farms in China are small, which makes it difficult and costly to individually fulfil requirements to ensure product quality. Collectively, however, the speedy delivery of products to processing plants 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.

Cooperation among producers

Cooperation among producers would 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 to use food safety as a pretext to take advantage of the seller could be minimized with timely information on prices and knowledge of pricing mechanisms.

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 Hazard Analysis and Critical Control Point (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 practice and guidelines for good management and manufacturing practices is needed.

Cooperation among governments

A common and cohesive stand among Asian governments on issues that impact 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 and would also facilitate and expand intra-regional trade.

Domestic marketing system

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 in market infrastructure, although municipal governments now involve the private sector in the management of the markets. An expanding population and its growing affluence, as well as changing population structures are important factors that should be considered in the development of the domestic market.

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 particular appreciation for the highly rated species, which represent a considerable development opportunity. These include freshwater species such as 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 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 the production of species that are low in the food chain, and with a wide adaptability and high productivity.

LIVELIHOOD OPPORTUNITIES RELATED TO MARICULTURE DEVELOPMENT

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

The Chinese government seeks to improve the ability of aquaculture farms 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 fora. 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's contribution to improve the welfare of farmers and develop the rural economy.

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 (NGOs) that can serve the fisheries and aquaculture sectors. It is also necessary to improve the abilities for self-protection and self-development of the labour 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;
- 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-economic progress and environmental improvements in the aquaculture sector in Shandong Province and further in China, five training courses and workshops were held between 2003 and 2005 in the cities of Beijing, Qingdao and Rizhao. The training courses and workshops, which were organized by the Yellow Sea Fisheries Research Institute focused on the introduction of HACCP management systems and European Union (EU) Food Safety and Sanitation Regulations and Directives on the mariculture of shellfish, especially on the assessment of water quality and safety, the implementation of harvesting area classification systems, the implementation of a marine biotoxin/harmful algal blooms monitoring regime and information about EU markets and how Chinese farmed shellfish products can enter them. Nearly 240 technicians, managers and governmental officials joined the meetings.

Following these training sessions, an additional three training courses were held in 2006 in Shandong Province. The courses focused on the depuration centres and technique, the traceability of shellfish products and the enforcement of EU hygiene legislation, so as to improve environmental and products quality, foster long-term sustainable development of shellfish in China and then find a gateway for Chinese shellfish products into EU markets. Further capacity building will be required in all key areas.

MAJOR MARICULTURE SPECIES AND FARMING TECHNOLOGIES

The major mariculture species in China are shown in Table 4.

TABLE 4
Major mariculture species and production (tonnes) in 2004 for selected spaces

Finfish	Bastard halibut *(Paralichthys olivaceus)*		57 270
	Blackfin seabass *(Lateolabrax latus)*		80 625
	Convict grouper *(Epinephelus septemfasciatus)*		33 033
	Black porgy *(Acanthopagrus schlegelii)*		46 248
	Parrotfish *(Oplegnathus fasciatus)*		-
	Red seabream *(Pagrus major)*		-
	Other seabreams		-
	Brown croaker *(Miichthys miiuy)*		-
	Red drum *(Sciaenops ocellatus)*		43 506
	Yellowtail *(Seriola quinqueradiata)*		12 572
	Puffers		14 861
	Korean rockfish *(Sebastes schlegeli)*		-
	Other rockfishes		-
	Mullets *(Mugil* spp.*)*		-
	Okhostk atka mackerel *(Pleurogrammus azonus)*		-
	Konoshiro gizzard shad *(Konosirus punctatus)*		-
	File fishes *(Stephanolepis* sp.*, Thamnaconus* sp.*)*		-
	Other finfish		-
		subtotal	**582 566**
Crustaceans	*Fenneropenaeus chinensis*		54 380
	Penaeus japonicus		45 173
		subtotal	**722 172**

TABLE 4
Continued

Shellfish	*Crassostrea gigas*		3 750 910
	Rapana venosa		202 452
	Haliotis discus hannai		-
	Chlamys farreri nipponensis		-
	Cyclina sinensis		2 799 004
	Mactra chinensis		-
	Scapharca subcrenata		323 225
	Solen spp.		676 391
	Ruditapes philippinarum		-
	Meretrix lusoria		-
	Atrina pectinata		-
	Scapharca broughtonii		-
	Mactra veneriformis		-
	Mytilus coruscus		717 368
	Other shellfish		-
		subtotal	**10 247 151**
Seaweeds	*Porphyra* spp.		81 017
	Laminaria japonica		801 128
	Undaria pinnatifida		219 607
	Gelidium amansii		115
	Gigartina spp.		-
	Codium fragile		-
	Hijika fusiforme		-
	Enteromorpha spp.		-
	Other seaweeds		-
		subtotal	**1 467 545**

The major farming technologies are shown in Table 5.

TABLE 5
Aquaculture methods used in China

Commodity		Culture methods
Finfish		Land-based tank culture
		Pond culture
		Cage culture
		Other methods
Crustaceans		Pond culture
Shellfish		Hanging culture (scallop, oyster, abalone, mussel, etc.)
		Bottom culture (clam, oyster, abalone, etc.)
		Land-based tank culture (abalone)
Seaweeds		Floating net method
		Longline method
		Other methods
Others:	Sea cucumber	Pond culture
	Polychaetes	Pond culture
	Jellyfish	Pond culture
	Sea urchin	Bottom culture

Polyculture

One possible solution to avoid and lessen aquaculture impacts on the environment is extensive and balanced "polyculture" – an integrated fish-farming practice adopted over 4 000 years ago in China and over 1 500 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 to

aquaculture. While polyculture has not been implemented to 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.

Examples of integrated culture

Some examples of integrated mariculture systems are:

Israel	sea bream + *Ulva* abalone + fish + *Ulva* abalone + fish + bivalve + *Ulva*
China	shrimp + crab + seaweeds (pond culture) mussel + scallop + *Laminaria*/*Undaria* (longline culture) fish + *Gracilaria* fish + seagrass + *Kappaphycus*, scallops and crab (lantern net culture) seaweeds + sea urchin + sea cucumber + abalone (bottom culture)
Japan	shrimp + *Ulva*
Norway	salmon + mussel + seaweed
USA (Maine) (Hawaii)	salmon + *Porphyra* shrimp + *Gracilaria*
Chile	seaweed biofilter – *Gracilaria* + turbot
Philippines (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*

Phytoremediation

Phytoremediation is considered as an efficient approach with potential for removing aquatic contaminants. Much research has been conducted to identify plant species capable of accumulating undesirable toxic compounds such as heavy metals, and numerous plants are 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. Other freshwater 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 percent of the biomass dry weight. Being unicellular marine

algae, *Tetraselmis suecica* and *Chlorella* spp. NKG16014 are used in heavy metal bioremediation. Some experiments have shown that gametophytes of *Laminaria japonica* play an important role as a heavy metal decontaminator, especially to cadmium (Cd). Clean seawater is required in the breeding of algae and marine animals in aquaculture. The use of marine algae as efficient heavy metal decontaminators can assist in ensuring a suitable environment in hatcheries and also in sustaining clean environments in mariculture areas.

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ABSTRACT

Marine fish culture in China, Hong Kong, Special Administrative Region (China, Hong Kong SAR) involves the culture of fish in cages suspended from rafts in the sea. The activity is regulated by the Marine Finfish Culture Ordinance Cap. 353. All marine fish culture operations are required to be licensed and conducted in designated areas. Grouper is the major species cultured in China, Hong Kong SAR (over 50 percent). Other significant species include snappers, seabreams and pompano. Cultured marine finfish production in 2005 was 1 500 tonnes, with a farm gate value of US$9.7 million.

Fish disease has been a difficult problem encountered by fish farmers. Under the Fish Health Inspection Programme, fish farms are visited regularly to facilitate early detection of disease outbreaks and to advise fish farmers on good husbandry techniques and disease prevention measures.

After the 1998 red tide episode, a comprehensive red tide management programme was implemented. It comprises an interdepartmental red tide reporting network, a phytoplankton monitoring programme, a Geographic Information System (GIS), and various contingency plans to address different issues including mariculture, food safety and human health.

To investigate the possibility of reducing the impact of self-pollution from fish- farming activities, a trial study on the efficiency of artificial reefs (AR) as a biofilter in fish culture zones was conducted. The study aimed at quantifying the efficiency of AR in removing nutrients from fish farms and evaluating the changes in environmental and biological conditions after AR deployment. According to field studies and modelling, deployment of 16 pieces of 3x3x4 m specially designed AR can remove an estimated 2 352 kg, 624 kg and 103 kg per year of carbon, nitrogen and phosphate, respectively.