Species & System Selection: For Sustainable Aquaculture
Edited by PingSun Leung, Cheng-Sheng Lee, Patricia J. O'Bryen

Part 2
Practices

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Chapter 7

The Role of Species and Systems in the Development and Growth of Aquaculture in Asia: Needs and Prospects

Mahfuzuddin Ahmed, Madan Mohan Dey, and Yolanda T. Garcia

Abstract

During the previous three decades aquaculture development in Asia was characterized by a broad spectrum of users, systems, practices, and species through a continuum ranging from backyard household operations to industry-scale commercial systems. These systems produced the largest quantities of affordable food fish for domestic markets and home consumption in the world, making aquaculture one of the fastest growing food-producing subsectors in the region. With a steady growth of 9–11% per annum, Asia's aquaculture constitutes 90% of the global farmed fish output. Urbanization, a rising middle class, and growth of export trade have had a major impact on the choice of species and systems, including postharvest technologies.

This paper reviews the current practices in Asian aquaculture and emerging trends in species and systems against a backdrop of changing structure of demand, supply, and trade. It examines key issues concerning the role of aquaculture as an engine for economic growth in rural areas of developing Asia. Taking examples from South and Southeast Asia, the paper also analyzes the prospects and needs of the sector by identifying key technological, socioeconomic, and policy factors that will enhance its role in providing animal protein, employment, income, and foreign exchange to the economy and its population.

Introduction

From 1973 to 1997, global fish consumption doubled, from 45.4 million metric tons (t) to 91.3 million t (Delgado et al. 2003). This increase was attributed mainly to the global population growth, urbanization, and expansion in per capita income experienced both in developed and developing countries. On the other hand, the global fish supply increased from 47.6 million t to 93.2 million t over the same period, resulting in a surplus production of about 2 million t, which, in turn, was processed into various seafood products or animal feeds.

Except for sub-Saharan Africa, most of the developing countries were self-sufficient in fish (Table 7.1). China, South Asia, and Southeast Asia became major net exporters. On the other hand the European Union, Japan, and the United States consistently remained net importers, which rendered the entire developed world a fish deficit region, despite remarkable surpluses made in Latin America. Asia has figured prominently in

Table 7.1 World production and consumption of food fish and other marine products.

	Total Production (Million t[a])		Total Consumption (Million t)		Net Production over Consumption (Million t)	
Country	1973	1997	1973	1997	1973	1997
China	4.9	33.3	4.9	33.2	0	0.1
Southeast Asia	5.4	12.6	5.4	11.3	0	1.3
India	1.9	4.8	1.8	4.5	0.1	0.3
Other South Asia	1.2	2.1	1.1	2.0	0.1	0.1
Latin America	2.3	6.4	2.1	3.8	0.2	2.6
West Asia and North Africa	0.7	2.2	0.6	2.1	0.1	0.1
Sub-Saharan Africa	2.1	3.7	2.6	3.7	–0.5	0
United States	1.8	4.4	2.9	5.4	–1.1	–1
Japan	8.2	5.2	7.6	7.9	0.6	–2.7
EU 15[b]	6.1	5.9	6.3	8.8	–0.2	–2.9
East Europe and former Soviet Union	7.9	4.9	7.3	4.4	0.6	0.5
Other developed countries	2.9	4.8	0.9	1.6	2	3.2
Developing World	20.7	68.0	20.4	63.2	0.3	4.8
Developing World except China	15.9	34.6	15.4	30.1	0.5	4.5
Developed World	26.9	25.2	25.0	28.1	1.9	–2.9
World	47.6	93.2	45.4	91.3	2.2	1.9

Source: Delgado et al. (2003).
[a]t, metric tons.
[b]EU 15 includes Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and the United Kingdom.

the recent "blue revolution." As of 2001 Asia contributed 61% to the total global fish production (Table 7.2), the largest share among all regions of the world.

A large part of the global fish production coming from both the developed and developing countries was contributed by aquaculture. Since 1990, aquaculture production has grown steadily, overtaking the growth of capture fisheries, which has become stagnant in recent years due to declining fish stocks caused by overfishing and degraded natural habitats. About 90% of the total

Table 7.2 Distribution of global fish production, 2001.

Region	Production (Million t[a])	Percent of World Total
Asia	79	61
Africa	7	5
Europe	18	14
North and Central America	9	7
South America	16	12
Oceania	1	1
World	130	100

Source: FAO (2004).
[a]t, metric tons.

global aquaculture production is contributed by Asia, which had an impressive growth rate of 11% during the period 1990 to 2003 (Dey and Ahmed 2005). Thus, aquaculture is one of the fastest growing food producing sectors in the region.

Changing Structure of Fisheries in Developing Countries

The fishery industry supports millions of people worldwide, either directly or indirectly, for employment, income, and livelihood. Of these, the majority is poor and lives in pockets of poverty in Asia, Africa, Latin America, and the Pacific. Landless fisheries workers and artisanal fishers are among the poorest segments of coastal and riverine populations. Subsistence fishing in nearby water bodies served as the main livelihood to this sector in the past.

Continuous harvesting of fish and other marine products, however, has severely depleted the resource base in these aquatic environments. Some traditional fishing grounds are now seriously threatened. This has resulted in a declining fish catch, which has made subsistence fishers more vulnerable to poverty and unstable food supplies. Due to the well-recognized risks of further exploiting wild fisheries vis-a-vis the sustainability of the fishery sector, aquaculture has emerged as an alternative strategy to ensure a continued supply of fresh fish. Similarly, it offers new livelihood options for the fishing communities that were once solely dependent on wild-caught fish.

From traditional seeding or ranching of communal ponds intended for home consumption, aquaculture evolved into multiscale ventures with market-oriented motives. The growth of agribusiness-focused aquaculture inspired the development of a host of new and better technologies for fish cultivation. At the same time it opened up a whole chain of activities ranging from fry production to grow-out culture and processing of harvested fish that are traded either domestically or internationally. These activities served as a strong catalyst for economic growth of the rural sector in both developed and developing countries. By allowing income benefits to flow from the backward linkage of aquaculture, such as production and marketing of fish seeds and aquafeeds, to the forward linkage activities, such as transport, storage, processing, and value-addition that result in new and innovative seafood products, aquaculture contributed considerably to the world's gross domestic product (GDP) and foreign exchange earnings. The ability of the fish market to be highly segmented reinvented the industry by opening up new channels for its products. Additional employment and income created by these new market segments resulted in increased growth of the fishery sector as well as rural economies.

The key to a blue revolution is technological change. Recent innovations and improvements in aquaculture have generally been focused on the production of relatively high-value species and the intensification of production technologies. Specifically such innovations include (a) captured breeding of broodstock, (b) hatchery and nursery technology for fish seeds, (c) resource-intensive production technologies, and (d) new ways of value adding to and processing fish. Success in these new technological developments has pushed forward the frontier of production possibilities for the fishery sector and placed aquaculture as a key contributor to rural economic growth.

Emerging Trends in Species and Systems

Production and Supply

The phenomenal rise of Asia as the world's leading fish producer was propelled by the remarkable growth of aquaculture production in the region. The growth of the sector was faster in some countries (e.g., China, Thailand, and Malaysia) due to favorable factors such as abundant aquatic environments and rapid adoption of new aquaculture technologies. The demand for fish and existing infrastructure and institutions in the various countries has also contributed to realizing the potential of aquaculture in the region.

Aquaculture farming is commonly practiced under three different production environments: marine, freshwater, and brackish water systems. In a study conducted by WorldFish Center and its partners (WFC 2005), farmed fish output data from major aquaculture producing countries were disaggregated by ecosystem source to determine their

Table 7.3 Aquaculture production by type of culture system in selected Asian countries, 1999–2001.

	Aquaculture Production (Million t[a])			
Country	Marine	Brackish Water	Freshwater	Total
Bangladesh	–	0.10	0.69	0.79
China	4.93	6.37	12.3	23.6
India	–	0.10	2.5	2.6
Indonesia	0.20	0.43	0.99	1.62
Malaysia	0.92	0.12	0.15	1.19
Philippines	0.92	0.25	0.15	1.32
Sri Lanka	–	0.01	–	0.01
Thailand	–	0.44	0.25	0.69
Total Production	6.97	7.82	17.03	31.82
Percent	22%	24%	54%	100%

Sources: Ahmed et al. (2004); Garcia et al. (2004); Huang et al. (2004); IFEP (2004); Ministry of Marine Affairs and Fisheries (2004); Omar et al. (2004); Piyasena et al. (2004).
[a]t, metric tons.

relative contributions. Table 7.3 shows that 54% of the total aquaculture production in selected Asian countries was contributed by inland freshwater culture systems, followed by brackish water systems (24%) and marine aquaculture (22%).

The culture practices in these systems vary by location, and they range from high-input intensive systems commonly found in Japan, Taiwan, and Malaysia to the traditional low-input system of stocking catchments and seasonal ponds, which are popular in Bangladesh, India, and Burma (Myanmar). In some countries aquaculture is integrated with crop farming or animal husbandry such as the rice-fish system in Viet Nam and the duck-fish system in India and Thailand. The choice of a specific production system and culture technologies is highly dependent on the type of water resources, available technology, and capital available to the fish farmer.

Freshwater Aquaculture in Asia

Freshwater aquaculture is the largest source of farmed fish in the region, with China, India, Bangladesh, Viet Nam, Indonesia, and Thailand as the top producers. Freshwater aquaculture production has increased markedly, from 6.57 million t in 1990 to 19.48 million t in 2000, representing 196% growth within a decade (Dey et al. 2005a). Fish is commonly grown in ponds, embankments, cages, pens, and net enclosures that are set up in reservoirs, catchments, lakes, rivers, channels, and paddy fields. Pond aquaculture is the most popular type of production system in the region, based on area and yield.

Culture practices in freshwater aquaculture include diverse production techniques and methods, which vary according to farm characteristics such as farm size, water depth of the pond or pen, the management system for seeding and feeding rates, tenure status, rearing period, and pond system. The interplay of these factors determines the quantity of production, yield, and efficiency of an aquaculture farm.

Table 7.4 shows the diversity in characteristics and management of freshwater aquaculture farms in selected Asian countries. The average farm size in the region is generally more than 1 ha, except in Bangladesh, India, and southern Viet Nam, where farms are smaller, ranging from an average of 0.2 to 0.87 ha. The minimum water depth during the dry season ranges from 1 to 4 m but rises to 6 m in the wet season. Most of the farms are privately owned and are operated year round, except for some seasonal ponds in Bangladesh, India, Thailand, and Viet Nam. Although monoculture and polyculture systems are both practiced in the region, polyculture of carp (*Cyprinus carpio*)

Table 7.4 General characteristics of freshwater aquaculture in Asia.

	Bangladesh	China	India	Indonesia		Philippines		Thailand	Viet Nam (Ponds)	
Characteristic	Ponds	Ponds	Ponds	RWS[a]	Cages	Ponds	Cages	Ponds	Northern	Southern
Average size of pond (ha)	0.2	1.7	0.87	n.d.[b]	n.d.	1.56	1.54	1.21	1.16	0.82
Farm ownership (%):										
Private	100	41	63	100	100	75	99	90	35	96
State/common/rented	0	59	37	0	0	25	1	10	65	4
Minimum water depth (m):										
Dry season	1.3	n.d.	2.9	n.d.	n.d.	0.9	4.2	1.27	1.56	0.93
Wet season	4.25	n.d.	4.78	n.d.	n.d.	1.3	5.6	2.12	2.44	1.37
Rearing cycle (%):										
Seasonal	26	0	13	0	0	0	0	9	8	41
Perennial	74	100	87	100	100	100	100	91	92	59
Pond system (%):										
Monoculture	0	4	0	0	0	100	100	8	2	30
Polyculture	100	96	100	100	100	0	0	92	98	70
Management System	Extensive	Semi-intensive, intensive	Extensive	Extensive, semi-intensive, intensive	Extensive, semi-intensive, intensive	Extensive, semi-intensive, intensive			Extensive, semi-intensive, intensive	

Source: Dey et al. (2005b).
[a]Running water system.
[b]n.d., not determined.

with other species such as tilapia (*Oreochromis* sp.), silver barb (*Barbodes gonionotus*), and black tiger shrimp (*Penaeus monodon*) is the dominant practice, while monoculture of milkfish (*Chanos chanos*), tilapia, or shrimp is more favored in the Philippines, Taiwan, and Indonesia. All types of management systems, ranging from extensive to semi-intensive and intensive systems, are generally found in the region. These management systems are often determined by the rate of fry stocking and feeding practices adopted by the farmer.

Extensive systems are popular in India and Bangladesh and commonly operated with low seeding rates and without any supplemental feeding. The fish species being raised often depend on natural foods like green algae and plankton that grow in the pond. On the other hand, Malaysia and Mainland China and Taiwan tend to use higher seeding rates and rely heavily on supplemental feeds. These practices allow for higher production and yields.

Aquaculture technologies and culture systems in the region cover a wide range of techniques and methods that are uniquely suited either to a specific fish species or group of species. This led to the production of a vast array of species that are farmed in Asia. China produces over 40 cultured species (Cen and Zhang 1998) dominated by freshwater carp varieties such as silver carp (*Hypophthalmichthys molitrix*), grass carp (*Ctenopharyngodon idellus*), common carp (*Cyprinus carpio carpio*), big head carp (*Aristichthys nobilis*), and crucian carp (*Carassius carsius*). Carp is similarly important in aquaculture in India (Mruthunjaya et al. 2004), consisting mainly of rohu (*Labeo rohita*), catla (*Catla catla*), and mrigal (*Cirrhinus mrigala*). These major carp species account for approximately 67% and 87% of the total freshwater aquaculture production in China and India, respectively (FAO 2002 as cited in WFC 2005).

The inland freshwaters of Bangladesh are inhabited by 20 species of shrimp and numerous species of finfish (60 native and 13 exotic), of which the majority are grown in impounded water bodies (Ahmed et al. 2004). Carp species account for more than 78% of total pond production in Bangladesh (FAO 2002 as cited in WFC 2005).

Milkfish and carp are the most popular culture species in Indonesia, accounting for 45% of the country's total aquaculture production in 2004 (Sugama 2007). Cultured freshwater species include tilapia, Nile carp (*Osteohilus hasseltii*), and Java barb (*Barbodes gonionotus*). River eel is an emerging freshwater culture species, with a remarkable growth rate of 45% in the past decade (FAO 2002 as cited in WFC 2005).

Malaysia produces about 20 species of freshwater finfish, dominated by carp, tilapia, Malaysian river catfish (*Mystus nemurus*), and shrimp. In the Philippines cultured milkfish contributes 53% of total aquaculture production, followed by tilapia, which contributes 29% (BAS 2003). Tilapia is the major freshwater cultured species in the Philippines, accounting for 63% of the total freshwater aquaculture production.

Nile tilapia (*Oreochromis niloticus*), Siamese gourami (*Trichogaster pectoralis*), and Thai silver barb (*Barbodes genionotus*) are the most popular freshwater species in Thailand. These species contributed around 38%, 27%, and 16%, respectively, to the total freshwater aquaculture production in 2000. Production of these species has been expanding steadily at the annual rates of 17%, 11%, and 16%, respectively (FAO 2002 as cited in WFC 2005).

In Viet Nam, carp contributed 29% of the country's fish production in 1996 (ICLARM 1998, 2001). Other important freshwater species in the country are tilapia, catfish, and Thai silver barb.

To date, Asia produces about 94% of the world's freshwater aquaculture production. Given the shrinking prospects of capture fishery production, freshwater aquaculture is expected to play a more important role in providing food fish not only for Asian people but also for the entire world.

Brackish Water Aquaculture in Asia

Asia has the greatest number of brackish water aquaculture ponds, which are spread over its 7.5 million ha of mangrove (Primavera 2000). About half of this area is in Indonesia, where the earliest record of brackish water aquaculture was documented (Schuster 1952). Black tiger shrimp (*Penaeus monodon*) is the most popular species grown in brackish water ponds and is produced mainly for export. Thailand, Indonesia, India,

Malaysia, the Philippines, and Viet Nam are major shrimp exporters in the region. China, on the other hand, produces shrimp mainly for domestic consumption. The cage culture of milkfish, tilapia, mullet (*Mugil cephalus*), seabass (*Dicentrarchus labrax*), mollusks (oysters, clams, and snails), and crustaceans (blue crab [*Callinectes sapidus*] and mudcrab [*Scylla serrata*]) has also grown rapidly during the past three decades.

Brackish water aquaculture is commonly practiced in pond or pen systems located in open areas or integrated with mangrove trees (also referred to as *silvofisheries* or *aquasilviculture*). Integrated mangrove-aquaculture systems evolved as an attempt to make brackish water aquaculture more environmentally sustainable after the "shrimp fever in the 1980s," which resulted in a massive loss of mangroves in Southeast Asia (Primavera 1997). Current aquasilviculture operations in Asia include (a) the traditional *gei wai* system or extensive shrimp culture in Hong Kong (Cha et al. 1997), (b) variations of the tambak (pond) system in Indonesia, such as *tambak empang parit*, or mixed-farming crop ponds, and *huttan tambak*, or forest-canal pond systems (Soemodihardjo and Soerianegara 1989), (c) integrated shrimp-mangrove farming systems in Viet Nam that combine shrimp culture with mangrove rehabilitation (Binh et al. 1997), (d) integrated mangrove ponds and pens for fish and crabs in the Philippines (Baconguis 1991), and (e) mudcrab pen culture in logged mangrove areas in Malaysia (Chang Wei Say 1997).

Marine Aquaculture in Asia

Adoption of marine aquaculture (also referred to as *mariculture*) in Asia in the past decade has been steadily increasing, especially in Indonesia, Malaysia, the Philippines, Thailand, and China. Mariculture areas in these countries were previously mostly devoted to seaweed and mollusk culture. The recent growth in the market for live reef finfish such as grouper, snapper (*Sparus auratus*), and humphead wrasse (*Cheilinus undulates*) in Hong Kong, Taiwan, and Mainland China has broadened the frontier of marine aquaculture. The system is viewed as an option to relieve pressure on wild fish stocks while closing the gap between increasing fish demand and declining capture fishery supplies (Williams 1996).

At present, mariculture still relies heavily on wild fry and mixed fish feed, which pose additional threats to wild fish populations (Sadovy 2000). The growing demand for fry of reef finfish led to the development of a vigorous seed market in the region, especially for Serranidae species (e.g., grouper). Similarly, the hatchery-based mariculture system opened a new avenue for aquaculture to help increase the supply of marine fish and provide livelihoods to the coastal communities in the region.

Demand

The expansion of fishery production and increased trade of fresh and processed fish products have met the growing demand for fish in the region and in developed countries. The recent shift in the global production and supply of fish from the developed to the developing world is attributed to the rise of Asia as the lead supplier and consumer of both capture and farmed fish. For people in the majority of Asian households, this is particularly important for their livelihoods and animal protein intake, which are generally characterized as poor and insecure.

In a fish demand study of nine Asian countries conducted by the WorldFish Center from 2001–2004 (M. M. Dey and Y. T. Garcia unpublished report), fish was found to be an important source of animal protein, constituting 13% of the total household food expenditure, next to meat, which accounted for 15% (Table 7.5). Generally, the expenditure for fish in urban areas was found to be higher than that of rural areas, i.e., averaging 16% and 9%, respectively. In addition, expenditures for fish were higher among higher income households than in those in the lower income groups, averaging 15% and 13%, respectively. This demonstrates the potential of the fishery sector to expand production as countries in Asia and the rest of the world become urbanized and the average family income increases.

Table 7.6 shows that people spent more on freshwater fish than on marine fish, averaging to 52% versus 35%. This result emphasizes the preference for freshwater finfish species among Asian

Table 7.5 Share of fish in total food expenditure in selected countries of Asia, 2005.

Country	Share in Total Food Expenditure	Rural	Urban	Lowest Income	Highest Income
Bangladesh	0.20	0.10	0.21	n.d.[a]	n.d.
China	0.05	0.03	0.07	n.d.	n.d.
India	0.06	0.07	0.06	0.05	0.08
Indonesia	0.09	n.d.	n.d.	n.d.	n.d.
Malaysia	0.21	0.15	0.32	n.d.	n.d.
Philippines	0.14	n.d.	n.d.	0.16	0.12
Sri Lanka	0.09	n.d.	n.d.	n.d.	n.d.
Thailand	0.16	n.d.	n.d.	0.15	0.18
Viet Nam	0.19	n.d.	n.d.	0.15	0.21
Average	0.13	0.09	0.16	0.13	0.15

Sources: Ahmed et al. (2004); Garcia et al. (2004); Huang et al. (2004); IFEP (2004); Ministry of Marine Affairs and Fisheries (2004); Omar et al. (2004); Piyasena et al. (2004).
[a]n.d., not determined.

consumers. The preference was more pronounced for high-value freshwater species, which accounted for an average 26% of total food expenditure, compared to the 10% for marine species. High-value freshwater species are large finfish species that are preferably sold live in the market (e.g., carps in Bangladesh, China, and India; snakehead [*Channa striata*] and silver barb in Thailand and Viet Nam; and milkfish in the Philippines). High-value marine species include both large demersal and pelagic species like tuna (*Thunnus obesus*), grouper, snapper, and Pacific mackerel (*Rastrelliger brachysoma*).

Expenditures were observed to be the same for freshwater and marine low-value finfish species, i.e., 26% for freshwater and 25% for marine species, but they were comparable to the share of high-valued freshwater species (i.e., 26%).

Table 7.6 Share in expenditure and average price of various fish types in selected countries of Asia, 2005.

Fish Types	Share in Fish Expenditure (%)	Average Fish Prices ($/kg)
Freshwater:		
High-value	26	1.52
Low-value	26	0.98
Marine:		
High-value	10	1.69
Low-value	25	0.86
Non-fish:		
Shrimp	n.d.[a]	3.37
Other crustaceans/ mollusks	8	1.23
Processed (i.e., dried) fish	13	1.46
Total	100	1.61

Sources: Ahmed et al. (2004); Garcia et al. (2004); Huang et al. (2004); IFEP (2004); Ministry of Marine Affairs and Fisheries (2004); Omar et al. (2004); Piyasena et al. (2004).
[a]n.d., not determined.

Low-value freshwater species include tilapia, common carp, catfish, and other assorted small fish; low-value marine fish include anchovy (*Engraulis* spp.), roundscad (*Decapterus* spp.), and other small pelagic and demersal species.

The observed pattern in the average expenditures on the various fish types points to the importance of low-value fish species (both from freshwater and marine environment) as a primary source of animal protein among the Asian households. It is also evident from the results reported that aquaculture of freshwater species like carp, shrimp, tilapia, milkfish, and catfish played an important role in the growth of per capita fish consumption in the region.

Variation in fish prices is an important factor in the consumption of different fish types. The average price of fish and other marine products in Asian markets was observed to vary widely, ranging from $0.86/kg to $3.37/kg (Table 7.6). The average price of high-value marine fish was higher than that of high-value freshwater fish, i.e., $1.69/kg and $1.52/kg, respectively. The opposite, however, was true for low-value species, i.e., $0.86/kg for freshwater fish and $0.98/kg for marine fish. This further explains the general preference for low-value freshwater species among Asian consumers, especially those in lower income groups. By providing a consistent supply to meet demand, aquaculture was a major factor in stabilizing the price of freshwater species and in making fish affordable across the region.

Dey and Garcia (personal communication, November 30, 2004) also estimated the own-price and income elasticities of various types of finfish in the nine above-mentioned countries to measure fish demand responsiveness to price and income changes. Table 7.7 shows that the demand for high-value species was generally *price elastic* (i.e., the elasticity value is <1). This suggests that the demand for this category of fish was relatively susceptible to price changes. The observed elasticities ranged from −1.17 to −1.28. On the other hand, demand for the low-value species was found to be mostly *price inelastic* (i.e., the elasticity value is <1), with values ranging from −0.89 to −0.96.

Average price elasticity generally increased across income groups as income declined. On the average, fish demand among consumers in lower income groups was more elastic at −1.22, compared to −1.06 for those in upper income groups. More importantly, among the lower-income households all fish types except for low-value marine and processed (dried) fish registered elastic demand. Such demand response is expected because these fish types are relatively low priced.

Table 7.8 shows the estimated income elasticities for all fish types in selected countries in Asia (M. M. Dey and Y. T. Garcia unpublished report).

Table 7.7 Own-price elasticity of fish demand in selected countries of Asia, 2005.

Fish Types	All Countries	Lowest Income Group	Highest Income Group
Freshwater:			
High-value	−1.27	−2.05	−1.16
Low-value	−0.93	−1.10	−0.98
Marine:			
High-value	−1.17	−1.19	−1.16
Low-value	−0.94	−0.85	−0.94
Non-fish:			
Shrimp	−1.28	−1.15	−1.25
Other crustaceans/ mollusks	−0.96	−1.02	−0.92
Processed (i.e., dried) fish	−0.89	−0.78	−0.80
Average	−1.11	−1.22	−1.06

Sources: Ahmed et al. (2004); Garcia et al. (2004); Huang et al. (2004); IFEP (2004); Ministry of Marine Affairs and Fisheries (2004); Omar et al. (2004); Piyasena et al. (2004).

Table 7.8 Income elasticity of fish demand in selected countries of Asia, 2005.

Fish Types	All Countries	Lowest Income Group	Highest Income Group
Freshwater:			
High-value	0.98	1.21	0.72
Low-value	1.08	1.36	0.69
Marine:			
High-value	1.21	1.60	0.92
Low-value	1.04	1.26	0.69
Non-fish			
Shrimp	1.17	1.25	0.80
Other crustaceans/ mollusks	1.18	2.43	0.75
Processed (i.e., dried) fish	0.98	1.48	0.16
Average	1.08	1.40	0.76

Sources: Ahmed et al. (2004); Garcia et al. (2004); Huang et al. (2004); IFEP (2004); Ministry of Marine Affairs and Fisheries (2004); Omar et al. (2004); Piyasena et al. (2004).

All income elasticities were found to be positive, which suggests that the Asian consumers consider fish as a normal good, i.e., one that increases in demand as income increases. As with price elasticity, income elasticity was likewise found to decrease as income increased with an average value of 1.4 for the lowest income group and 0.76 for the highest income group. As such, fish was income elastic among poorer consumers, but inelastic among consumers in higher income brackets. This further indicates that among richer consumers, fish is treated as an ordinary food commodity, but poorer consumers considered it to be a luxury item. Hence, given the increases in per capita income brought about by the recent economic development experienced in the region, the demand for fish in Asia (both for cultured and wild species) is expected to increase, especially among consumers in poorer households.

In terms of average expenditures and elasticities (both price and income), the structure of fish demand highlights the relative importance of low-value freshwater species, e.g., tilapia, carp, and catfish, in the growth of aquaculture in the region. This suggests that a large part of the decision of farmers to culture these species appeared to be demand driven. Similarly, the industry for high-value finfish and other seafood products (e.g., grouper, seabass, shrimp, oysters, and crabs) has been fueled by the demand for the species for export. In many instances countries choose a particular aquaculture species for farming mainly for its economic importance as an export commodity (Liao 2003). Therefore the contribution of certain species to the growth of aquaculture may depend heavily on the viability of these species in the local and international markets.

Trade

One important feature of Asia's aquaculture is its export orientation. Over the years, the industry has evolved from the production of fish for domestic consumption to the export of fresh and processed fishery products. More recently, the industry has expanded to include the backward linkages of the fish market (i.e., the trade of fry and fingerlings) to its forward linkages (various forms of processed fish products). Japan, Taiwan, Malaysia, and Thailand have specialized in modern techniques of processing of, and value-addition to, fisheries products. Similarly, hatcheries for various aquaculture species including tilapia, milkfish, grouper, seabass, and shrimp have proved to be viable segments of the fishery trade. This diversification in fishery products has greatly expanded the trade of fish within Asia and the world. At the same time, the introduction of some species as new trade

commodities, e.g., salmon (*Oncorhynchus* spp.), tilapia, milkfish, and catfish contributed much to this trade expansion.

About one-third of the global value of fish output was traded across international borders (FAO 2003), of which half was contributed by the developing countries (Dey et al. 2003). Specifically, the less-developed food-deficit countries, such as Viet Nam, Indonesia, Thailand, and Malaysia, contributed more than 20% of this trade. In these countries, fish exports were equivalent to nearly 42% of their food imports, which comprised a major source of foreign exchange to pay for their growing food imports (Ahmed et al. 2003).

The fishery industry is currently one of the largest trade sectors in agriculture (Ahmed et al. 2003). In 2000, global fish exports accounted for 21% of the total agricultural exports. It was higher than all meat exports combined (19%), all cereals combined (14%), and all beverages combined (12%).

The recent shift in the flow of trade in fisheries products was driven in part by the efforts of the World Trade Organization to liberalize trade, which effectively lowered tariffs and nontariff barriers for tradable goods. Trade issues, however, remain a volatile tension point for developed and developing countries, given the stringent food safety and public health concerns of major importers such as the European Union, Japan, and the United States. Due to the perishable nature of the fish products, exports are likely to be affected by the health safety regulatory measures due to their inherent food safety risks (Unnevehr 2000). For example, the fish-processing sector in many Asian countries is dominated by traditional methods of drying, salting, smoking, and curing fish that often fail to satisfy the strict food safety requirements of the importing countries. Compliance to food safety standards and hazard analysis and critical control point processes adds to production costs, which are often prohibitive for small producers and processors (Dey et al. 2005a). Hence, the future of fish exports from the developing countries largely depends on the ability of their producers to bear the cost of compliance. It is important to note that production of high-quality fish products must be seen as a competitive strategy to stay ahead of the other exporters in the world market.

Supporting Aquaculture through National Policies

Governments in Asian countries played an important role in aquaculture development, especially in the 1970s and 1980s. Although aquaculture has been transformed to a private sector undertaking during the past two decades, most countries in the region continue to allocate public resources to promote aquaculture development through any of the following: (a) establishing hatcheries and ensuring seed stock availability; (b) establishing demonstration and training farms; (c) training of farmers by fielding extension workers; (d) providing special loan programs, marketing assistance, or both; and (e) extending financial incentives for large-scale development (FAO 2006).

More recently, governments in Asia have been preoccupied with land and area development for aquaculture, particularly in high-value and exportable aquatic products (e.g., aquaculture investment zones [AIZs] in Malaysia, mariculture parks in the Philippines, aquaculture zones in Indonesia). From time to time, governments have allotted public land for managed aquaculture development and provided physical planning and financial assistance, usually targeted to smallholders (e.g., nucleus-estate aquaculture development in Indonesia).

The present thrust of many Asian countries is in mitigating the negative consequences of "runaway" aquaculture development by instituting rules and regulations, such as environmental impact assessments, limits to allowable size and spacing of fish cages, bans on mangrove forest clearing and the use of certain chemicals and therapeutants, and imposition of quarantine procedures on the movement of live fish. In addition, most of the countries in Southeast Asia are increasingly promoting voluntary compliance to a code of conduct for responsible aquaculture (e.g., the Food and Agriculture Organization of the United Nations' Code of Conduct for Responsible Fisheries).

In general, however, aquaculture and fisheries subsectors in most Asian countries remained peripheral to national poverty reduction strategy plans (PRSPs) and national development plans (Thorpe 2005). Aquaculture continues to have a

very low profile in macroeconomic decision making, and its interaction with the rural economy is hardly reflected in growth, development, and equity benefit terms. Only three countries (Cambodia, Oman, and the Philippines) gave exceptional consideration to fisheries and aquaculture-related concerns (Thorpe 2005). The Cambodian PRSP, the Omani Sixth Five-Year Development Plan, and the Philippine Medium-Term Development Plan all made explicit reference to aquaculture and fisheries as a principal tool for rural development. On a lesser scale, however, Viet Nam's PRSP highlights the rapid growth aspects of aquaculture and announced a Sustainable Aquaculture for Poverty Alleviation Strategy and Implementation Programme as part of a wider Hunger Eradication and Poverty Reduction Programme (Government of Viet Nam 2001). India cites the importance of food safety issues in the export of fish and fish products in its national policy documents, and Malaysia's 5-year plans link aquaculture with food security. The national PRSP of Bangladesh sets clear targets for aquaculture, and there are public and private sector efforts to develop an action plan for aquaculture and fisheries along the strategies of PRSP (Karim et al. 2006). Thailand's policy documents make no specific reference to aquaculture (Thorpe 2005).

Providing Aquaculture with a General Institutional Framework

The relevant national agency directly concerned with the overall management of the aquaculture sector often has to interact and work with other national agencies since aquaculture activities always require other nonfisheries services. For example, in Bangladesh leasing of public water bodies is under the jurisdiction of the Land Administration and Land Reform Division, and aquaculture as part of rural development is carried out through the Bangladesh Rural Development Board. The use of mangrove forests in the Philippines is administered by the Bureau of Forestry Development under the Department of Environment and Natural Resources, which also enforces environmental compliance of all aquaculture activities through its Environmental Management Bureau. Meanwhile, aquaculture exports and trade issues are handled by the agency generally concerned with trade, such as the Export Promotion Bureau in Bangladesh and the Bureau of Export Trade and Promotion of the Philippine Department of Trade and Industry. In India, the Marine Products Export Development Authority under the Ministry of Commerce was created to promote the export of fisheries and aquaculture products.

The day-to-day administration of aquaculture activities in Asia, however, varies across countries. With India's federal form of government, all aquaculture management functions including extension are the responsibility of the state. Malaysia's federal government still maintains control over aquaculture in marine waters, with land-based aquaculture under the jurisdiction of state governments. The nonpeninsular states of Sabah and Sarawak have control over all aquaculture activities, whether land- or sea-based.

In China, Indonesia, and the Philippines, day-to-day administration of aquaculture concerns is delegated to the local government. Licensing and permits are handled by the People's Government at the county level or higher in China, at the provincial level in Indonesia, and at the municipal level (except for the issuance of fishpond lease agreements for public lands, which is done at the national level) in the Philippines. Extension services remain as a national government function in most of Asia, including China and Indonesia. The Philippines is the only exception, where agriculture extension services have been devolved to the municipal governments since the passage of the Local Government Code of 1991.

Learning Lessons from the Past: Factors of Success and Failure

The flexibility of emerging technological, organizational, and management models of aquaculture created an opportunity for rural communities to integrate and diversify farming systems through modest and gradual investment. Some examples are the Vuon-Ao-Chuong (garden/orchard-fish pond-animal pen), or VAC system, in Viet Nam and pond polyculture and aquaculture in seasonal

ponds in Bangladesh (Gupta et al. 1998; Mandal et al. 2004). Transferability of the technology also contributed to the successful development of aquaculture in Asia. Borrowing pond polyculture technology, for example, the Chinese, Vietnamese, and Bangladesh rice farmers have extended aquaculture into their rice paddies, increasing fish production by fourfold in less than a decade and earning (in China) close to $1,800/ha/year as net income (Xiuzhen 2003). Farmers also benefited from government investment in aquaculture research, development, and extension that helped in prioritizing and diversifying species combinations and improving farm management, leading to huge growth in productivity.

In rural China and Viet Nam, aquaculture development was driven mainly by a set of liberal policies (particularly on land use and farm management) that created a household responsibility system (e.g., in China) for diversified operation of farmland and capital, encouraging family self-reliance and income. Liberalization of price controls on products and inputs also provided economic incentives to adopt aquaculture on rural farms (Wang 2001). The VAC movement in Viet Nam has been playing an important role in diversifying Vietnamese agriculture and protecting natural resources and the environment to ensure sustainable (aquaculture) development (VACVINA 1995). The recent policies for sustainable aquaculture development also helped expand their export market, which increasingly requires safe and high quality food products.

In Bangladesh, three essential factors for success were identified in community aquaculture projects: (a) identification of a floodplain area where an aquaculture project can be established with minimum initial investment; (b) selection of dedicated, honest, and self-motivated local people and their election to the project's management teams; and (c) a transparent and accountable system that ensures equity and the right to participate for all stakeholders. The projects built partnerships with nongovernmental and community-based organizations that worked for the effective and sustainable management of natural common property resources (Rahman et al. 2005).

A shared vision between the public and the private sectors likewise plays a crucial role in fulfilling aquaculture's long-term potential for rural development, global food security, and poverty alleviation. Governments can support research, development, and extension on environmentally benign systems; eliminate implicit subsidies for ecologically unsound fish production; and establish and enforce regulatory measures to protect aquaculture ecosystems. Nongovernmental organizations play an important role in strengthening the farmers' financial and technical capacity to develop viable and sustainable aquaculture on their farms (FAO/NACA 1995). In Bangladesh, the often participatory extension approach of public-private partnerships in aquaculture projects encouraged participation among women, which in turn contributed to increased household income, increased self-confidence, and higher social status. Often, the project's sustainability depended on the provision of quality support services by partner nongovernmental organizations (Mandal et al. 2004).

Conclusions—Issues and Concerns

Despite the remarkable growth in Asia's aquaculture, the potential for expansion is still far from exhausted. Most of the more traditional production techniques and practices currently in use in the region are less efficient compared to the modern and superior practices in developed countries. Aquaculture production in Asia can still be increased through (a) expansion of pond and cage areas devoted to fish culture, (b) more intensified and efficient use of production inputs (e.g., high stocking rate, supplemental feeding, proper timing and quantity of feeding, and better harvesting techniques), and (c) development of new culture technologies (such as genetic enhancement, improved pond and water management, and improved feed and disease control) that can easily be transferred to farmers (Dey et al. 2005b). The Asian experience in aquaculture expansion has shown that these options are being either singularly or simultaneously explored.

The challenge for aquaculture is to expand production to meet the growing demand for fish, which can no longer be supplied by capture fisheries due to dwindling fish stocks around the world. Sustainable intensification of aquaculture

will lower the prices of fisheries and aquaculture products (especially those of popular low-value freshwater species), making them more affordable to poorer sectors of the population. A related concern, however, is that aquaculture expansion is becoming increasingly dependent on capture fisheries for aquafeeds, exerting pressure on the already dwindling wild fish stocks used both as food and feed. This is a major concern among conservationists, because the net amount of fish input to aquaculture as aquafeed and the volume output as food fish is not yet well established. To ease aquaculture's dependence on fisheries output, new technology for feed formulation needs to be developed to increasingly replace fish protein with that from grains or oilseeds.

Governments must realize that on the path to aquaculture development they must consider both socioeconomic and environmental factors confronting the farmers. Farmers who are better off are more likely to take advantage of more modern technology because of their higher literacy rates, larger landholdings, higher crop intensities, and greater intensification of fish culture system, resulting in higher fish production and greater benefits. Lack of time and financial resources often constrain marginal farmers to adopt or improve their fish culture systems.

In general, the benefits of aquaculture growth and development are yet to be fully enjoyed by small-scale producers and subsistence-oriented farmers, in whose hands a large part of the industry rests. Often limited access to land and water resources, capital, and technical know-how constrains these marginal groups from taking advantage of the benefit flow. The devolution of institutions, including technology and institutional support through effective awareness campaigns and training systems, is one strategy being used to enhance the participation of resource-constrained small-scale producers in aquaculture. This will help improve the skills and human capital of small-scale farmers, in turn helping increase the technical efficiency of their farm operations.

At a more macro level, policy reforms should support small-scale farmers' increased access to credit and infrastructure for better access to both input and output markets. Similarly, increasing their participation in domestic (and/or international) trade can also help create more equitable sharing of benefits for all operators in the industry. It must be recognized that participation in the world market requires strict compliance with international food safety standards, for which knowledge on good production practices and safe management must be extended to help producers minimize their costs of compliance. In addition, industry representatives, political leaders, and international policy makers should aim to forge trade arrangements that provide small-scale operators greater access to export markets, affording them a fair share of the benefits of the burgeoning fish trade.

The prospects of aquaculture development in Asia remain bright. Future aquaculture technologies and development strategies, however, must be ecologically feasible, socially acceptable, and economically viable (Leung and Shang 2003). Though these requirements sound daunting, they aim only to sustain aquaculture's many roles in the development of Asian economies.

References

Ahmed, M., M.M. Hossain, N.M. Humayun, M.B. Hossain, M.S. Haque, R.K. Talukder, and S. Alam. 2004. Final country report: Bangladesh. Strategies and Options for Increasing and Sustaining Fisheries and Aquaculture Production to Benefit Poor Household in Asia Project (ADB-RETA 5945). The WorldFish Center, Penang, Malaysia.

Ahmed, M., M.A. Rab, and M.M. Dey. 2003. Changing structure of fish supply, demand and trade in developing countries—Issues and needs. Paper No. 238 *in* Fisheries in the Global Economy. Proceedings of the Biennial Conference of the International Institute on Fisheries Economics and Trade (IIFET) 2002, Wellington, New Zealand, 19–22 August 2002. The Institute on Fisheries Economics and Trade, Department of Agricultural and Resource Economics, Oregon State University, Corvallis, Oregon, USA.

Baconguis, S. 1991. Aquasilviculture technology: Key to mangrove swamp rehabilitation and sustainable coastal zone development in the Philippines. Canopy International 17(6): 5–12.

BAS (Bureau of Agricultural Statistics). 2003. Fisheries Statistics of the Philippines, 1999–2003. Department

of Agriculture, Quezon City, Philippines. http://www.bas.gov.ph.

Binh, C.T., M.J. Phillips, and H. Dermaine. 1997. Integrated shrimp-mangrove farming systems in the Mekong delta of Vietnam. Aquaculture Research 28: 599–610.

Cen, F. and D. Zhang. 1998. Development and status of aquaculture in the People's Republic of China. World Aquaculture, June 1998.

Cha, M.W., L. Young, and K.M. Wong. 1997. The fate of traditional extensive (*gei wai*) shrimp farming at Mai Po marshes nature reserve, Hong Kong. Hydrobiologia 352: 295–303.

Chang Wei Say, W. 1997. Pen culture of mudcrabs in the ecosystems in Sarawak (East Malaysia). Aquaculture Asia 4(4): 3–5.

Delgado, C.L., M.W. Rosegrant, N. Wada, S. Meijer, and M. Ahmed. 2003. Fish to 2020: Supply and demand in a changing world. 2020 Vision Paper. International Food Policy Research Institute, Washington, DC, USA, and WorldFish Center, Penang, Malaysia. 236 pp.

Dey, M.M. and M. Ahmed. 2005. Aquaculture—Food and livelihoods for the poor in Asia: A brief overview of the issues. Aquaculture Economics and Management 9(1–2): 1–10.

Dey, M.M., M. Ahmed, K.M. Jahan, and M.A. Rab. 2003. Liberalization versus barriers: Experiences from selected countries in Asia. Paper No. 241 *in* Fisheries in the Global Economy. Proceedings of the Biennial Conference of the International Institute on Fisheries Economics and Trade (IIFET) 2002. Wellington, New Zealand, 19–22 August 2002. The Institute on Fisheries Economics and Trade, Department of Agricultural and Resource Economics, Oregon State University, Corvallis, Oregon, USA.

Dey, M.M., F.J. Paraguas, X. Yuan, N. Srichantuk, R. Bhatta, and L.T.C. Dung. 2005a. Technical efficiency of freshwater pond polyculture production in selected Asian countries: Estimation and implication. Aquaculture Economics and Management 9(1–2): 39–63.

Dey, M.M., M. Rab, K.M. Jahan, A. Nisapa, A. Kumar, and M. Ahmed. 2005b. Food safety standards and regulatory measures: Implications for selected fish exporting Asian countries. Aquaculture Economics and Management 9(1–2): 217–235.

FAO (Food and Agricultural Organization of the United Nations). 2002. The State of World Fisheries and Aquaculture (SOFIA) 2002. Food and Agriculture Organization of the United Nations, Rome, Italy. http://www.fao.org/docrep/005/y7300e/y7300e00.htm.

———. 2003. Fisheries statistics. Food and Agriculture Organization of the United Nations, Rome, Italy. http://www.fao.org.

———. 2004. Fisheries statistics. Food and Agriculture Organization of the United Nations, Rome, Italy. http://www.fao.org.

———. 2006. Regional review on aquaculture development. 3. Asia and the Pacific—2005. FAO Fisheries Circular No. C1017/3. Food and Agriculture Organization of the United Nations, Rome, Italy. ftp://ftp.fao.org/docrep/fao/009/a0597e/a0597e00.pdf.

FAO/NACA (Food and Agricultural Organization/Network of Aquaculture Centres in Asia Pacific). 1995. Regional study and workshop on the environmental assessment and management of aquaculture development. Publication TCP/RAS/2253. NACA Environment and Aquaculture Series No. 1. Network of Aquaculture Centres in Asia Pacific, Bangkok, Thailand. 477 pp.

Garcia, Y.T., N.A. Lopez, J.O. Dickson, R.D. Ramiscal, A.C. Costales, R.L. Tan, U.P.E. Rodriguez, and S.M.M. Navarez. 2004. Final Country Report: Philippines. Strategies and Options for Increasing and Sustaining Fisheries and Aquaculture Production to Benefit Poor Household in Asia Project (ADB-RETA 5945). The WorldFish Center, Penang, Malaysia. 311 pp.

Government of Viet Nam. 2001. Sustainable Aquaculture for Poverty Alleviation (SAPA) Strategy and Implementation Programme. Hanoi, Viet Nam. 54 pp.

Gupta, M.V., J.D. Sollows, M.A. Mazid, A. Rahman, M.G. Hussain, and M.M. Dey. 1998. Integrating aquaculture with rice farming in Bangladesh: Feasibility and economic viability, its adoption and impact. ICLARM Technical Report 55. International Center for Living Aquatic Resources Management (ICLARM), Manila, Philippines. 90 pp.

Huang, J., L. Lu, W. Miao, H. Yuan, and L. Liu. 2004. Final Country Report: China. Strategies and Options for Increasing and Sustaining Fisheries and Aquaculture Production to Benefit Poor Household in Asia Project (ADB-RETA 5945). The WorldFish Center, Penang, Malaysia. 121 pp.

ICLARM (International Center for Living Aquatic Resources Management). 1998. Dissemination and evaluation of genetically improved tilapia species in Asia: Final report. Asian Development Bank Regional Technical Assistance No. 5558. International Center for Living Aquatic Resources Management, Makati City, Philippines. 151 pp.

———. 2001. Genetic improvement of carp species in Asia: Final report. Asian Development Bank Regional Technical Assistance No. 5711. International Center

for Living Aquatic Resources Management, Penang, Malaysia. 158 pp.

IFEP (Institute of Fisheries Economics and Planning). 2004. Final Country Report: Vietnam. Strategies and Options for Increasing and Sustaining Fisheries and Aquaculture Production to Benefit Poor Household in Asia Project (ADB-RETA 5945). The WorldFish Center, Penang, Malaysia. 95 pp.

Karim, M., M. Ahmed, R.K. Talukder, M.A. Taslim, and H.Z. Rahman. 2006. Dynamic agribusiness-focused aquaculture for poverty reduction and economic growth in Bangladesh. Policy Working Paper. Ministry of Fisheries and Livestock, Bangladesh, The WorldFish Center, Penang, Malaysia, and Bangladesh Shrimp and Fish Foundation, Dhaka, Bangladesh. 38 pp.

Leung, P.S. and Y.C. Shang. 2003. A historical review of aquaculture economics research. Pages 205–217 *in* C.-S. Lee, editor. Aquaculture: Retrospective and Outlook. An Aquaculture Summit. Asian Fisheries Society, Manila, Philippines and World Aquaculture Society, Baton Rouge, Louisiana, USA.

Liao, I C. 2003. Aquaculture: Personal experiences and visions. Pages 1–21 *in* C.-S. Lee, editor. Aquaculture: Retrospective and Outlook. An Aquaculture Summit. Asian Fisheries Society, Manila, Philippines and World Aquaculture Society, Baton Rouge, Louisiana, USA.

Mandal, S.A., G. Chowhan, G. Sarwar, A. Begum, and A.N.M. Rokon Uddin. 2004. Mid-term review report on development of sustainable aquaculture project CDSAP. WorldFish Center, South Asia Office, Dhaka, Bangladesh. 84 pp.

Ministry of Marine Affairs and Fisheries. 2004. Final Country Report: Indonesia. Strategies and Options for Increasing and Sustaining Fisheries and Aquaculture Production to Benefit Poor Household in Asia Project (ADB-RETA 5945). The WorldFish Center, Penang, Malaysia. 64 pp.

Mruthunjaya, M., N.G.K. Pillai, P.K. Kathiha, A. Kumar, R. Bhatta, R.L. Shiyani, and P. Kumar. 2004. Final country report: India. Strategies and Options for Increasing and Sustaining Fisheries and Aquaculture Production to Benefit Poor Household in Asia Project (ADB-RETA 5945). The WorldFish Center, Penang, Malaysia. 277 pp.

Omar, H.I., S.Y. Tai, K.M. Nor, N.M.R. Abdullah, and C.F. Lim. 2004. Final Country Report: Malaysia. Strategies and Options for Increasing and Sustaining Fisheries and Aquaculture Production to Benefit Poor Household in Asia Project (ADB-RETA 5945). The WorldFish Center, Penang, Malaysia. 260 pp.

Piyasena G., P.P.G.S.N. Siriwardane, D.S. Jayakody, A. Seneratne, S. Athula, J.A.D.B. Jayasooriya, R. Maldeniya, R.M.U.D. Pakumara, and A.H.S. Ediriweera. 2004. Final Country Report: Sri Lanka. Strategies and Options for Increasing and Sustaining Fisheries and Aquaculture Production to Benefit Poor Household in Asia Project (ADB-RETA 5945). The WorldFish Center, Penang, Malaysia. 164 pp.

Primavera, J.H. 1997. Socio-economic impacts of shrimp culture. Aquaculture Research 28: 815–827.

———. 2000. Integrated mangrove-aquaculture systems in Asia. Integrated Coastal Zone Management (autumn edition): 121–130.

Rahman, H.Z., M. Nuruzzaman, S.Z. Ahmed, M.Z. Rahman, and M.B. Hossain. 2005. The interface of community approaches and agri-business: Insights from floodplain aquaculture in Daudkandi. Draft Final Report. Power and Participation Research Centre, Dhanmondi, Dhaka, Bangladesh. 50 pp.

Sadovy, Y. 2000. Regional survey for fry/fingerling supply and current practices for grouper mariculture: Evaluating current status and long-term prospects for grouper mariculture in Southeast Asia. Final Report to the Collaboration Asia-Pacific Economic Cooperation Grouper Research and Development Network (FWG 01/99). Asia-Pacific Economic Cooperation, Singapore. 102 pp. + appendices.

Schuster, W.H. 1952. Fish culture in brackish water ponds of Java. Indo-Pacific Fisheries Council Special Publication 1: 1–143.

Soemodihardjo, S. and I. Soerianegara. 1989. The status of mangrove forests in Indonesia. Biotrop Special Publication: 73–109.

Sugama, K. 2007. Public policy for sustainable development of milkfish aquaculture in Indonesia. *In* P.S. Lueng, C.-S. Lee, and P. O'Bryen, editors. Species and System Selection for Sustainable Aquaculture. Blackwell Publishing, Ames, Iowa, USA.

Thorpe, A. 2005. Mainstreaming fisheries into national development and poverty reduction strategies: Current situation and opportunities. FAO Fisheries Circular No. 997. FIPP/SFLP/C997. Food and Agriculture Organization of the United Nations, Rome, Italy. 134 pp.

Unnevehr, L.J. 2000. Food safety issues and fresh food product exports from LDCs. Agricultural Economics 23: 231–240.

VACVINA (National Association of Vietnamese Gardeners). 1995. Intensive small-scale farming in Vietnam. Centre for Information on Low External Input and Sustainable Aquaculture (ILEIA) Newsletter 11(1): 4.

Wang, Y. 2001. China P.R.: A review of national aquaculture development. Pages 307–316 *in* R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery, and J.R. Arthur, editors. Aquaculture in the Third Millennium. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20–25 February 2000. Network of Aquaculture Centres in Asia-Pacific, Bangkok, Thailand and Food and Agriculture Organization of the United Nations, Rome, Italy.

WFC (WorldFish Center). 2005. Strategies and options for increasing and sustaining fisheries and aquaculture production to benefit poorer households in Asia. ADB-RETA 5945. Project Completion Report submitted to the Asian Development Bank, February. The WorldFish Center, Penang, Malaysia. 563 pp.

Williams, M.J. 1996. Transition in the contribution of living aquatic resources to sustainable food security. Discussion paper No. 13. International Food Policy Research Institute, Washington, DC, USA. 41 pp.

Xiuzhen, F. 2003. Rice-fish culture in China. Aquaculture Asia 8(4): 44–46.