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Recommendation Domains for Pond Aquaculture

Country Case Study: Development and Status of Freshwater Aquaculture in Bangladesh

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RECOMMENDATION DOMAINS FOR POND AQUACULTURE

Country Case Study: Development and Status of Freshwater Aquaculture in Bangladesh

Madan M. Dey
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LIST OF ABBREVIATIONS

ADB	Asian Development Bank
AEZ	agro-ecological zone
BARC	Bangladesh Agricultural Research Council
BBS	Bangladesh Bureau of Statistics
BFRI	Bangladesh Fisheries Research Institute
BRRI	Bangladesh Rice Research Institute
cm	centimetre
DoF	Department of Fisheries
DSAP	Development of Sustainable Aquaculture Project
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FDA	Food and Drug Administration, USA
FY	fiscal year
FYP	5-year plan
GDP	gross domestic product
GIFT	genetically improved farmed tilapia
GoB	government of Bangladesh
ha	hectare
HACCP	hazard analysis and critical control point
HCI	head count index
IB	investment bias
ICLARM	International Center for Living Aquatic Resources Management
IRRI	International Rice Research Institute
kg	kilogram
mm	millimetre
MoF	Ministry of Finance
MoFL	Ministry of Fisheries and Livestock
NGO	nongovernmental organization
PC	Planning Commission
R&D	research and development
RDA	recommended dietary allowance
SPS	sanitary and phytosanitary
t	tonne (1,000 kg)
TE	technical efficiency
TSP	triple super phosphate
TYP	2-year plan
TYRIP	3-year rolling investment programme
UK	United Kingdom
US/USA	United States of America
WTO	World Trade Organization
yr	year

GLOSSARY

baor	=	oxbow lake
beel	=	seasonally flooded large water body on dry-season cropland
haor	=	flooded basin
taka	=	currency of Bangladesh ($1 = 69 taka in June 2008)
upazila	=	sub-district

NOTE: In this report, “$” refers to US dollars.

The fiscal year (FY) of the government of Bangladesh ends on 30 June. FY before a year denotes the year in which the fiscal year ends. For example, FY2005 begins on 1 July 2004 and ends on 30 June 2005. A period other than an FY that straddles 2004 and 2005 is denoted as 2004/05, and the whole 2-year period of 2004 and 2005 is denoted as 2004-05.

ACKNOWLEDGEMENTS

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We are grateful to the many collaborators and researchers of past WorldFish projects in collaboration with national institutes in Bangladesh (i.e., “Dissemination and evaluation of genetically improved tilapia in Asia”, “Genetic improvement of carp species in Asia”, ”Strategies and options for increasing and sustaining fisheries and aquaculture production to benefit poorer households in Asia”, “Production, consumption, accessibility and marketing of aquaculture products in Asia”, and “Development of sustainable aquaculture project”), who collected relevant information used in this paper.

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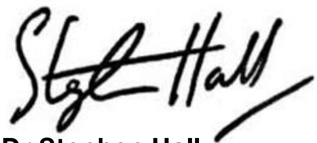
FOREWORD

This monograph is a result of a 3-year project to produce a decision-support toolkit with supporting databases and case studies to help researchers, planners and extension agents working on freshwater pond aquaculture. The purpose of the work was to provide tools and information to help practitioners identify places and conditions where pond aquaculture can benefit the poor, both as producers and as consumers of fish. By undertaking the project in four countries (Cameroon and Malawi in Africa, and Bangladesh and China in Asia), each at a different stage of aquaculture development, project researchers were better able to test the toolkit for wide applicability and utility.

Applying such a toolkit requires a clear understanding of the existing state of pond aquaculture in each country, the circumstances underpinning its development, and the factors driving its adoption or discontinuation. To achieve this, country case studies were conducted by extensive literature review supplemented with analysis of primary and secondary data.

This monograph is the case study for Bangladesh. Written in three parts, it describes the historical background, practices, stakeholder profiles, production levels, economic and institutional environment, policy issues, and prospects for aquaculture in the country. First, it documents the history and current status of the aquaculture in the country. Second, it assesses the technologies and approaches that either succeeded or failed to foster aquaculture development and discusses why. Third, it identifies the key reasons for aquaculture adoption.

I hope that this monograph will help development practitioners and researchers interested in aquaculture development in Bangladesh. The WorldFish Center and its research and national partners are grateful to the Federal Ministry for Economic Cooperation and Development, Germany, for funding the project. We also thank all other partners, including fish farmer respondents, who have contributed to this effort.



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[1] Research partners: University of Kassel and the University of Hohenheim, Germany; National partners: Institut de Recherche Agricole pour le Développement in Cameroon, Fisheries Department in Malawi, Department of Fisheries in Bangladesh and Chinese Academy of Fishery Sciences.

1. INTRODUCTION AND COUNTRY PROFILE

1.1 RATIONALE AND PURPOSE OF THE CASE STUDY

Aquaculture has increased the availability of fish for consumption and contributed to improving livelihoods for millions of households in Bangladesh. Although aquaculture has grown significantly as an industry over the years, its full potential has not yet been realized, and faster development is required to keep up with growth in demand for fish. The type of aquaculture appropriate for Bangladesh depends on the prevailing policy and institutional settings, socioeconomic conditions of the farmers, and agro-ecological environments of the country. The number of potential fish farmers and beneficiaries is considered to be very large in Bangladesh. For this potential to be realized, it is necessary to identify the following:

- Who can practice aquaculture to reap its benefits? Identify the types of farming systems and agro-ecological zones into which aquaculture can be sustainably incorporated.
- What aquaculture practices are appropriate for farmers' specific endowment? Study, document, analyze and develop systems that fit the prevailing ecological, economic, nutritional and socio-cultural context.
- Which technology gaps still exist? Identify technology leaps required to raise the performance of a system from a functioning farmer trial to a profitable and therefore widely acceptable enterprise.
- How can this knowledge be successfully imparted? Formulate strategies and mechanisms that will be cost effective and successful in promoting the widespread adoption of smallholder aquaculture.
- What support, inputs and policies are required, and for how long, until the desired impact can be achieved?

The main purpose of this case study is to provide a historical overview of aquaculture development in Bangladesh, with the aim of identifying factors and causal relationships and creating conditions that enable the successful development of aquaculture. Specifically, this report provides an overview of agro-ecological conditions, farming systems, aquaculture potential, institutional capability for diffusion, socioeconomic conditions, market demand, input-output delivery systems, policy environment and, finally, the potential for aquaculture development. The outputs of this case study provided inputs for determining recommendation domains for freshwater pond aquaculture in the country.

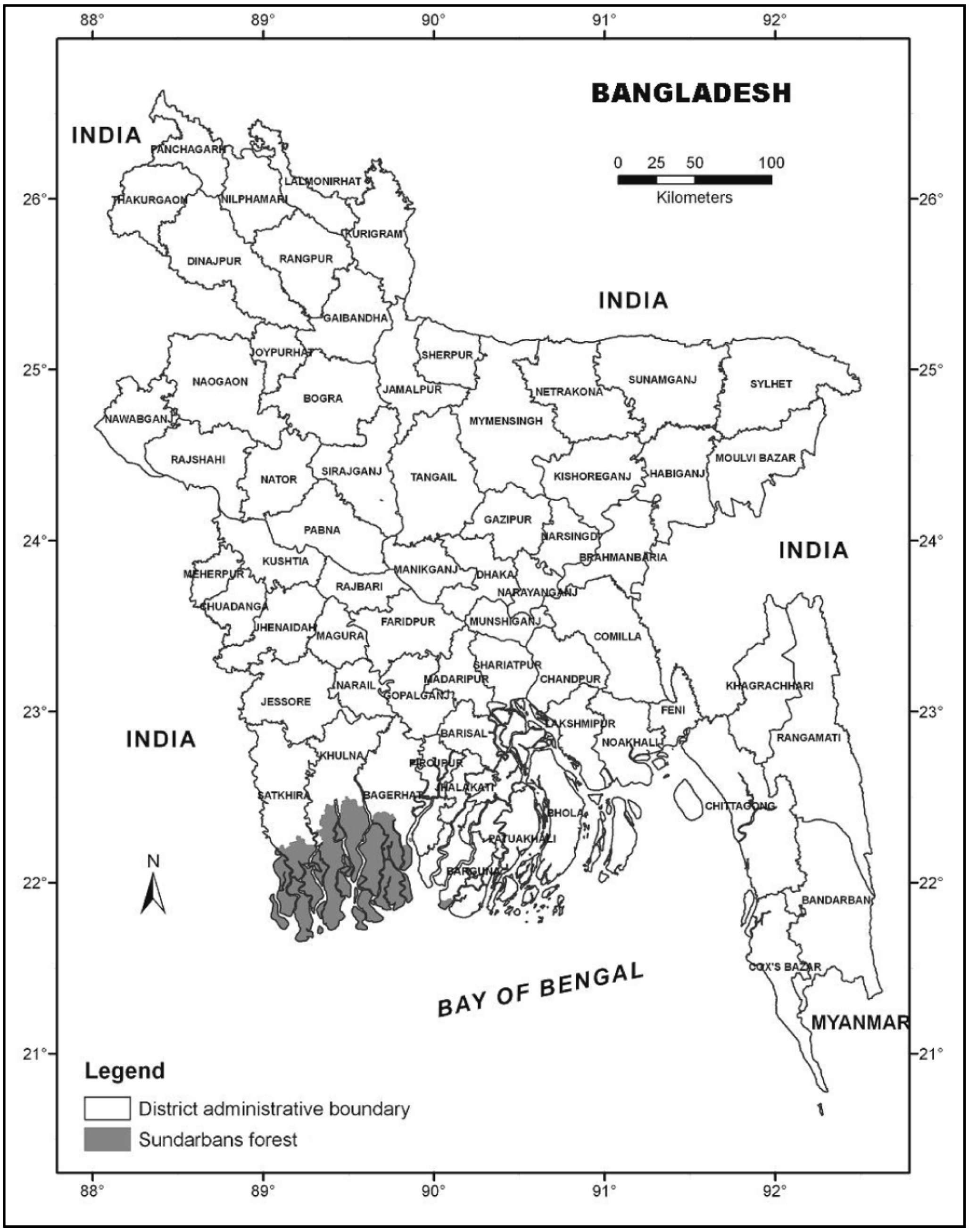
The case study is based on secondary data from various sources, such as government documents, the database of the Food and Agriculture Organization (FAO) of the United Nations and other literature, and on primary data collected by the WorldFish Center and its partners over the past decade through field surveys. The analytical approach followed includes both qualitative and quantitative analyses (descriptive statistics, regression models and charts).

1.2 COUNTRY PROFILE

Bangladesh is located between north latitudes 20° 34' and 26° 38' and east longitudes 88° 01' and 92° 41'. The country is bordered by India on the west, north and northeast; Myanmar on the southeast; and the Bay of Bengal on the south (Figure 1). The area of the country is 147,570 square kilometres (km^2), 7% of which is permanently under water (BBS 2007a, CIA 2008). The population is 153 million (CIA 2008), a quarter of which is urban. Bangladesh occupies the eastern part of what was Bengal province in British-ruled India from 1757 to 1947 and was subsequently East Pakistan until 1971, when Bangladesh established itself as an independent state (Islam 1993).

Bangladesh enjoys a generally warm and humid subtropical environment with a mild winter from October to March, a hot and humid summer from March to June, and a warm and humid rainy monsoon from June to October (BBS 2007a). Temperatures range from a minimum of 7-13° Celsius during the winter to a maximum of 31-37°C in the summer. The average annual rainfall varies among the regions from a minimum

Figure 1: District administrative map of Bangladesh



Sources: Prepared using base map digital data collected from the Local Government Engineering Department and the computer center of Bangladesh Agricultural Research Council in Dhaka, Bangladesh, in 2000.

recorded value of 1,429 millimetres (mm) to a maximum 4,338 mm.

From the early days of its civilization, Bangladesh has been largely agrarian, and it remains so, though economic growth has been achieved in the past 3 decades through fast-growing non-farm sectors. It is mostly a flat delta with fertile alluvial soils, a favourable tropical climate, and readily accessible surface and ground water. Diverse ecologies support the year-round farming of multiple rice crops, over 100 other crops (including various types of other cereals, oilseeds, pulses, spices, fruits, vegetables, roots and tubers), livestock, poultry and fish (BBS 2004a and 2007a, Bose 2001). Because of the ubiquitous presence of water bodies large and small, most inhabitants of the vast floodplains were, from time immemorial, never far from where fish was naturally available. Fish remains the preferred and most important protein source for Bangladeshis.

The history of fishing in Bengal is more than 4,500 years old (Breazley 1993). For generations, people have harvested fish from ponds, rivers, flooded land, the coast and the deep sea, learning to cooperatively use fishing grounds and market their catch. Fish harvesting and marketing were traditionally considered undignified jobs, so fishers were mainly the low-caste Hindu tribes such as the Majhi, Jaley and Malo. Ponds and lakes continue to feature prominently in the landscape and the lives of rural people. Ponds were traditionally created as borrow pits excavated to supply soil for raising homesteads above flood levels during the wet monsoon. The ponds serve multiple purposes for the rural household, used not only for fish culture but also to supply water for washing, bathing and other household needs. Fish culture in such closed water bodies as ponds and lakes was recorded to have started in 350 BC on the Indian subcontinent (Banglapedia 2008a).

In the past, fish farming was extensive and subsistence in nature, stocked with wild fry and fingerlings caught in rivers and cultured without the use of fish feeds. Following the introduction of technology for inducing carp to spawn in the late 1960s and the subsequent development of fishpond management technologies in the 1970s and 1980s, fish farming became widespread and market driven. Culturing various carp and exotic fish species in ponds and lakes became popular all over the country, with the broad participation of all religious and ethnic groups.

1.3 CHANGING STRUCTURE OF THE BANGLADESH ECONOMY AND THE CONTRIBUTION OF THE FISHERIES SECTOR

Today, about three quarters of Bangladeshis live in rural areas and remain largely dependent on agriculture and natural resources for food and livelihoods. However, some structural changes have occurred in the economy of Bangladesh over the past 3 decades (Hossain and Bose 2000), reducing the prominence of the agriculture sector in favour of the industrial and service sectors, as has been experienced in other developing countries in Asia. The Bangladesh economy has been growing at a respectable rate; average long-term gross domestic product (GDP) growth was 5.7% per year from fiscal year (FY) 1973 to FY2005 (BBS 1993 and 2007a, MoF 1990 to 2007 various issues). Although the agricultural GDP has more than doubled in absolute terms, its share of the national GDP declined dramatically from 54.6% during FY1973-75 to 19.7% during FY2003-05. This reflected the increasing prominence of the industrial and service sectors, which together contributed 45.4% of the GDP during FY1973-75 and 80.2% during FY2003-05 (Table 1).

Despite the decline in the share of agriculture in the national GDP, the fisheries sector (including both capture fisheries and aquaculture) has maintained an average contribution of 4-6% to the national GDP (BBS 2007a). Within agriculture, the contribution of fisheries has increased significantly from 7% during FY1973-75 to 15% during FY1993-95 and to 22% during FY2003-05 (Table 2). The fisheries sector experienced 8.9% growth per annum during the decade of 1985 to 1995, the highest growth rate in agriculture, then slowed to 3.7% per annum in the following decade.

Several studies have suggested that Bangladesh needs to achieve sustained GDP growth of at least 8-10%, export growth of 20-25% and import reduction of 18-20% to be economically developed before 2025 (Bhattacharya 2002, PC 1995). It appears that the fisheries sector can play a vital role in achieving higher growth in the national economy and exports. Recently, garments and fish have become Bangladesh's two most important exports.

1.4 FISHERIES SECTOR DEVELOPMENT, POVERTY AND FOOD SECURITY IN BANGLADESH

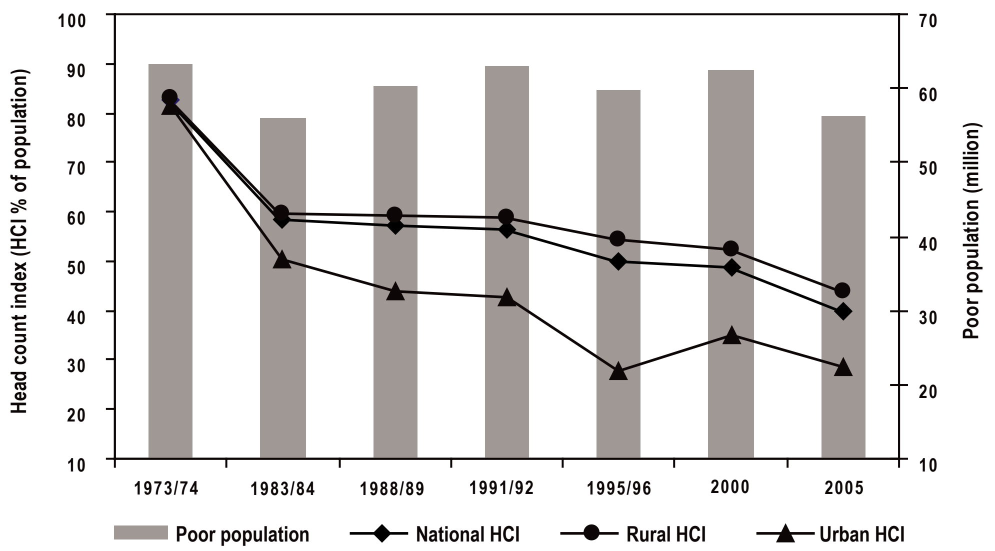
The incidence of poverty in Bangladesh remains high. Although the poverty rate declined by an average of 1% per year from 1972 to 2005, the number of poor people, 56 million, remained almost same in 2005 as it was 2 decades earlier in 1983/84 (Figure 2). About 44% of total population remains below

Table 1: Growth in GDP and its structural change from FY1973-75 to FY2003-05 in Bangladesh

Average period	Population (million)	Average annual GDP (million $) and its share (%) by major sector						National GDP (million $)	Per capita GDP $/yr
		Agriculture		Industry		Services			
		GDP	Share	GDP	Share	GDP	Share		
FY1973-75	76.2	5,435	54.6	1,157	11.6	3,365	33.8	9,957	131
FY1983-85	95.5	5,811	41.2	2,298	16.3	5,983	42.5	14,093	148
FY1993-95	115.5	8,005	30.4	4,636	17.6	13,723	52.1	26,364	228
FY2003-05	136.1	11,178	19.7	14,625	25.8	30,823	54.4	56,625	416
% increase from FY1973-75 to FY2003-05	78.5	105.7	-63.8	1163.5	122.2	816.0	61.1	468.7	218.5
Annual growth (%):									
FY1973-75 to FY2003-05	2.0	2.4	-3.3	8.8	2.7	7.7	1.6	5.7	3.9
FY1973-75 to FY1983-85	2.3	0.7	-2.8	7.1	3.4	5.9	2.3	3.5	1.2
FY1983-85 to FY1993-95	1.9	3.3	-3.0	7.3	0.8	8.7	2.1	6.5	4.5
FY1993-95 to FY2003-05	1.7	3.4	-4.2	12.2	3.9	8.4	0.4	7.9	6.2

FY = fiscal year, GDP = gross domestic product, yr = year.
Sources: MoF 2006 and 2007, MoF 1990 to 2000 various issues, BBS 1980 to 2007a various issues, BBS 2003a and 2003b.

Figure 2: Trends of HCI poverty incidence in Bangladesh from 1973/74 to 2005



HCI = head count index.
Sources: BBS 1998 and 2007b.

Table 2: Growth of agricultural GDP and its sub-sectors from FY1973-75 to FY2003-05 in Bangladesh

Average period	Annual average agricultural GDP (million $) and its share (%) by agricultural sub-sector								Agric. GDP (million $)	Per capita GDP $/yr
	Crops		Livestock		Forestry		Fisheries			
	GDP	Share	GDP	Share	GDP	Share	GDP	Share		
FY1973-75	4,582	84.3	280	5.1	194	3.6	379	7.0	5,435	71
FY1983-85	4,669	80.4	368	6.3	395	6.8	378	6.5	5,811	61
FY1993-95	5,003	62.5	905	11.3	880	11.0	1,217	15.2	8,005	69
FY2003-05	6,471	57.9	1,336	11.9	936	8.4	2,435	21.8	11,178	82
% increase from FY1973-75 to FY2003-05	41.2	-31.3	377.4	132.1	381.9	134.3	542.4	212.3	105.7	15.2
Annual growth (%):										
FY1973-75 to FY2003-05	1.2	-1.2	5.3	2.8	5.4	2.9	6.4	3.9	2.4	0.5
FY1973-75 to FY1983-85	0.2	-0.5	2.8	2.1	7.4	6.7	0.0	-0.7	0.7	-1.6
FY1983-85 to FY1993-95	0.7	-2.5	9.4	6.0	8.3	4.9	12.4	8.9	3.3	1.3
FY1993-95 to FY2003-05	2.6	-0.8	4.0	0.6	0.6	-2.7	7.2	3.7	3.4	1.7

agric. = agricultural, GDP = gross domestic product, yr = year.

the poverty line, as estimated with a head count index (HCI) of people falling below the income poverty threshold for food and other basic needs. The poverty threshold is based on an assessment of the costs of basic needs specific to Bangladesh, which include a 2,100 kilo-calorie food basket and minimal housing, education, health and clothing (Hossain et al. 2000). Most of the poor live in rural areas, as indicated by the higher rates of rural poverty in Figure 2.

Neither national economic growth nor the redistribution of wealth among sectors has so far significantly contributed to poverty reduction. Based on the micro-level study, Hossain (2004) indicated that the growth of off-farm activities in rural Bangladesh contributed a higher rate of poverty reduction than could have been achieved by people dependent only on agriculture. Moreover, income inequality among rural and urban households is widening (Hossain et al. 2000, Sen 2003, Bose and Dey 2007). More equitable growth remains an important goal for the government of Bangladesh (GoB).

The fisheries sector is closely associated with poverty in the developing countries of Asia, including in Bangladesh. Fish (broadly defined as living aquatic resources) is associated with many dimensions of the poverty alleviation strategy in Bangladesh, as it provides food, livelihood and income, as well as generating foreign exchange.

1.4.1 FISH FOR FOOD SECURITY

Fish provides food for millions of poor people in Bangladesh, where it is regarded as “poor people’s protein”. In fact, fish has long been the main source of protein in Bangladesh. Fish is also an important source of vitamins and micronutrients for the poor in Bangladesh (Thilsted et al. 1997). Bangladeshis, like most Asians, consume rice as their staple and supplement it with substantial amounts of vegetables, tubers and pulses, and reasonable amounts of animal protein, mainly fish and meat. In Bangladesh, two traditional sayings reveal the preferred foods of the people. One is the old Bengali proverb *masse-bhatee Bangali* (rice and fish makes a Bengali), and the other is *dal-bhat*, which refers to a meal of rice and pulses, considered the poor-man's meat. As the per capita consumption of pulses declined sharply from 1991/92 to 2005, dependency on fish increased (BBS 2003c and 2007b). Table 3 shows trends in the consumption of various types of food from 1962 to 2005. The high cereal number shows continued dependence on cereals for their energy and protein (BBS

Table 3: Actual average per capita food basket and protein intake (grams/day) by food type, 1962-2005, and the recommended food basket for Bangladesh

Food groups	RDA[1] per capita/day	1962-64[a]	1991/92[b]	2000[c]	2005[c]	Desirable intake[2] in 2020
Cereals	490	488.0	516.2	486.7	469.2	358
Roots/tubers	100	48.8	43.7	55.0	63.3	228
Pulses	30	27.6	17.9	15.6	14.2	70
Vegetables	125	134.5	137.4	140.5	157.0	143
Fruits	50	15.1	16.9	28.4	32.5	114
Animal foods	109	74.2	66.5	87.8	95.3	121
- Meat	20	9.5	8.2	14.4	15.6	21
- Fish	45	35.4	34.5	38.5	42.1	50
- Milk products	30	27.4	19.1	29.7	32.4	42
- Eggs	14	1.9	4.7	5.2	5.2	8
Fats/oils	20	8.3	10.1	12.8	16.5	38
Sugar/molasses (*gur*)	10	8.8	8.8	6.9	8.1	28
Others (spices, etc.)	10	3.2	68.7	60.0	91.6	na
Total	944	808.5	886.2	893.7	947.7	1,100
Energy (kilocalorie)	2,280	2,118	2,266	2,240	2,239	2,280
Protein (gram)		55.3	62.7	62.5	62.5	
Meat protein (gram)[d]			2.5	3.8	4.4	
Fish protein (gram)			6.8	7.9	8.5	
Share (%) of fish in animal protein			73.0	67.8	66.0	

na = not accounted.
[1] Recommended dietary allowance as set by the Bangladesh National Nutrition Council (official communication on 5 June 1997).
[2] Computed from RDA as provided by the Bangladesh National Nutrition Council.
[a] Pakistani Ministry of Health in collaboration with the University of Dhaka. 1966. Nutrition survey of East Pakistan (1962-64). Dhaka.
[b] BBS 1998.
[c] BBS 2007b.
[d] Meat includes mutton, beef, chicken and duck.

2007b), which may reflect the availability of cereals, market prices and people's poverty. Fish consumption is still below the recommended dietary allowance. With population and demand for fish, including export demand, rising, the expansion of fish supply to maintain food security has emerged as a priority concern.

Most of the fish consumed in Bangladesh is from domestic production. We estimated the degree of self sufficiency in fish consumption in Bangladesh, which is the proportion of consumer demand that is met by domestic production, for 1976 to 2005 based on the following formulae:

1. $PS_t = TCP_t/TC_t$

2. $CPS_t = (TCP_t - E_t)/TC_t$

where

PS_t = production self-sufficiency (%) for a particular year *t,*

CPS_t = consumable production self-sufficiency (%) for a particular year *t,*

TCP_t = total consumable production in million tonnes (t) for a particular year *t,*

TC_t = total consumption in million t for a particular year *t,* and

E_t = exports in million t for a particular year *t.*

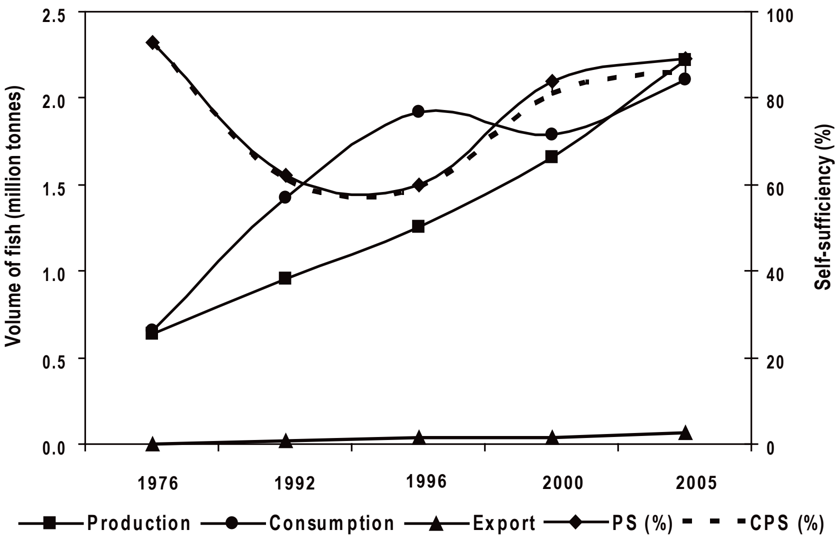
The results, depicted in Figure 3, show that Bangladeshis depend primarily on domestic sources of fish. Given the importance of fish in their diet (Table 3), these results highlight the importance of domestic fish production to protein food security in Bangladesh. Statistics collected by the Bangladesh Department of Fisheries (DoF 2007) show that shrimps and prawns, which constitute the main export fish items, account for only 3% of total fishery production in the country. This is borne out by the lack of significant differences between the PS and CPS estimates (Figure 3). The gap between fish consumption estimates based on household surveys by the Bangladesh Bureau of Statistics (BBS) and fish production statistics of DoF indicates that the latter did not include all sources of fish production in Bangladesh, and the consumption trend line rises above the production trend line.

1.4.2 FISHERIES SECTOR FOR EMPLOYMENT AND LIVELIHOODS

The fisheries sector provides livelihoods and income to the vast majority of the poor in Bangladesh. It plays a particularly important role among disadvantaged groups as a main or supplementary source of employment, livelihood and income. Most Bangladeshi poor live in rural areas with very limited employment opportunities. The *Poverty Reduction Strategy Paper* and National Fisheries Strategy indicated that income-generating opportunities for rural households are most promising in the fisheries sector (PC 2005, DoF 2006). Fully 73% of rural households are involved in some kind of freshwater aquaculture on the floodplains throughout the country (Mazid 1999).

Job growth in manufacturing, construction and power generation and services has absorbed many workers but has not kept pace with an ever-expanding workforce. The fisheries sector is the second largest part-time and full-time employer in rural areas, directly engaging over 60% of the rural population, as estimated based on agriculture census data (BBS 1999). An estimated 1.2 million people are directly employed in this sector. A further 12 million rural people indirectly earn livelihood from fisheries-related activities, such as the downstream activities of fish trading and processing (Dey et al. 2008a). Data from the labour force survey indicate that employment in the fisheries sector increased by 19.1% per annum from FY2000 to FY2003 (BBS 2004b). Detailed data on employment in the fisheries sector (full-time and part-time, regular and occasional, skilled and unskilled) are not available at the national level. Besides capture fisheries, aquaculture can open up new employment opportunities in rural areas by increasing both self-employment and demand for hired labour (Karim et al. 2006).

Figure 3: Trends in fish production, self-sufficiency, consumption and exports in Bangladesh, 1976-2005



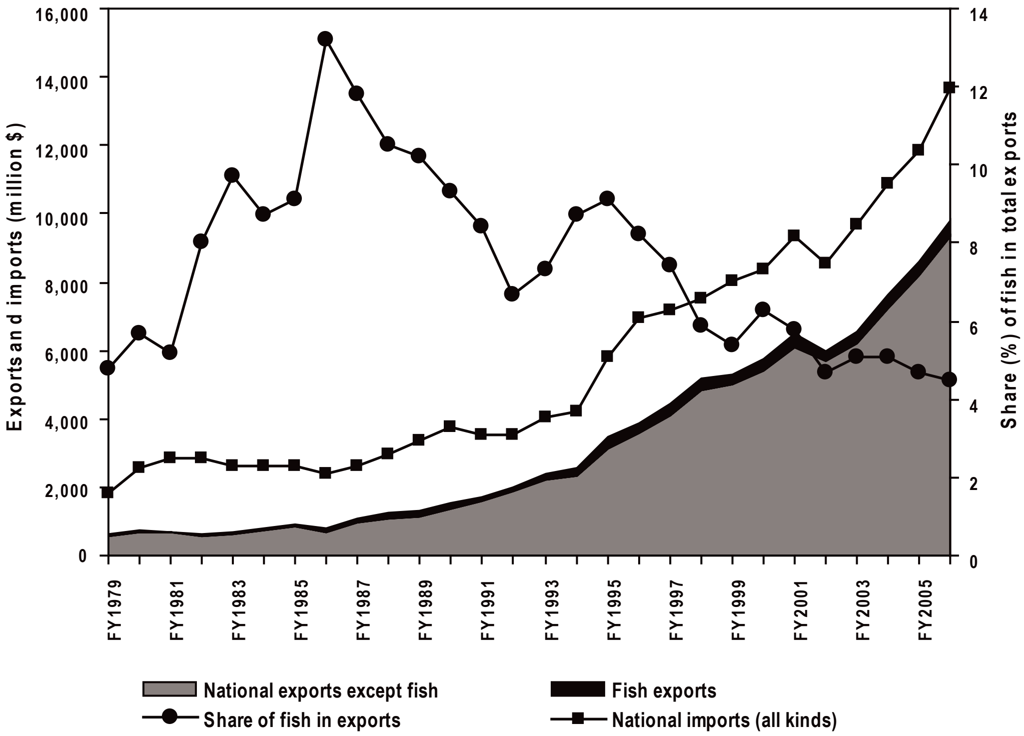
CPS = consumable production self-sufficiency, PS = production self-sufficiency.

1.4.3 FISHERIES SECTOR FOR EXPORT EARNINGS

The fish trade is a significant source of foreign currency earnings for Bangladesh and delivers benefits at both the macro- and microeconomic levels (Dey et al. 2005a). Fish is the third largest contributor to Bangladesh's export earnings and is growing annually by 5-8%. Revenue from traditional exports of non-fish agricultural products are gradually being outpaced by fishery products, to the extent that fish has become the most important primary commodity that Bangladesh exports (Dey et al. 2005a and 2008a).

During the latter half of the 1980s, fish contributed over 8% of total exports, reaching a peak of 13% in 1986 (Figure 4). Although the share of fish in total export value has declined in recent years with growth in manufacturing (e.g., garments) and services, the absolute value of fisheries exports has actually increased. The value of fish exports increased by 15 times from \$30 million in FY1979 to \$440 million in FY2006, constituting an annual growth rate of 9.4%. Given the consistently large trade deficit (Figure 4) and recent food shortage in Bangladesh, the contribution of fish exports toward earning foreign currency to pay for imports of other food has become increasingly important. As in other Asian countries, fish production from aquaculture increasingly contributes to the foreign exchange earnings of the fisheries sector of Bangladesh (Dey et al. 2005b).

Figure 4: Trends in fish export earnings and their contribution to the national economy from FY1979 to FY2006



FY = fiscal year.
Sources: BBS various issues, Statistical Yearbook of Bangladesh, DoF various issues, Fish Catch Statistics and Fishery Statistical Yearbook.

2. AQUATIC ECOSYSTEM AND ENVIRONMENT FOR AQUACULTURE

The United Nations Commission for Environment and Development Conference of 1992 brought significant recognition of the place of human economy, environment and sustainable development in planning and management actions (Muir 2005). It has been argued that aquaculture development should strive to improve both human and ecological well-being and the ability to achieve them (FAO 2007). Acceptable aquaculture development requires that land, water and living resources be managed sustainably. Therefore, it is necessary for aquaculture planners and researchers in Bangladesh to have detailed understanding of biophysical and agro-ecological environments within which Bangladeshi farmers adopt aquaculture technologies. Aquaculture development in a riverine alluvial delta like Bangladesh requires detailed understanding of river channels, landforms, climate and natural hazards. This section deals with the spatial nature of regional biophysical environments for aquaculture in Bangladesh, with particular focus on aquatic ecosystems and agro-climatic environments.

2.1 LAND AND WATER USE PATTERNS IN BANGLADESH

The topography of Bangladesh is predominantly characterized by the delta, a flat alluvial plain less than 10 metres above sea level that occupies 93% of the land area (some mountains occupy part of the southeast). About 88% of arable land is floodplain, which receives alluvium deposits every year as some 300 rivers overflow during the wet monsoon (BBS 2006).

The major uses of land and water in 2003 are given in Table 4. About two thirds of the country is under water at some point in a typical year, and over one third remains inundated for a good portion of the year and is therefore favourable for use as fish nurseries and for grow-out culture. Patterns of land and water use vary by season, as water bodies expand and areas for terrestrial crop production shrink significantly during the wet season. Also important is that there have been some changes in specific land uses during the last 4 years. For example, the area of brackish water has expanded from 190,000 hectares (ha) to 220,000 ha.

2.2 FRESHWATER AQUATIC ECOSYSTEMS

Freshwater bodies in Bangladesh can be broadly classified into seven major ecosystems, which are (1) rivers, (2) depressed basins (*haors* and seasonally deeply flooded land), (3) *beels* (seasonally flooded large water bodies on dry-season cropland), (4) *baors* (oxbow lakes, or cut-off loops of rivers), (5) other lakes, (6) seasonally flooded floodplain, and (7) pond and ditches.

River ecosystem. Bangladesh is a land of rivers situated in a gigantic delta traversed by the distributaries of the Ganges-Padma, Brahmaputra-Jamuna and Meghna rivers (Figure 5). Its mostly flat terrain is crisscrossed by over 300 major rivers and thousands of smaller rivers and canals totalling 24,000 kilometres (Future Fisheries 2003, BBS 2006). There are two categories of river catchments, namely (1) principal and other rivers (480,000 ha) and (2) estuary (552,000 ha). Flowing south into Bangladesh, the Brahmaputra changes its name to the Jamuna before joining the southeast-flowing Ganges to form the southeast-flowing Padma. The Padma joins the southwest-flowing Meghna (which forms in northeast Bangladesh as the Surma and also carries waters from the Old Brahmaputra), and the combined Lower Meghna continues to the Bay of Bengal. Rainfall and water flows from India are the main sources of water passing though these river. This river system typically connects with many water-filled depressions and flows through many small rivers and canals. The high water flows cause riverbank erosion and flooding that displaces people during the rainy season from May to August. Low discharge during drought in the dry season causes loss of aquatic resources.

Table 4: Land use in Bangladesh showing seasonal variations

Type of land use	Area in dry season		Area in wet season		Seasonal variation (%)[2]
	Area ('000 ha)	National share (%)[1]	Area ('000 ha)	National share (%)[1]	
Rivers	640.0	4.3	770.0	5.2	20.3
Main rivers	286.0	1.9	394.0	2.7	37.8
Minor rivers	188.0	1.3	210.0	1.4	11.7
Rivers in Sundarbans	166.0	1.1	166.0	1.1	0.0
Estuarine area	860.0	5.8	860.0	5.8	0.0
Standing water bodies	424.5	2.9	950.0	6.4	123.8
Haors	45.0	0.3	370.0	2.5	722.2
Beels	17.7	0.1	150.0	1.0	747.5
Baors	5.5	0.0	6.0	0.0	9.1
Ponds, tanks, ditches	300.0	2.0	350.0	2.4	16.7
Kaptai Lake	56.3	0.4	74.0	0.5	31.4
Cultivated area	7,760.0	52.6	7,350.0	49.8	-5.3
Seasonal field crops	5,100.0	34.6	1,714.0	11.6	-66.4
Seedbed only for seasonal crops	60.0	0.4	60.0	0.4	0.0
Seasonal fallow	1,700.0	11.5	1,676.0	11.4	-1.4
Current fallow	410.0	2.8	410.0	2.8	0.0
Brackish aquaculture	190.0	1.3	190.0	1.3	0.0
Rural household, plantation & forests	3,291.0	22.3	3,291.0	22.3	0.0
Village land (homestead, orchard, etc.)	840.0	5.7	840.0	5.7	0.0
Tree crops (including plantation)	490.0	3.3	490.0	3.3	0.0
Forest areas (protected & mangrove)	1,961.0	13.3	1,961.0	13.3	0.0
Non-agricultural area (urban, transport, etc.)	1,610.0	10.9	1,610.0	10.9	0.0
Salt beds	5.0	0.0	0.0	0.0	-100.0
National area	14,757.0		14,757.0		

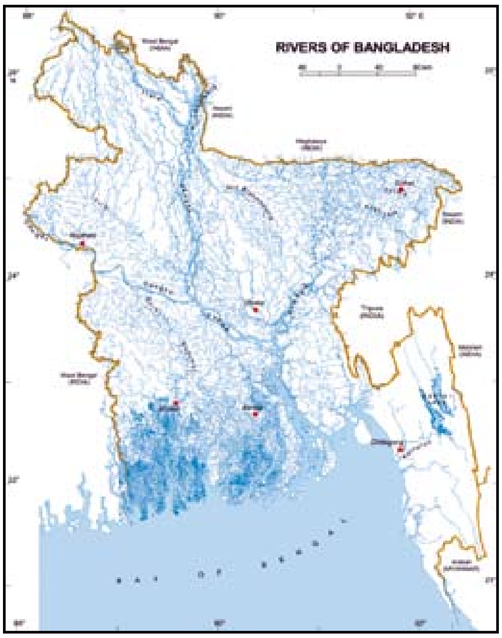
ha = hectare.

[1] Land-use areas overlap and therefore add up to more than 100%.

[2] Change in wet season area compared with dry season.

Source: Adapted from Asiatic Society of Bangladesh. 2003. Landuse. In: Banglapedia national encyclopaedia of Bangladesh. Dhaka. 6:235-239.

Figure 5: Map of the river network in Bangladesh



Source: Banglapedia, 2008b.

Depressed basin (haor) ecosystem. The basin flooded every year during the wet monsoon is located mainly in the greater Sylhet district and is called the Sylhet basin. It measures 113 km both east-west and north-south and covers 7,250 km^2 (Banglapedia 2008c). A numbers of beels (large lakes) and haors (large swamps) cover this saucer-shaped area. Haors are also located in the greater Mymensingh district. Most of the area of the basin (the haors) is submerged to 9-10 metres every year. This area receives a substantial amount of river water from India, as well as considerable local rainfall. Early flooding is a common phenomenon for this area, and people living around the basin fish for about 8 months of the year. A number of indigenous fish species, both large and small, grow in the area.

Beel ecosystem. Beels can be defined as extensive areas seasonally flooded to varying depths during the rainy season, with poor drainage keeping them waterlogged for more than 4 months. There are hundreds of beels in Bangladesh, largest of which are Chalan, Dakatia, Baghia and Chanda (also called Gopalganj-Khulna beel), and Arial. Hundreds of indigenous fish species and other aquatic animals and plants naturally grow in this ecosystem, providing the livelihoods of many of the people living around them.

Baor (oxbow lake) ecosystem. The distinction between beels and baors (also called *jheels*) is not always maintained, but the term baor is narrowly applied to oxbow lakes. These are river loops that become cut off, leaving a crescent-shaped lake that is usually perennial. Baors are classified as semi-closed water bodies and therefore common pool resources. There are about 500 such lakes with a combined area of 5,488 ha, located mainly in southwest Bangladesh (Chowdhury and Yakupitiyage 2000), These areas are normally deeply flooded, receiving local rainfall and runoff water during the wet monsoon, as well as water from the parent river during floods. The adjacent floodplain areas are sometimes affected by spill over. Some of these water bodies are used for fish culture, and the peripheral areas are either sown with crops or used for grazing livestock during the dry season. Baors are rich fishing grounds with high potential for freshwater fish polyculture. The margins of baors are raised areas always occupied by human settlements.

Lake fisheries. The three major lakes in Bangladesh are Rainkhyonkine and Bogakine in the Chittagong Hill Tracts and the Ashuhila beel at the northern end of the Barind Tract. One large reservoir, Kaptai Lake, is in the southeast of the country in Khagrachhari and Rangamati districts.

Seasonal floodplain. Aside from beel, haor and baor areas, plenty of other open water bodies develop during the rainy season and are often poorly drained. These areas, totalling more than 3 million ha, are seasonally submerged and classified as medium lowland (57%, submerged 2-4 months), lowland (4-6 months) and very lowland (>6 months). The water depth on medium lowland reaches 90-180 centimetres (cm) and exceeds 180 cm on lowland and very lowland.

Pond and ditches. Ponds in Bangladesh are categorized into three types according to aquaculture activity: (1) cultured, using fish culture technology; (2) culturable, but in need of limited infrastructure development; and (3) derelict, in need of substantial investment. Culturable and derelict ponds produce fish but depend largely on natural fish migration from open water sources. Occasionally, people stock fingerlings from the market for fish production but do not follow the culture system. Bangladesh has about 2.5 million ponds, and about 65% of them have already been brought under commercial fish culture. Although pond aquaculture in Bangladesh has a long history, semi-subsistence and commercial pond aquaculture started only 3 decades ago. Currently, many highly commercial farmers are constructing new ponds, but at the same time many ponds in urban areas have been filled for housing and road construction.

Bangladesh's many water bodies create ample opportunity for long-duration fish culture. During the monsoon season, about 5 million ha of inland open water areas become favourable for fish migration and reproduction. These become sources of wild fish spawn and fingerlings for fish hatcheries and nurseries and grow-out culture. Fishermen have traditionally caught fish and marketed them for 4-8 months of the year from the seasonally flooded lowland areas, and in the rest of the year from rivers, but river catches are in decline.

2.3 FRESHWATER AQUACULTURE SYSTEMS

Aquaculture is an intervention for farming fish, molluscs, crustaceans and other aquatic animals or plants that may entail stocking, feeding and providing protection from predators. The freshwater aquaculture systems used in Bangladesh are pond aquaculture, rice-fish culture (either rice and fish together or rice followed by fish) on seasonal farmland, cage culture in rivers and lakes, pen culture in closed and open water bodies, and fish culture in such commonly held perennial water bodies as oxbow lakes. Pond aquaculture has spread widely in the past decade, as have the rice+fish and rice-fish culture systems. Aquaculture systems generally use free water sources, but some receive commercial irrigation or hire irrigation equipment.

Pond fish culture. Pond aquaculture in a closed water body is a low-input activity for household consumption, as traditionally pursued by large landlords on the Indian subcontinent until the middle of the 20th century. Large, tasty, fresh fish was a luxury for the rich. Most people did not have land rights under the zamindari system, in which local landlords served as tax collectors for the British Raj until independence in 1947. Today, almost every household in lowland floodplains has at least one pond excavated initially to acquire soil to raise the homestead floor above the high water mark during the rainy season. Those without a river nearby also need to have a pond to supply water for household use. Most of the ponds connect with other water bodies during the rainy season, receiving runoff and becoming home to indigenous fish, which people catch during and after the rainy season. Many small ponds in northern and central Bangladesh dry up completely during the dry season. Fish farmers have adopted a variety of culture systems to suit the diversity of ponds.

Rice-fish culture. Rice-fish culture started in the 1990s through pioneering adaptive research done by the WorldFish Center (Gupta et al. 1999) in open water bodies, particularly with carp polyculture and tilapia mixed culture in the greater Mymensingh region. Rice-fish culture follows two patterns:

- *Pond or ditch beside rice land.* The fisheries extension department of the government and NGOs put a lot of effort into scaling up this method, and a remarkable number of poor people are gradually adopting it. The ponds of small farmers are usually dominated by such exotic fish as tilapia, sarpunti and catfish, with lesser numbers of carp. The major difficulties of this culture system are poor water quality and vulnerability to seasonal flooding, which allows fish to swim away, leaving farmers with serious economic losses. Farmers see this culture system as second only to rice in terms of importance to their food, nutrition and income security.

- *Fish culture in seasonally flooded rice land.* Two rice-fish culture systems are practiced in seasonally flooded rice areas. One is concurrent culture of deepwater rice with stocked fish during the flood season, followed by dry-season (*boro*) rice in shallow flooded areas. The other is alternating culture, with boro rice followed by stocked fish in a closed area during the flood season. Local entrepreneurs and farm communities increasingly practice fish culture in seasonally flooded paddies. Community-based fish culture is very appropriate for these environments.

Fish culture in communally held water bodies. Many types of communally held water bodies (jalmahals) are used for fish culture, including rivers, oxbow lakes, canals and perennial lowland water bodies. Except with cage culture, aquaculture in these types of water bodies is often operated by fisher cooperatives, community groups and farmer groups. Indian carp and exotic fish species are cultured mostly in carp polyculture and mixed culture systems, which also support indigenous fish species.

Cage culture. Cage culture using net boxes in open water bodies is a very new concept to Bangladeshi fish farmers and a highly commercial enterprise. It first started in 1997 in an oxbow lake in Jessore (Chowdhury and Yakupitiyage 2000). The Bangladesh Fisheries Research Institute (BFRI) encourages private entrepreneurs to expand this aquaculture system in other perennial water bodies, especially in freshwater rivers.

Pen culture. Pens for fish culture are made of bamboo and netting of polyethylene, nylon or plastic and usually placed in such semi-closed water bodies as irrigation and drainage canals, but sometimes in large, open water bodies like haors. Traditionally, fish feed mainly on naturally occurring plankton, though farmers sometimes apply low-protein natural materials as supplemental feed. Carp, punti, tilapia and pangus are suitable for this type of aquaculture.

Hatchery culture. Many hatcheries are operated in Bangladesh, both privately and publicly, with a number of specialized hatcheries for specific species. Private hatcheries are becoming more numerous. In freshwater environments, hatcheries choose carp and catfish. In the coastal saline environments of the southeast and southwest, most hatcheries choose shrimp.

Nursery culture. Almost every district in Bangladesh has a DoF nursery, most of which produce carp for freshwater aquaculture. During the past decade, private nurseries have expanded in parts of the country.

2.4 AGRO-CLIMATIC ENVIRONMENT

Bangladesh is divided into 30 agro-ecological zones (AEZs), which vary widely in terms of climate, landform, and the physical and chemical characteristics of the soil. In Bangladesh, people know that, where there is water, there is fish. Fish is captured and/or cultured in all AEZs under various aquatic ecosystems. Topography and climate make the construction of ponds and fish culture suitable over almost the entire country, but aquaculture productivity is frequently influenced by rainfall and temperature and such calamities as flooding and drought. The potential for aquaculture development therefore varies considerably across the country.

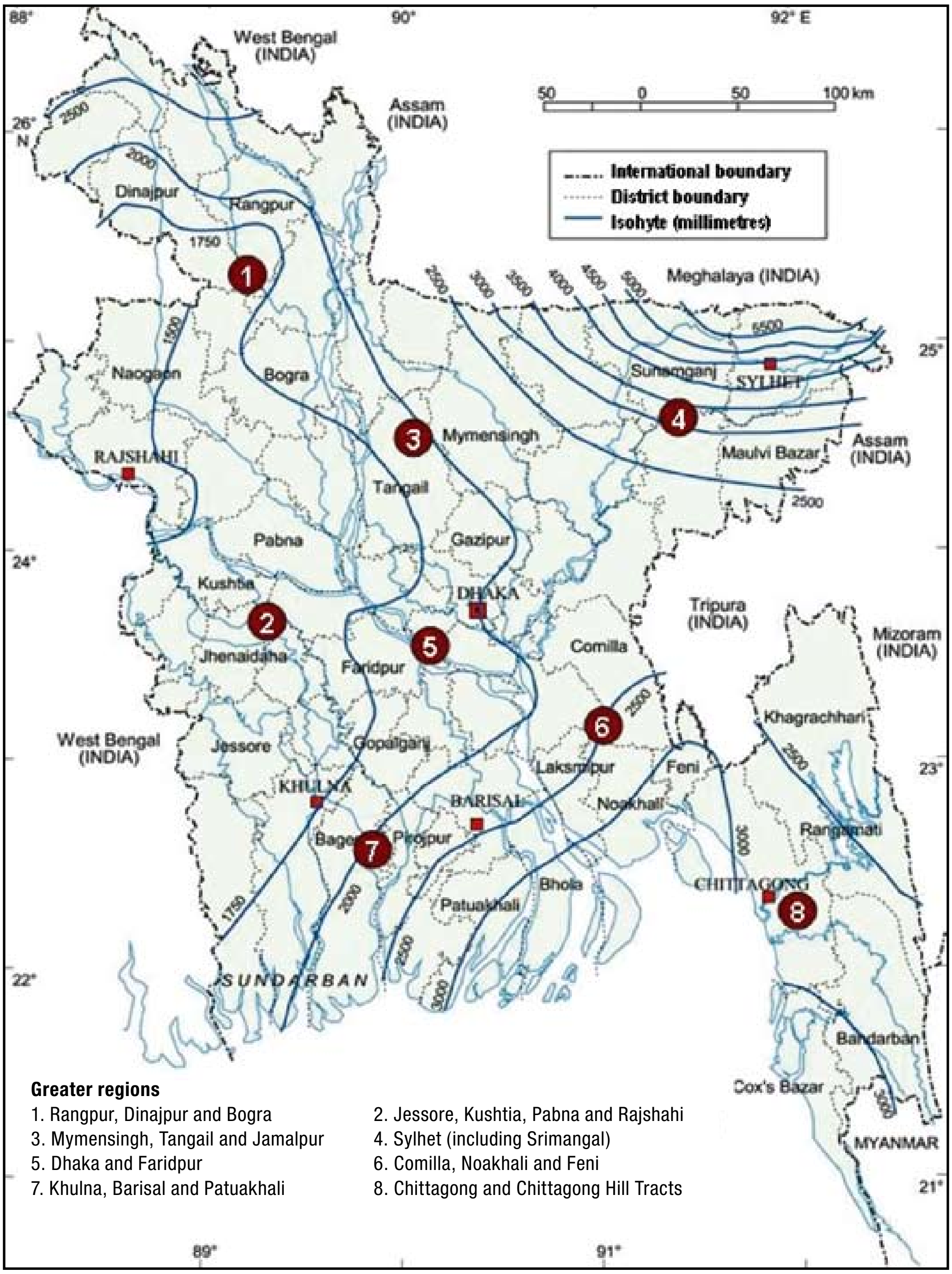
2.4.1 RAINFALL AND TEMPERATURE

Pond aquaculture varies in different AEZs. Researchers, extension agents and practitioners need to take into account geo-spatial and climatic factors that influence culture and productivity before developing technologies for adoption at the farm level. Rainfall and temperature are two major climatic factors affecting pond culture. Figure 6 shows mean annual rainfall (Banglapedia 2008d), and figures 6a to 6h show region-specific weekly averages of rainfall and temperature from 1988 to 2005. In general, December to February is cold and May to October is hot, followed by the wet monsoon. Areas with low rainfall, such as in the west from Jessore to Rajshahi may not be suitable for longer-duration pond aquaculture.

2.4.2 TOPOGRAPHY, FLOODING AND DROUGHT

In freshwater areas of Bangladesh, land and water use varies under different agro-ecosystems depending on the land type and the availability of water: land in freshwater areas with or without normal flooding;

Figure 6: Mean annual rainfall in Bangladesh



Source: Banglapedia 2008d; also see UNDP-FAO 1988a.

Figure 6a: Weekly average rainfall and temperature from 1988 to 2005 in Rangpur, Dinajpur and Bogra

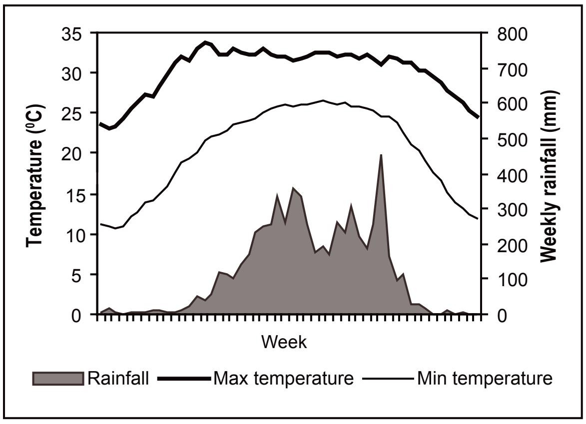


Figure 6b: Weekly average rainfall and temperature from 1988 to 2005 in Jessore, Kushtia, Pabna and Rajshahi

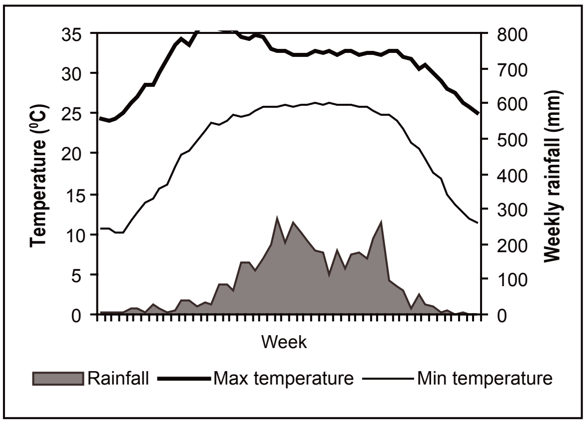


Figure 6c: Weekly average rainfall and temperature from 1988 to 2005 in Mymensingh, Tangail and Jamalpur

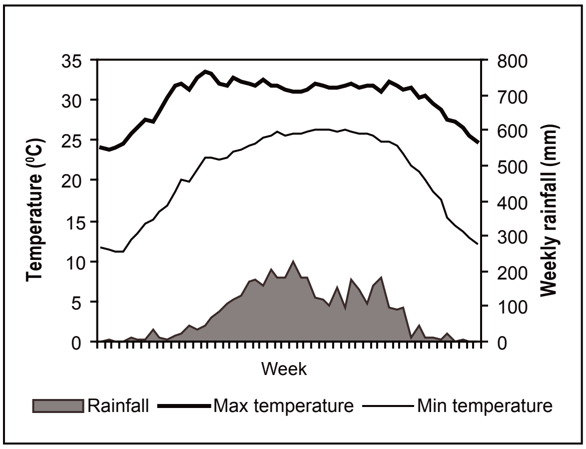


Figure 6d: Weekly average rainfall and temperature from 1988 to 2005 in Sylhet, including Sunamganj

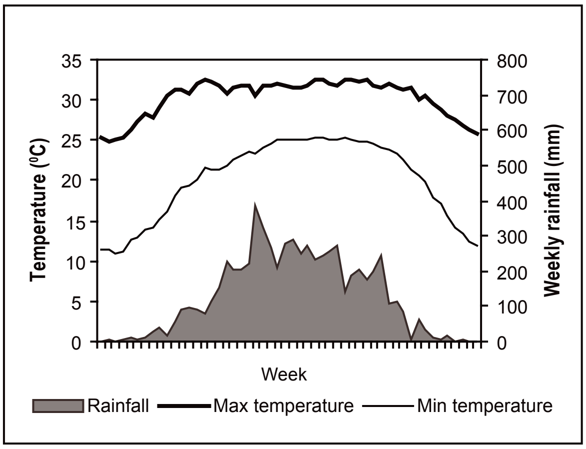


Figure 6e: Weekly average rainfall and temperature from 1988 to 2005 in Dhaka and Faridpur

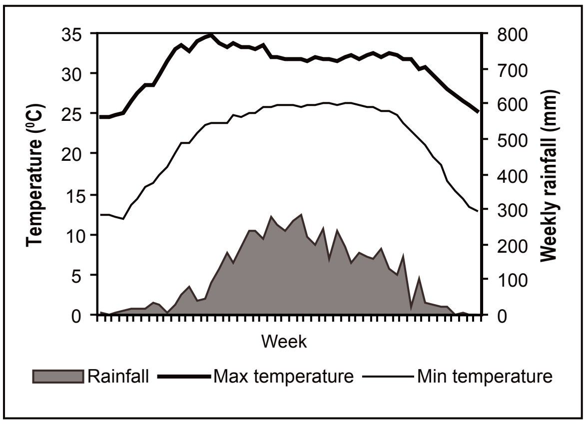
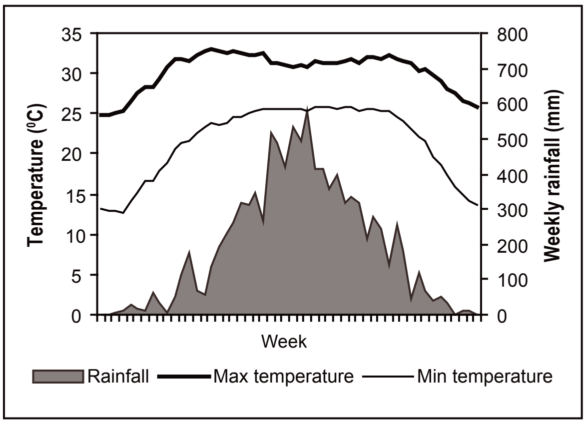


Figure 6f: Weekly average rainfall and temperature from 1988 to 2005 in Comilla, Noakhali and Feni



Note: Figures 6a to 6h show region-specific weekly averages of rainfall and temperature from 1988 to 2005. The y-scales of these figures are the same comparability, with the left showing temperature (35 oC) and the right showing rainfall (800 mm). The x-axis is the time (weeks of the year 1988-2005).

Figure 6g: Weekly average rainfall and temperature from 1988 to 2005 in Khulna, Barisal and Patuakhali

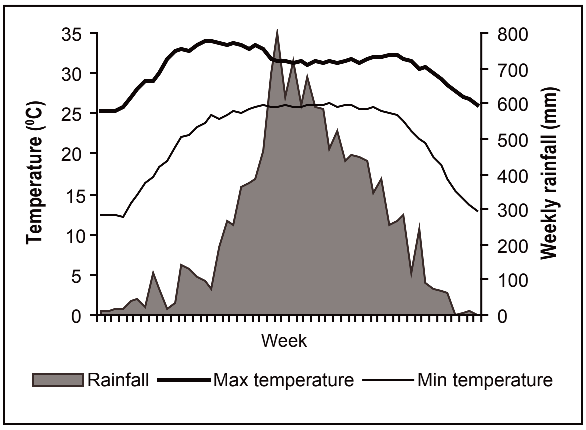


Figure 6h: Weekly average rainfall and temperature from 1988 to 2005 in Chittagong and Chittagong Hill Tracts

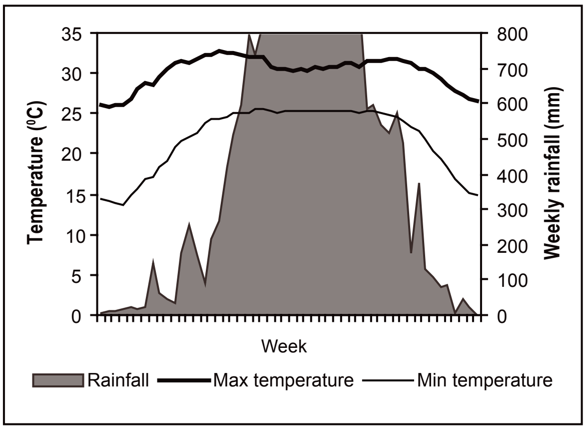
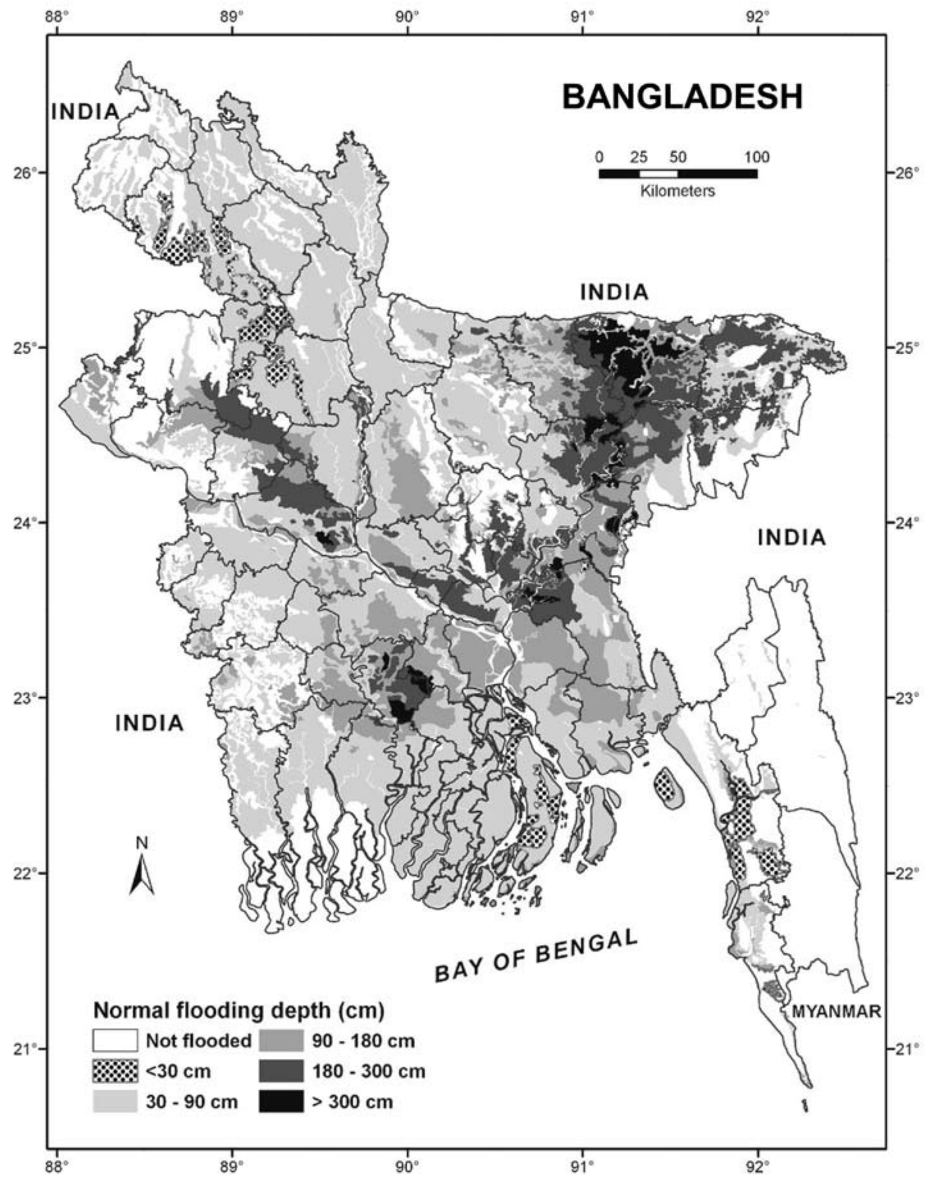


Figure 7: Normal flooding depth in Bangladesh



cm = centimetre.
Sources: Prepared using base map digital data collected from the Local Government Engineering Department and the computer center of the Bangladesh Agricultural Research Council in Dhaka, Bangladesh, in 2000.

very low-lying areas (wetlands); and hilly areas with greater precipitation and good drainage. The sources and quality of water, depth of land inundation, and operational management of different water bodies are the three major spatial factors affecting aquatic resources. Diverse environments occur not only regionally but also locally. At the height of the rainy season each year, more than a third of the total arable land area is flooded (Khan et al. 1994). Figure 7 shows the normal flooding depth, with the darkest blue indicating inundation by more than 300 cm.

Table 5 shows land phase areas in seven broad categories of AEZ. Highland normally is not inundated, medium highland is inundated to 90 cm, medium lowland to 90-180 cm, lowland to 180-300 cm, and very lowland to more than 300 cm. About 40% of the arable land is normally inundated to more than 90 cm during the wet monsoon.

Table 6 shows that 3.04 million ha of lowland floodplains are poorly drained, providing high potential for pond aquaculture development with engineering interventions. Remarkably, except in the region of Mymensingh, the adoption of pond aquaculture is higher in regions with few beels or poorly drained areas. This suggests that the people in areas with a lot of beels can capture adequate fish from natural sources and are therefore less interested in fish culture. This illustrates that the physical potential for aquaculture does not alone predict the rate of adoption. Rather, local demand for fish for consumption and marketing may be a bigger influence. Additional fish production will therefore require efficient channels for fish growers to market their production.

Lowland and basin areas currently offer very limited livelihood opportunities other than employment in rice-related activities for about 4 months of the year or full-time fishing. At the same time, these areas have

Table 5: Land phase area under different land type by AEZ in Bangladesh

Agro-ecological zones by broad category, hectare (%)	Highland	Medium highland	Medium lowland	Lowland	Very lowland	Settlements and water bodies	Total
Ganges floodplains	742,536 (17.68)	2,078,934 (41.33)	509,283 (28.76)	153,298 (13.92)	14,169 (7.33)	659,100 (30.26)	4,157,320 (28.72)
Tracts, hills and terraces	2,255,271 (53.70)	456,549 (9.08)	62,703 (3.54)	53,014 (4.81)	428 (0.22)	197,631 (9.07)	3,025,596 (20.90)
Meghna floodplains	26,973 (0.64)	630,028 (12.53)	396,307 (22.38)	204,374 (18.55)	41,083 (21.26)	638,544 (29.32)	1,937,309 (13.39)
Brahmaputra-Jamuna floodplains	323,925 (7.71)	614,274 (12.21)	321,527 (18.15)	133,444 (12.11)	90 (0.05)	241,171 (11.07)	1,634,431 (11.29)
Tista floodplains	331,726 (7.90)	543,459 (10.80)	40,358 (2.28)	5,131 (0.47)	0 (0.00)	109,773 (5.04)	1,030,447 (7.12)
Other floodplains and piedmont plains	449,007 (10.69)	490,288 (9.75)	194,327 (10.97)	225,373 (20.46)	5,104 (2.64)	170,026 (7.81)	1,534,125 (10.60)
Beels, basins and coastal areas among the floodplains	70,514 (1.68)	216,192 (4.30)	246,597 (13.92)	326,926 (29.68)	132,368 (68.50)	161,800 (7.43)	1,154,397 (7.98)
Total	4,199,952 (100.00)	5,029,724 (100.00)	1,771,102 (100.00)	1,101,560 (100.00)	193,242 (100.00)	2,178,045 (100.00)	14,473,625 (100.00)
Percentage of total area of Bangladesh	(29.02)	(34.75)	(12.24)	(7.61)	(1.34)	(15.05)	(100.00)

Source: Adapted by authors from BARC's Land Resources Database (see UNDP-FAO 1988b).

Table 6: Current aquaculture areas and water bodies in Bangladesh

Region (Former district)	Closed water bodies during 2005					Open water bodies (ha)					
	Pond area		Semi-closed water body (ha)			Beel area	Poorly drained seasonal area				
							By duration of inundation			By depth of water	
	Area (ha)	% cultured	Baor & lake	Seasonal	Shrimp cultured area		2-4 months	4-6 months	>6 months	90-180 cm depth	>180 cm depth
Barisal	23,719	70.8	0	99	7,900	79	15,973	14,045	26,492	47,781	8,729
Bogra	12,539	66.7	0	80	0	3,801	11,653	18,785	0	28,224	2,214
Chittagong	28,753	62.2	0	0	34,629	89	29,047	240	24,862	54,033	116
Chittagong HT	0	0.0	68,800	0	0	367	0	0	0	0	0
Comilla	29,649	77.3	0	4,186	0	1,103	264,102	61,145	14,528	198,961	140,814
Dhaka	13,659	51.0	0	3,318	4	4,918	180,151	108,884	10,129	131,329	167,835
Dinajpur	19,891	64.5	0	374	0	1,252	1,423	5,611	0	7,034	0
Faridpur	12,587	51.1	965	255	185	1,915	192,537	80,456	25,022	197,901	100,114
Jamalpur	3,079	59.1	0	0	1	6,868	34,049	20,237	764	52,959	2,091
Jessore	17,084	88.6	2,734	535	7,804	5,037	30,185	98,850	23,303	118,425	33,913
Khulna	11,815	84.3	331	96	163,702	365	9,524	50,744	14,259	58,917	15,610
Kushtia	3,772	72.9	1,458	875	0	2,197	28,263	26,238	1,651	49,398	6,754
Mymensingh	19,882	84.3	0	2,780	52	22,538	139,852	182,326	47,338	177,143	192,373
Noakhali	23,295	76.1	0	596	75	0	61,058	33,636	0	89,898	4,796
Pabna	14,241	45.0	0	271	0	3,255	148,006	43,721	0	97,550	94,177
Patuakhali	13,274	70.7	0	118	3,525	0	7,142	0	6,524	13,666	0
Rajshahi	29,487	46.9	0	2,032	0	19,849	116,635	84,511	2,420	111,238	92,328
Rangpur	8,273	50.0	0	207	0	5,492	2,6405	15,314	347	33,905	8,161
Sylhet	17,009	37.2	0	2,693	0	32,700	220,039	318,027	84,385	212,498	409,953
Tangail	3,017	57.9	0	2,287	0	2,333	70,221	11,049	635	66,018	15,887
Total	305,025	65.0	74,288	20,799	217,877	114,161	1,586,265	1,173,819	282,659	1,746,878	1,295,865

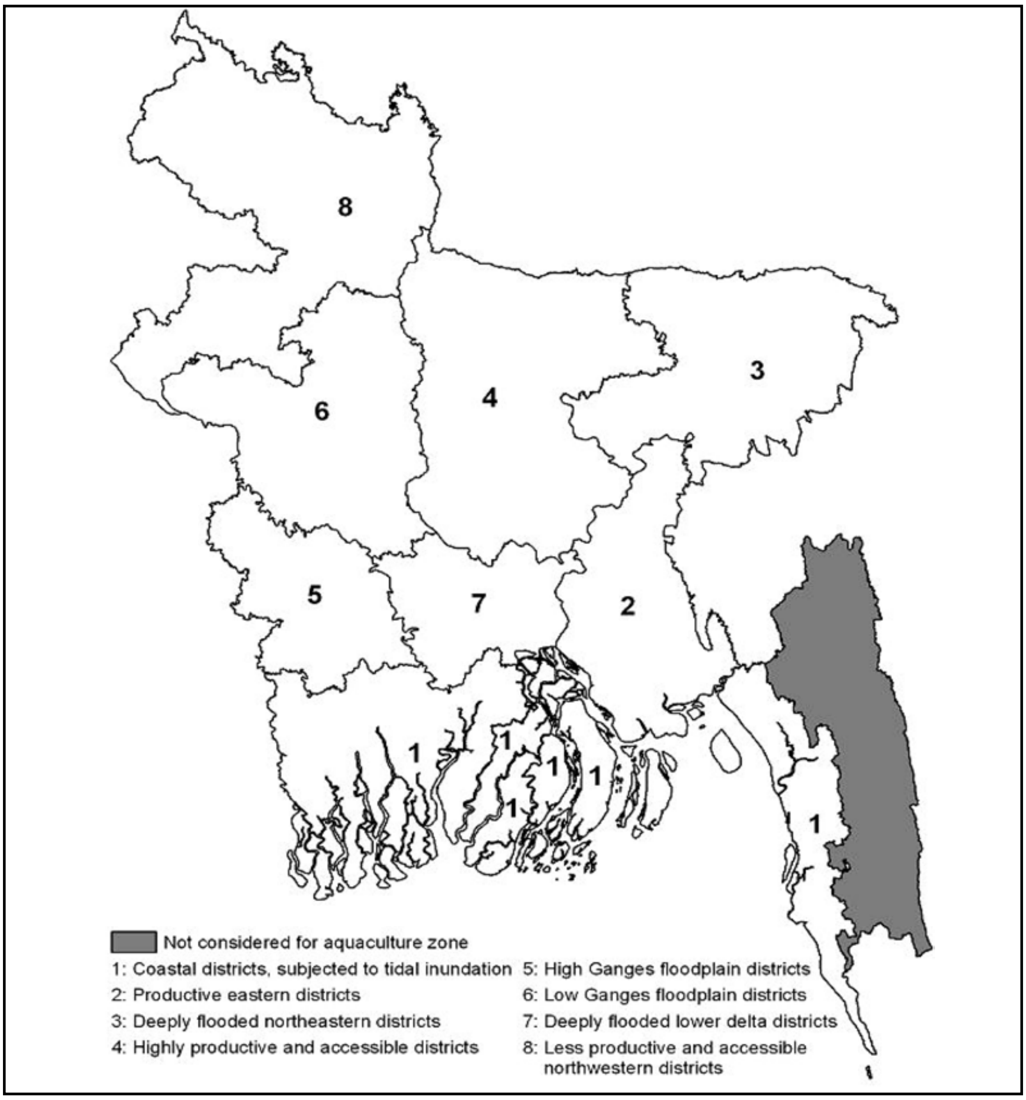
cm = centimetre, ha = hectare, HT = hill tracts.
Source: DoF 2006 and authors' estimate based on Land Resource Inventory data collected from BARC.

a high risk of flooding for pond aquaculture. The development of infrastructure and ecosystem-specific fisheries technology (e.g., cage aquaculture) may create a favourable environment for small-scale aquaculture.

Flooding is a serious problem for aquaculture development in Bangladesh. In addition, some regions of the country have high temperatures and low availability of water, causing seasonal drought that lowers agricultural yields. Figure 8 shows eight broad aquatic regions of Bangladesh in light of how prone they are to flood and drought, which affects water availability for pond aquaculture. Regions five and six are mostly drought-prone Ganges floodplain.

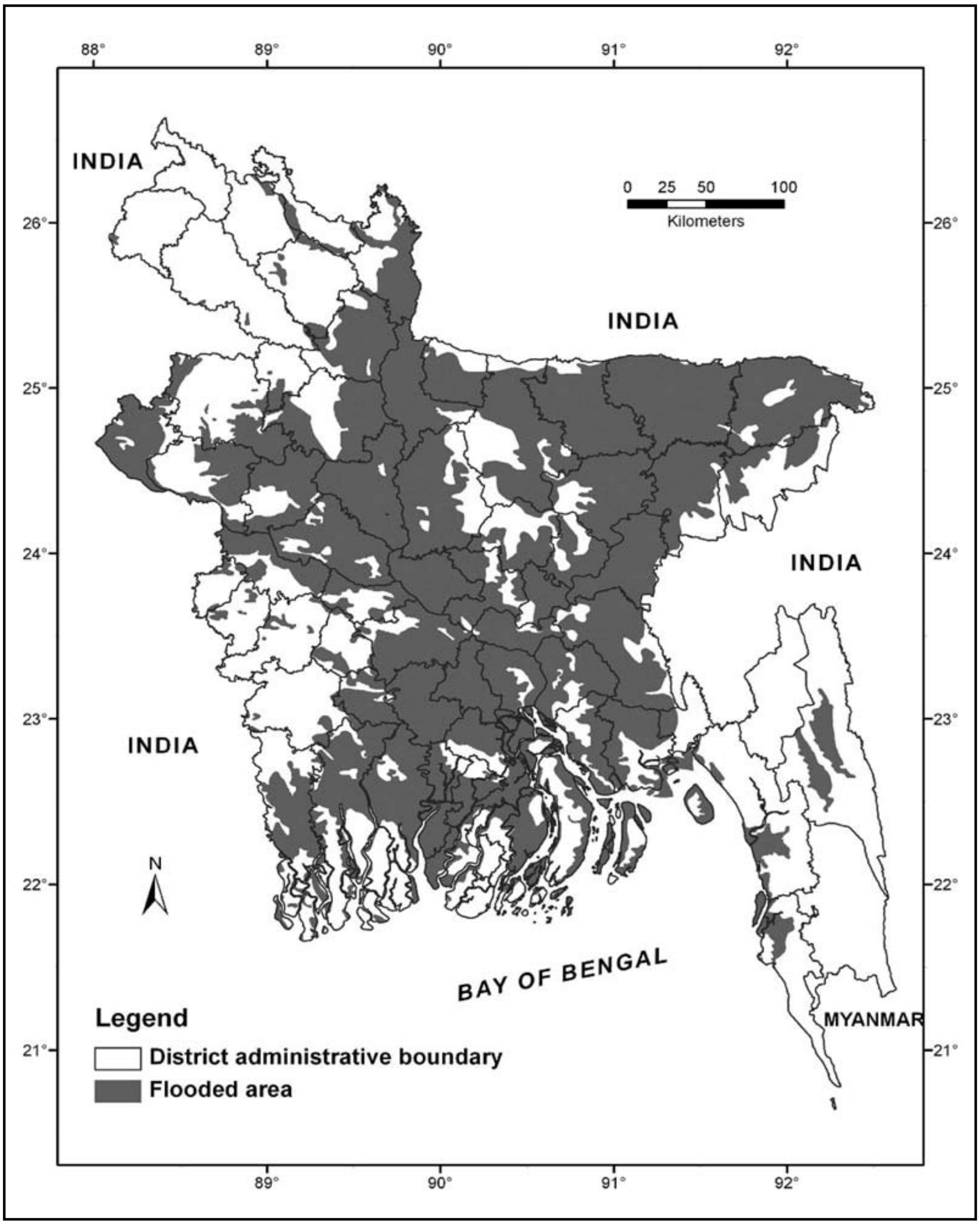
Seasonal flooding is deep in the northeast districts of Moulvibazar, Hobiganj, Sylhet and Sunamganj, and in parts of Kishoreganj and Mymensingh districts. It is generally shallow in the southeast. The districts in the northern and west-central parts of the country, such as Sirajganj, Pabna, Bogra, Kurigram, Nawabganj and Rajshahi, have flooded at least in part almost every year in the past decade. Figure 9 shows severe flooding in 1998; similar flooding occurred in 1974, 1987, 1988 and 2007. In the south, seasonal flooding is mainly shallow and fluctuates with the tide. Some of these areas are saline.

Figure 8: Aquatic regions of Bangladesh



Source: WorldFish 2008. Map generated from recommendation domains project data.

Figure 9: Flood-affected areas in 1998



Source: BCA V.3.0 (undated). Map generated using digital shape file data flood1998.shp from Bangladesh Country Almanac.

3. OVERVIEW OF THE NATIONAL AQUACULTURE SECTOR

Bangladesh is ideally suited for fish production, with 1 ha of water for every 20 people (Task Force 1991), one of the highest ratios in the world. Year-round sunshine and suitable water temperatures make the climate highly favourable for fish culture. The objective of this section is to provide an overview of past trends and the current status of freshwater aquaculture in the country.

3.1 MAIN PRODUCTION ENVIRONMENTS AND TRENDS IN FISH PRODUCTION

The inland waters of Bangladesh cover an area of about 4.5 million ha, including open and closed water bodies. The major inland open water bodies consist of floodplains, rivers, natural depressions and lakes. Closed water bodies include ponds, oxbow lakes and coastal ponds for shrimp farming. The fisheries sector comprises three distinct sub-sectors:

1. Inland capture production takes place in open bodies like rivers, estuaries, beels, the Sundarbans (mangrove forest in the southwest), Kaptai Lake (a large artificial lake in Rangamati) and floodlands.
2. Inland culture production is done in ponds, ditches, baors, and coastal shrimp and fish farms.
3. Marine capture occurs in the saline waters of the Bay of Bengal. The water areas and production levels of these three systems are detailed in Table 7.

National fish production for FY2006 was estimated at 2.33 million t, of which 79.39% came from inland waters (41.08% from capture and 38.31% from aquaculture). The rest, 20.61%, was caught in marine open waters. Floodlands (including regulated polders and enclosures) are the biggest contributors to inland capture fisheries. Rivers and estuaries, despite being large in area, contribute relatively little to total fish production. This ecosystem, which contributed 24.14% in FY1986, declined steeply to 5.92% in FY2006 as catches shrank and contributions from other freshwater capture and pond culture rose (Table 7). Fish culture in ponds contributed 32.62% in FY2006 to total production, which doubled from 15.59% in FY1986 even though the water area is small compared with open waters. In marine waters, artisanal fisheries contribute the most at 19.14%, with industrial trawlers providing only 1.46% of total production.

The pattern of fish production in Bangladesh has undergone significant changes. From FY1986 to FY2006, the inland aquaculture sub-sector showed spectacular growth at 10.5% per annum, while inland capture grew by 3.8% and marine production by 4.3%.

The output from marine fisheries experienced a continual but slow rate of increase during this period. While there is no consensus that marine fisheries as a whole are overexploited, a consensus does exist that inshore areas are overexploited by trawl, seine and gill net fleets that operate there. In contrast, deep-sea areas are believed to have unexploited potential, mainly because exploiting them is capital intensive and beyond the reach of existing fleet operators.

In the inland fish sector, growth in aquaculture has outstripped that of capture fisheries to the extent that freshwater aquaculture currently contributes to fish production as much as inland capture fisheries did in the early 1970s. Indeed, during this period, fish production from rivers and estuaries declined by 1.3%, such that the importance of inland aquaculture and inland capture fisheries has reversed.

Many factors have been identified as responsible for the decline in production from inland capture fisheries (World Bank 1991, Lewis 1997, PC 1998), and they are categorized by Mazid (2002) as

1. environmental degradation by progressive physical alteration and pollution of natural water bodies, including siltation and changing water-management practices;

Table 7: Water area and production statistics of Bangladesh fisheries

Type of water body	Water area (ha)	Fish production in FY1986		Fish production in FY2006		Annual production growth rate (FY1986 to FY2006)[1]
		tonnes	% of total production	tonnes	% of total production	
A. Inland fisheries						
I. Capture:						
1. Rivers and estuaries	1,031,563	199,600	24.14	137,859	5.92	-1.3
2. Sundarbans[2]		7,112	0.90	16,423	0.70	5.0
3. Beels	114,161	45,258	5.70	76,365	3.28	3.3
4. Kaptai Lake	68,800	45,258	0.31	7,548	0.32	4.7
5. Floodlands	2,832,792	187,396	23.60	718,491	30.86	6.4
Capture total	4,047,316	441,799	55.65	956,686	41.08	3.8
II. Culture:						
1. Ponds and ditches	305,025	123,804	15.59	759,628	32.62	10.5
2. Baors	5,488	968	0.12	4,498	0.19	8.1
3. Shrimp/ fish farms	217,877	19,951	2.51	127,923	5.49	10.2
Culture total	528,390	144,723	18.23	892,049	38.31	10.5
Total inland waters (I+II)	4,575,706	586,446	72.88	1,848,735	79.39	6.5
B. Marine fisheries						
1. Industrial fisheries		11,898	1.50	34,084	1.46	6.4
2. Artisanal fisheries		195,503	24.62	445,726	19.14	4.2
Marine total		207,401	26.12	479,810	20.61	4.3
Country total (A+B)		793,923	100.00	2,328,545	100.00	5.9

FY = fiscal year.
[1] Semi-log annual compound growth rate.
[2] Area included in the figure for rivers and estuaries.
Sources: DoF 1986 and 2007.

2. overexploitation of resources, including overfishing caused by population pressure; indiscriminate killing of juveniles and destruction of spawning grounds; and obstruction of migration routes by dams and embankments built for flood control, drainage and irrigation; and
3. the intensification of agriculture, causing floodplains to shrink as rice areas expand and agro-chemicals to be increasingly used, affecting wild fish populations.

The gradual decline of the inland capture fisheries has put pressure on the domestic supply of fish, thereby pushing up the price of cultured fish and making aquaculture a very attractive option. Because aquaculture is managed, there is greater scope for interventions to increase production than exists in capture fisheries.

The manifold increase in aquaculture production over recent years can be attributed to (1) the generation of new technologies by various national research institutes such as BFRI and international research institutes such as the WorldFish Center; (2) the dissemination efforts of DoF, BFRI and NGOs; and (3) special projects such as the Mymensingh Aquaculture Extension Project, Northwest Fisheries Project, Development of Sustainable Aquaculture Project (DSAP) and other aquaculture projects coordinated by WorldFish; Concern Bangladesh's efforts to promote aquaculture; World Vision's aquaculture technology dissemination project; and numerous technology dissemination projects conducted by various NGOs.

DoF (2007) estimated the total pond area to be 305,025 ha. The ponds, as classified by the DoF, are (1) cultured, where such inputs as fingerlings and supplementary feeds are applied; (2) culturable, but where fish fry are not released; and (3) derelict, which must be rehabilitated to be suitable for fish culture. According to FY2006 DoF statistics, the annual yield of fish per hectare for cultured ponds is 3.24 t, for culturable ponds 1.19 t and for derelict ponds 0.96 t, with an overall average of 2.49 t.

Freshwater pond aquaculture is the dominant fisheries sub-sector in Bangladesh, contributing about 33% of total fish production and about 85% of total aquaculture production in FY2006 (Table 7). Past increase in freshwater pond production came mainly from expansion of the production area. Over the period FY1986 to FY2006, cultured pond production increased by an annual average rate of 9.69%, of which area expansion accounted for 9.04% and yield growth for only 0.65% (Table 8). The yield from cultured ponds increased marginally from an average of 3.0 t/ha during the mid-1990s to 3.2 t/ha a decade later (Table 8).

There are large variations in area and yield growth across regions (Table 8). The variation in annual area growth among regions, ranging from 7.6% to 13.2%, may arise from differences in biophysical environments and farmers' socioeconomic conditions. Although the area under cultured ponds has almost doubled over the past 2 decades, 22.58% of ponds are still culturable and 12.44% are derelict (DoF 2007). By any yardstick, these are underutilized resources. Yet many regions with high growth in cultured pond area (e.g., Bogra, Jamalpur and Mymensingh) experienced lower yield. This may reflect the expansion of aquaculture into unfavourable lands and/or the lack of appropriate location-specific technologies.

3.2 SPECIES USED AND CULTURE SYSTEMS

Bangladesh is rich in fish biodiversity. The inland freshwaters of Bangladesh are inhabited by 60 native and 13 exotic species of fish and 20 species of shrimp, of which the majority occur in impounded water bodies. The indigenous carp species of Bangladesh can be divided into two sub-groups: major carps (catla, rohu, mrigal and kalbasu) and minor carps (bata, reba, nandin and gonia). Most of the freshwater river systems and floodplains are natural breeding grounds for carp. The major carp species occur in deep pools of the Padma-Brahmaputra River system (Padma, Jamuna, Arial Khan, Kumar and Old Brahmaputra rivers) and the Halda River system in Chittagong. The minor carp species inhabit small rivers and the shallow waters of floodplains in the northeast (Mymensingh, Netrokona and Mohanganj), southwest (Faridpur and Jessore) and northwest (greater Rajshahi area).

Exotic species, comprising mostly Chinese carps, have been introduced since the 1950s (Table 9), but these introductions have not been well documented. Introduced species include silver carp, grass carp, bighead carp, black carp, common carp, silver barb, tilapia and mahseer.

Table 8: Area and yield of culture pond in Bangladesh, FY1986 to FY2006

Region (former district)	Area			Yield		
	Average during FY1986 to FY1988 (ha)	Average during FY2004 to FY2006 (ha)	Growth[1] rate during FY1986 to FY2006 (%)	Average during FY1986 to FY1988 (t/ha)	Average during FY2004 to FY2006 (t/ha)	Growth[1] rate during FY1986 to FY2006 (%)
Barisal	9,429	16,790	7.70	2.385	2.960	2.57
Bogra	3,846	8,363	10.30	3.109	3.100	-0.56
Chittagong	9,459	17,894	8.44	2.465	2.786	1.95
Comilla	11,946	22,909	8.62	3.545	3.619	0.35
Dhaka	3,228	6,969	10.30	3.111	3.324	0.35
Dinajpur	6,491	12,839	9.04	3.706	3.387	-1.00
Faridpur	2,975	6,430	10.30	3.421	3.330	-0.69
Jamalpur	800	1,820	11.00	3.405	3.338	-1.19
Jessore	7,691	15,129	8.98	3.122	3.204	0.06
Khulna	5,450	9,956	8.04	2.807	3.306	2.00
Kushtia	1,126	2,751	12.00	2.832	3.264	1.21
Mymensingh	8,893	16,767	8.41	3.498	3.120	-1.80
Noakhali	9,883	17,718	7.76	2.883	3.041	0.97
Pabna	2,956	6,415	10.20	2.704	3.050	1.13
Patuakhali	5,289	9,382	7.64	2.512	2.704	0.70
Rajshahi	5,909	13,841	11.20	3.513	3.776	1.31
Rangpur	1,540	4,133	13.20	2.798	3.295	1.62
Sylhet	2,615	6,325	11.70	2.773	3.541	2.72
Tangail	813	1,748	10.20	3.099	3.095	-0.29
Bangladesh	100,339	198,179	9.04	3.043	3.218	0.65

FY = fiscal year, ha = hectare, t = tonne.
[1] Estimated using inverse semi-log growth function.
Sources: DoF 1986 and 2006.

Table 9: Exotic fish species[1] introduced into Bangladesh, 1952-98

Species	Common name	Place of origin	Source	Year
Trichogaster pectoralis	Gourami	Thailand	Singapore	1952
Oreochromis mossambicus	Tilapia	Africa	Thailand	1954
Cyprinus carpio var. *communis*	Common carp	Temperate Asia/Europe	Not known	1960
Ctenopharyngodon idella	Grass carp	China	Hong Kong	1966
Hypophthalmichthys molitrix	Silver carp	China	Hong Kong	1969
O. niloticus niloticus	Nilotica (tilapia)	Africa	Thailand	1974
Puntius gonionotus	Sarpunti	Thailand	Thailand	1977
C. carpio var. *specularis*	Mirror carp	Temperate Asia/Europe	Nepal	1979
Chanos chanos	Milkfish	Red Sea, Indian & Pacific oceans	Not known	1979
Aristicthys nobilis	Bighead carp	China	Nepal	1981
Mylophanyngodon piceus	Black carp	China	China	1983
Clarias gariepinus	Catfish	Africa	Thailand	1989
Pangasius suchi	Large catfish	South Asia	Thailand	1989
O. niloticus	Tilapia (GIFT[2])	Africa	Philippines	1994
Chanos chanos	Milkfish	Red Sea, Indian & Pacific oceans	Thailand	1998
Tor tor	Mohashol	Local species, Nepal	Nepal	na

na = not available.
[1] Only edible fish species are listed.
[2] genetically improved farmed tilapia.
Sources: Adapted from Craig et al. 2004 and Banglapedia 2008d.

Carps are by far the most important species for pond culture. Three major Indian carps (rohu [*Labeo rohita*], catla [*Catla catla*] and mrigal [*Cirrhinus cirrhosus*] and one exotic carp (silver carp [*Hypophthalmichthys molitrix*]) accounted for about 80% of pond production in FY2006 (Table 10). Other major species in Bangladesh include the grass carp, common carp and tilapia.

BFRI has developed 24 technology packages for dissemination. DoF, the leading fisheries extension and development agency in the country, disseminates various aquaculture technology packages to farms. Several NGOs also do research on alternative technology packages focusing on poverty alleviation, such as the Cage Aquaculture for Greater Economic Security package. This small-scale cage culture produces a range of freshwater species such as tilapia, Chinese carp, catfish, silver barb and freshwater prawn (*Macrobrachium rosenbergii*), which provide food for home consumption as well as income. Table 11 summarizes the major aquaculture technologies in Bangladesh.

Table 10: Pond production in Bangladesh by species group, FY1996 and FY2006

Species	FY1996 (t)			FY2006 (t)			Share (%)		Growth rate (%)		
	Cultured	Other	Total	Cultured	Other	Total	FY1996	FY2006	Cultured	Other	Total
Rui (*Labeo rohita*)	67,090	7,505	74,595	157,894	14,384	172,278	24.2	22.7	8.9	6.7	8.7
Catla (*Catla catla*)	52,540	5,619	58,160	138,783	11,719	150,501	18.9	19.8	10.2	7.6	10.0
Mrigal (*Cirrhinus cirrhosus*)	40,419	3,425	43,844	105,049	10,473	115,522	14.2	15.2	10.0	11.8	10.2
Kalbasu (*Labeo calbasu*)	7,433	2,420	9,853	1,667	3,820	5,488	3.2	0.7	-13.9	4.7	-5.7
Mixed carp	4,032	696	4,728	12,634	5,149	17,783	1.5	2.3	12.1	22.2	14.2
Silver carp (*Hypophthalmichthys molitrix*)	43,480	2,243	45,723	149,813	17,059	166,872	14.8	22.0	13.2	22.5	13.8
Grass carp (*Ctenopharyngodon idella*)	5,757	144	5,900	14,494	709	15,203	1.9	2.0	9.7	17.3	9.9
Mirror carp (*Cyprinus carpio* var. *specularis*)	5,708	254	5,962	18,085	394	18,479	1.9	2.4	12.2	4.5	12.0
Tilapia (*Oreochromis mossambicus /O. niloticus*[1])	4,567	1,369	5,936	13,981	2,392	16,373	1.9	2.2	11.8	5.7	10.7
Shrimp	680	896	1,577	577	1,649	2,226	0.5	0.3	-1.6	6.3	3.5
Aor (*Mystus aor/Mystus seenghala*)	777	433	1,210	449	482	931	0.4	0.1	-5.3	1.1	-2.6
Boal (*Wallago attu*)	73	1,693	1,766	128	1,052	1,180	0.6	0.2	5.8	-4.7	-4.0
Shol/gazar & taki (*Channa* spp.)	389	8,023	8,412	385	6,930	7,315	2.7	1.0	-0.1	-1.5	-1.4
Koi (*Anabas testudineus*)	219	2,506	2,724	64	8,859	8,924	0.9	1.2	-11.5	13.5	12.6
Singi/magur (*Heteropneustes fossilis/Clarias batrachus*)	243	3,894	4,137	128	2,949	3,078	1.3	0.4	-6.2	-2.7	-2.9
Sarpunti (*Puntius sarana*)	704	63	767	3,656	463	4,118	0.2	0.5	17.9	22.1	18.3
Thai sarpunti (*Puntius gonionotus*)	486	56	542	3,656	86	3,742	0.2	0.5	22.4	4.4	21.3
Punti (*Puntius* spp.)	1,093	6,199	7,292	2,886	5,241	8,127	2.4	1.1	10.2	-1.7	1.1
Others	7,214	17,631	24,845	16,995	24,493	41,488	8.1	5.5	8.9	3.3	5.3
Total	242,905	65,069	307,974	641,324	118,304	759,628	100.0	100.0	10.2	6.2	9.4

[1] genetically improved farmed tilapia (GIFT).
Sources: DoF 1996 and 2006.

Table 11: Existing freshwater aquaculture technologies, culture systems, species and intensities in Bangladesh

Ecosystems/ technologies	Culture system	Species group	Intensity
Freshwater fish			
1. Mixed culture of carps	Polyculture/composite culture in ponds	Indian major carps,[1] Chinese carps,[2] common carps,[3] minnows, silver barb	Improved extensive Semi-intensive
2. Integrated fish culture	Polyculture with poultry/ duck/ dairy/horticulture in ponds	Indian major carps, Chinese carps, common carps, minnows, silver barb	Improved extensive Semi-intensive
3. Composite culture of carps and freshwater prawn	Mixed/polyculture in ponds	Indian major carps, Chinese carps, common carps, minnows, silver barb, giant prawn	Improved extensive Semi-intensive
4. Culture of tilapia	Monoculture in cages, seasonal ponds, rice fields	*Oreochromis* spp	Improved extensive Semi-intensive
5. Culture of exotic magur (catfish)	Monoculture in ponds, ditches	Catfish (*Clarias)*	Improved extensive Semi-intensive Intensive
6. Fish culture in cages	Monoculture/mixed culture in flood plains, rivers, reservoirs	Catfish,[4] GIFT tilapia, minnows[5]	Semi-intensive Intensive
7. Fish culture in pens	Polyculture	Indian major carps, Chinese carps, common carps, minnows, silver barb, giant prawn, catfish	Improved extensive
8. Culture of sarpunti	Monoculture/polyculture	Thai sarpunti *(Puntius gonionotus)*	Improved extensive
9. Culture of pangus	Monoculture/polyculture	Thai pangus *(Pangasius suchi)*	Improved extensive
10. Rearing of carp fingerlings	Monoculture/mixed culture in ponds	Indian major carps, Chinese carps, common carps	na
11. Paddy-cum-fish/ paddy-cum-prawn	Monoculture/polyculture in rice fields	Tilapia, common carps, silver barb, prawn	Improved extensive
12. Culture-based management of minor flood plains	Polyculture in flood plains	Indian major carps, Chinese carps, common carps, minnows, tilapia, catfish	Improved extensive
13. Baor management	Polyculture	Indian major carps, Chinese carps	Improved extensive
14. Establishment and management of carp hatchery	In hatcheries	Indian major carps, Chinese carps, common carps	na
Freshwater shellfish			
1. Culture and management of galda (freshwater prawn)	Monoculture/polyculture in ponds, rice fields	Giant fresh water prawn (*Macrobrachium rosenbergii*)	Extensive Improved extensive
2. Freshwater clam culture	Pond culture	Lamelidens marginalis	Semi-intensive
3. Hatchery management of galda (freshwater prawn)	In hatcheries	Giant freshwater prawn	Semi-intensive

GIFT = genetically improved farmed tilapia, na = not applicable.
1 Indian major carps: *Catla catla, Cirrhinus cirrhosus, Labeo rohita, L. calbasu.*
2 Chinese carps: *Hypophthalmichthys molitrix, Ctenopharyngodon idella, Hypophthalmichthys nobilis, Mylopharyngodon* sp.
3 Common carps: *Cyprinus carpio* var *comminis, Cyprinus carpio* var *specularis.*
4 Catfish: *Pangasius suchi, Ompak pabda, C. batrachus, C. gariepinus, Heteropneneustes fossilis.*
5 Minnows: *Puntius sarana.*
Source: Ahmed et al. 2004.

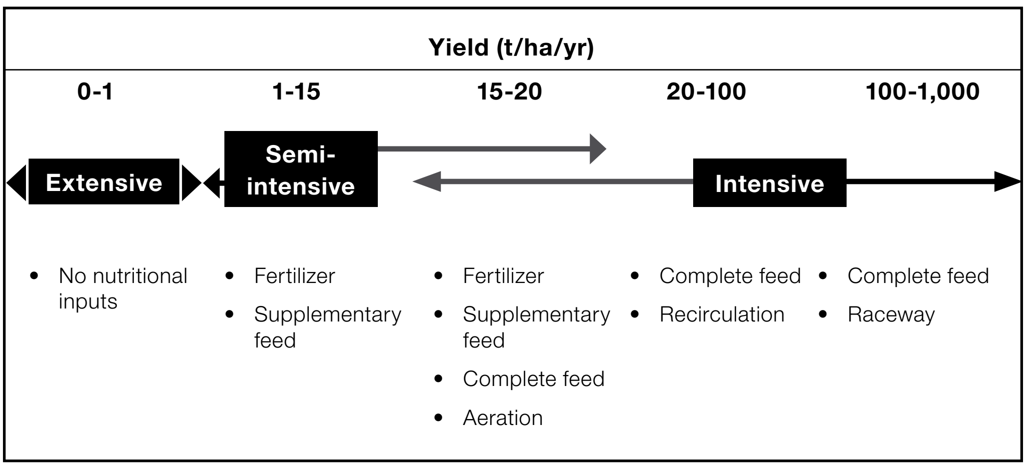
Freshwater fish-culture systems practiced in Bangladesh can be categorized into four groups: carp polyculture, mixed culture, monoculture and integrated fish culture. Mixed culture of fish is a type of polyculture in which carp and some other species are cultured together. In integrated systems, fish culture is integrated with other agricultural enterprises, such as rice-fish farming, rice-fish-duck farming, and fish-poultry farming. Polyculture of Indian and Chinese carps along with a few other exotic species is the most dominant system in Bangladesh. Other practices include pond monoculture of Thai pangus, mixed culture of Nile tilapia and carps in seasonal ponds or ditches, and culture of carps (mainly mirror carp) and silver barb in rice fields. Monoculture of genetically improved Nile tilapia in ponds is also becoming popular, particularly among commercial producers. Other culture systems include carp culture in baors and shrimp culture in brackish ponds.

It is estimated that polyculture of Indian major carps and Chinese carps (including small, indigenous species) in freshwater ponds accounts for 85% of aquaculture production. Monoculture in freshwater ponds, mainly of pangus (*Pangasius pangasius*) and Nile tilapia (*Oreochromis niloticus*), produces a further 3%. Other freshwater aquaculture systems of far less significance in terms of output include small-scale cage culture, fry nursing in hapas, commercial cage-fish culture, pen culture, and lake or enclosure stocking (Future Fisheries 2003).

Edwards (1993) classified fish-farming systems into (1) extensive systems relying on natural food produced in the water body without supplementary inputs, (2) semi-intensive systems relying mostly on natural feed but supplemented with feed and fertilizer, and (3) intensive systems relying on nutritionally complete concentrate feed and fertilizers. Figure 10 shows the incremental yield benefit moving from extensive to intensive systems mentioned by Edwards (1993). It is important to note that these systems are merely conceptual stages in a continuum (Pillay 1997) and that in practice many intermediate or sub-systems exist such as improved extensive (intermediate between extensive and semi-intensive) and improved semi-intensive (intermediate between semi-intensive and intensive).

Pond culture in Bangladesh may be characterized as semi-intensive, with high fingerling stocking rates but low use of feed and fertilizer. Fish farmers generally use less supplementary feed and other inputs compared with their counterparts in countries with more advanced aquaculture systems, such as China and Thailand (Table 12). Input application rates suggest that many fish farmers in Bangladesh still practise extensive systems (Dey et al. 2005c). The results of a survey conducted by WorldFish and DoF in 2006 indicate that improved extensive to semi-intensive carp polyculture is the dominant system practised in Bangladesh and has been adopted in all *upazilas* (sub-districts) (Table 13).

Figure 10: Intensification of aquaculture and potential incremental yield



t/ha/yr = tonnes per hectare per year.
Source: Modified from Edwards 1993.

Table 12: Inputs and output in carp polyculture ponds per ha/year in selected Asian countries

Output and input	Bangladesh	China	Thailand
Yield (kg/ha)	3,262	12,085	3, 777
Seed (number/ha)	10,261	27,867	67,328
Feed (kg/ha)	2,232	38,251	10,989
Rice bran	1,728	442	2,020
Commercial feed	0	19,220	1,229
Oil cake	505	16,380	0
Other	0	2,209	7,740
Fertilizer (kg/ha)	725	2,293	2,910
Organic	439	1,171	2,681
Inorganic	286	1,122	229
Triple super phosphate	65	0	0
Urea	221	150	0
Other	0	972	0
Lime (kg/ha)	93	0	285
Medicines/chemical pesticides ($/ha)	0	1,354	2
Labour (person-days/ha)	324	293	159

ha = hectare, kg = kilogram.
Note: 0 indicates zero or very negligible use.
Sources: ICLARM 2001.

Table 13: Geographical distribution in Bangladesh of adoption and coverage of fish culture system by culture pattern, 2006

Major cultural pattern Culture system	% of upazilas adopting culture system (number = 454)				Upazilas adopting system (%)
	Extensive	Improved extensive	Semi-intensive	Intensive	
Carp polyculture	13.7	64.8	41.0	1.1	100.0
Carp polyculture with pangus	11.9	42.5	32.6	2.6	82.2
Pangus monoculture	7.5	22.2	31.9	5.5	63.2
Carp-golda mixed culture	12.6	27.8	14.1	1.1	49.8
Tilapia monoculture	15.9	29.5	26.9	2.2	68.9
Other culture patterns	6.6	15.9	11.9	2.0	33.7

Source: WorldFish-DoF survey 2006.

3.3 FUTURE GROWTH POTENTIAL FOR POND AQUACULTURE

Although freshwater aquaculture has contributed substantially to the growth in total fish production, its full potential has not yet been explored, as indicated by the extensive area of derelict ponds and the dominance of semi-intensive pond culture. The objective of the Ministry of Fisheries and Livestock (MoFL) is to rehabilitate and bring underutilized pond resources (including culturable and derelict ponds and untapped rice fields) under fish culture at a similar intensity that is found in the cultured ponds (DoF-BARC 2001). It is believed that the area of ponds is much higher than estimated; land is taken out of agricultural production every day for residential construction (MoF 2003), with ponds created to supply soil. At the same time, rice paddies are being converted into permanent ponds for the more profitable activity of fish culture (Karim et al. 2006). DoF-BARC (2001) estimated the total pond area to be 320,000 ha and projected that it would increase to 411,488 ha by FY2011. Another estimate put the total pond area at 300,000 ha (Future Fisheries 2003). Karim et al. (2006) suggested that there is scope for bringing an additional 106,846 ha of land under pond aquaculture. Interestingly, a more recent estimate by DoF (2007) put the pond area at 265,500 ha. Regardless of the discrepancies in estimates of pond area, there is no doubt that Bangladesh has the potential to increase aquaculture production through area expansion and intensification.

Bangladesh has 2.6 million ha of rice fields suitable for fish culture. Unfortunately, only about 10,000-20,000 ha are currently used for rice-fish culture. If an integrated rice-fish system were to be adopted by paddy farmers, a huge additional quantity of fish could be produced in rice paddies in both the *boro* (dry) and *aman* (wet) seasons (Dey et al. 2005d). For fish culture in either the aman or the boro season, paddies would be as good as ponds.

Further potential exists for increasing freshwater aquaculture production by improving productivity. Cultured pond operators adopt only some of the recommended technologies and, in 2005/06, had an average productivity of 3.24 t/ha, which is much lower than in other Asian countries (Dey et al. 2005c, Karim et al. 2006). Aquaculture technology developed through research has the potential to increase productivity above levels that average farmers currently achieve. DoF-BARC (2001) projected the future productivity of perennial ponds to be 4 t/ha and of seasonal ponds to be 2 t/ha. Dey (2000a) and Hussain et al. (2002) showed that the adoption of improved strains has the potential to increase production significantly.

However, studies show that partial adopters of recommended technologies, who make up the bulk of fish farmers, adjust the technologies by varying stocking levels, feeding, fertilization, harvesting and marketing to suit their own situations. The use of feed and fertilizer is generally very low, while stocking is often excessive. Some farmers do not use supplementary feeds or chemical fertilizers.

The expansion and intensification of aquaculture is constrained by many factors. Important constraints identified by previous studies are joint ownership of ponds, inadequate technical knowledge, high prices for feed and other inputs, the lack of quality fingerlings, poor understanding of economics, and inadequate credit options (Ahmed and Rab 1992, Gupta et al. 1992 and 1999, Ahmed et al. 1994, Gupta and Rab 1994, Lewis 1997, Chowdhury and Maharajan 2001, Thomson et al. 2005, ADB 2005). As aquaculture is a very dynamic and fast-growing sector, some of these factors, such as joint ownership of ponds, may no longer be important. A survey conducted in traditional (control) and technologically advanced (project) areas by Chowdhury and Maharajan (2001) found that 62% of traditional farmers and only 32% of the advanced farmers considered joint-ownership a problem. This underscores the need for new studies on aquaculture adoption.

The type of aquaculture appropriate for Bangladesh depends on the prevailing socioeconomic conditions of the farmers. For practices to be sustainable, farmers need sufficient time to learn the technology.

Over time, as technology improves, the intensity of the practice will gradually move from traditional levels to semi-intensive and intensive, and the production of fish per unit of water area will increase.

Although freshwater aquaculture is seen to be the most important component of the fisheries sector in Bangladesh, public investment has historically been biased against this sub-sector. It is unfortunate that it is not properly supported by increased investment in research and development. The national fisheries policy adopted in 1998 (MoFL 1998) shows the government's firm commitment to increase investment in freshwater aquaculture, but it has not yet fully delivered.

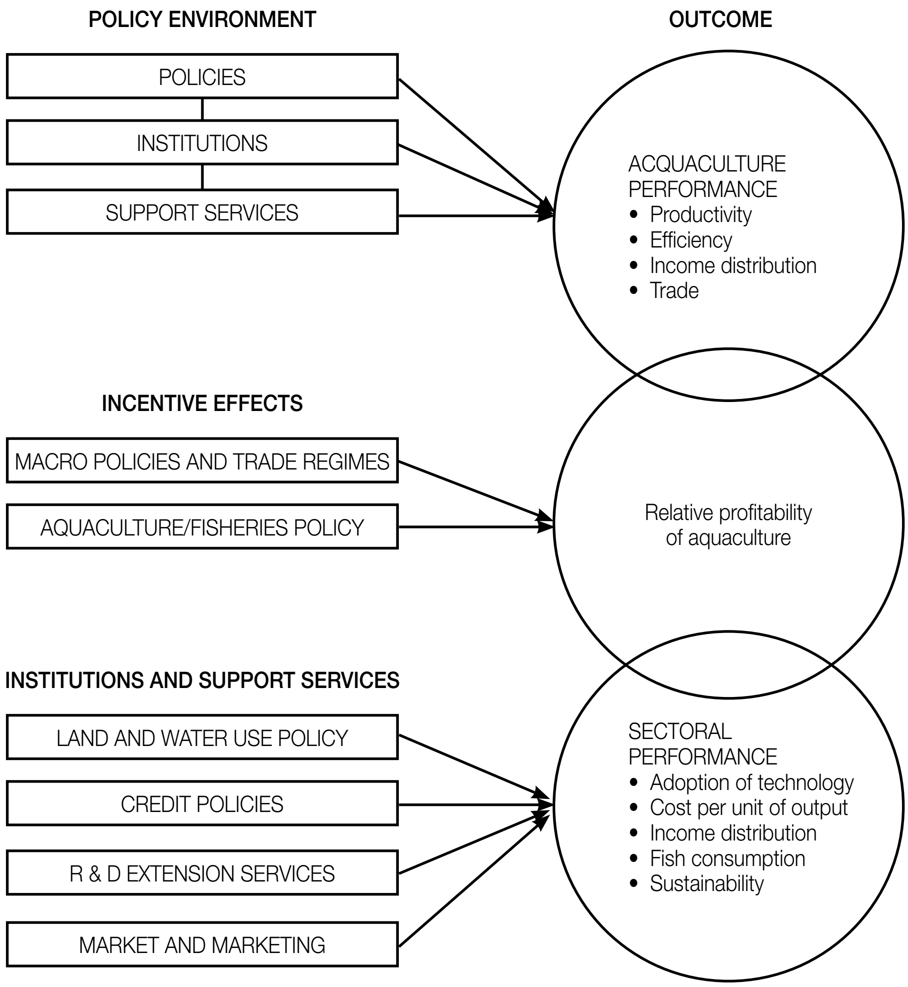
4. POLICY, INSTITUTIONS, INFRASTRUCTURE AND SUPPORT SERVICES

The development of the aquaculture sector depends on the policy and institutional environment, which spans a wide range of laws, regulations, administrative directives, institutions, services, infrastructure support and incentives. This section presents an overview of policy incentives, institutional environment, infrastructure and support services related to the aquaculture sub-sector in Bangladesh, based on the framework presented in Figure 11.

4.1 POLICY ENVIRONMENT

The fisheries and aquaculture sector is influenced by both sectoral and macroeconomic policies. Over the past 2 decades, the Bangladesh economy has experienced significant changes and reforms in policies both macroeconomic and regarding the fish sector.

Figure 11: Framework for analysis of the policy environment for aquaculture development in Bangladesh



4.1.1 NATIONAL AND SECTORAL POLICIES

One of the primary goals of Bangladesh has been to attain food self-sufficiency. Self-sufficiency in food grains has been achieved but not in other foods, including fish. GoB has declared fisheries and aquaculture as thrust sectors of the economy. For aquaculture development, GoB is guided by principles laid out in the following international, national and sectoral policy documents:

- international: Millennium Development Goals and FAO Code of Conduct for Responsible Fisheries;
- national: various 5-year plans and the National Strategy for Accelerated Poverty Reduction of 2005; and
- sectoral: the National Water Policy of 1999, National Land Use Policy of 2001, National Fisheries Policy of 1998, National Agricultural Policy of 1999, Fisheries Sectoral Review and Ten Year Perspective Plan of 2001, New Agricultural Extension Policy of 1996, and various draft fisheries sub-strategies (e.g., the aquaculture sub-strategy of 2006 and the aquaculture extension sub-strategy).

Like other developing countries, Bangladesh formulates economic development plans usually for 5-year periods. GoB prepared its First Five-Year Plan (1st FYP 1973-78) within the framework of a socialist economy, but it was not implemented accordingly. Subsequently, the government has developed the following development plans to target a policy strategy for national development: Two-Year Plan (TYP 1978-80), Second Five-Year Plan (2nd FYP 1980-85), Third Five-Year Plan (3rd FYP 1985-90), Fourth Five-Year Plan (4th FYP 1990-95), Ten-Year Perspective Plan (TYPP 1995-2005; GoB did not follow this document after mid-1997), Fifth Five-Year Plan (5th FYP 1997-02), and Three-Year Rolling Investment Programme (TYRIP 2003-06). Unlike 1st FYP, which placed high priority on social sectors, subsequent plans have been formulated in favour of more productive sectors of agriculture (including fisheries) and manufacturing (Hasnath 2006).

Recent national plans have placed major emphasis on culture and capture fisheries, the promotion of rice-fish farming systems in the vast floodplains, conservation and management, and institutional and manpower training. The major objectives of fisheries development during the recent plan periods are presented in Table 14.

Strategies have been designed to (1) promote semi-intensive polyculture of fish in all ponds, *dighies* (unusually big ponds) and

Table 14: Major objectives of fisheries development during recent plan periods

National plans for fisheries sector development (TYRIP 2003-06)	National fishery policies (established in 1998)
1. Generate additional employment opportunities in fisheries.	1. Develop fisheries resources and increase fish production.
2. Increase fish production and improve nutritional levels.	2. Alleviate poverty through self-employment and improve the socioeconomic status of fishers and fish farmers.
3. Improve the socioeconomic conditions of fishers, fish farmers and others engaged in fisheries.	3. Fulfil demand for animal protein.
4. Increase export earnings from shrimp, fish and fish products.	4. Earn foreign exchange through the export of fish and fish products and thereby increase economic growth.
5. Other objectives related to the improvement of environmental conditions; conservation of resources; and strengthening of research, extension and management.	5. Maintain the environmental balance, conserve biodiversity and improve public health.

Sources: MoFL 1998. MoF 2005.

other closed and semi-closed-water bodies; (2) improve access to credit facilities for fish farmers through the introduction of a credit guarantee scheme for marginal farmers; (3) liberalize the import of equipment for private-sector hatcheries, feed and feed ingredients by reducing duties and taxes; (4) introduce modern technology in shrimp culture; and (5) rehabilitate ponds on government land, *dighies,* canals and roadside ditches for fish culture with the participation of unemployed rural youth, marginal farmers and women living in acute poverty. As restoring the productivity of inland open-water bodies is very costly, it is hard to justify such a large public investment for a common pool resource. Therefore, the government effort to promote capture fisheries has been focused on a fingerling-stocking program.

Consistent with its market-oriented stance, the government encourages private entrepreneurship in fisheries and aquaculture. As a result, the private sector now provides a much higher share of investment in fish feed processing, manufacturing and fish seed production. There are currently 764 freshwater fish and/or shrimp hatcheries in the private sector and 110 in the public sector. In 2006 private hatcheries supplied more than 98% of hatchings and fry used in the country (DoF 2007), while the public sector continues to play the lead role in research and infrastructure development.

4.1.2 MACROECONOMIC POLICIES AND TRADE REGIMES

The Bangladesh economy has experienced significant macroeconomic reforms since the mid-1980s, including successive import liberalization, repeated currency devaluation and finally deregulation of the exchange rate.

Over the last decade, GoB has focused on increasing non-traditional exports such as fish, other fishery products, textiles and garments. The government offers several export incentives that encourage the export of fish products: (1) export finance at concessionary interest rates for working capital, (2) development funds, (3) foreign exchange for business travel abroad, (4) reduced or zero duties and excise taxes on the import of equipment and machinery for export-oriented industries, and (5) other financial and nonfinancial incentives. Before deregulating the exchange rate, it offered an export performance benefit equal to 100% of the difference between official exchange rate and the market exchange rate for every dollar earned through fish exports (Hossain 2002, Karim et al. 2006, World Bank 1991).

Bangladesh has been undergoing comprehensive structural reforms to liberalize trade regimes and comply with the objectives of the World Trade Organization. The government has reduced tariffs on fish and seafood imports from 59.33% in FY1992 to 28.23% in FY2002 (Dey et al. 2005a).

As such traditional barriers to trade as tariffs and quantitative restrictions have been partly liberalized through the General Agreement on Tariffs and Trade and, more recently, the Word Trade Organization, technical measures are becoming a particularly important issue for Bangladesh exports. The last decade or so has seen a proliferation and strengthening of sanitary and phytosanitary (SPS) standards and hazard analysis and critical control point (HACCP) standards in industrialized countries. These standards continue to evolve internationally, nationally and within individual supply chains. As fresh food categories such as fish and seafood products are subject to greater food safety scrutiny, they are more likely to be affected by the regulatory measures (Unnevehr 2000). The traditional methods of preservation and processing practised in Bangladesh and many other developing countries are challenged by the requirements of international-standard quality measures for fish and fish products (Dey et al. 2005a). Noncompliance with HACCP and SPS standards often leads to bans and/or rejection by importing countries, causing massive losses to exporting countries like Bangladesh.

Bangladeshi exports continue to remain vulnerable to regulatory barriers in foreign markets. The European Union (EU) ban on Bangladesh shrimp in 1997 remained in effect for 5 months and was a serious setback to fish exporters and people whose livelihoods depended on the industry. The estimated cost of the EU ban on Bangladesh was $14.1 million, and about a million people connected with the industry were affected (Cato and Santos 1998 and 2000). In 2002, Bangladesh suffered a 10% loss in shrimp exports because of perceived quality differences, causing a loss of $30 million. Another threat is the imminent withdrawal of the Generalized System of Preferences treatment Bangladesh receives in the EU.

Despite initial setup costs, Bangladesh has made considerable headway in HACCP implementation. In recent years, it has enacted quality assurance legislation and invested enormous resources to comply with SPS and HACCP processes (Dey et al. 2005a). In 1997, the government amended its Fish and Fish Product (Inspection and Quality Control) Ordinance of 1983 and related rules of 1989 to accommodate HACCP procedures (Ali and Islam 2002, Dey et al. 2005a). Bangladesh now comes under the top compliance category based on classifications of the EU and FAO. Bangladesh is a List 1 country for exporting fish and fishery products to the EU (European Commission 2004), indicating that Bangladesh has policies and procedures fully harmonized with the legislation and policies of EU countries and has safety standards that satisfy the EU inspection team.

However, problems remain in terms of inadequate capacity and lack of proper management of the inspection system. According to the US Food and Drug Administration (FDA) report of 2003 and 2004, fish and seafood products from Bangladesh are still frequently refused entry (FDA 2004). There are currently 129 fish-processing plants in Bangladesh producing both for domestic markets and for export to the EU, USA and Japan. Sixty of those in operation have a combined annual capacity to process 250,000 t of fish. However, scarcity of raw materials means only 20-25% of installed capacity can be utilized. Fifty-three of these plants have European Commission approval to export to EU (Dey et al. 2005a, Dey et al. 2008a).

4.2 INSTITUTIONS AND SUPPORT SERVICES

Development and growth in the aquaculture sector are sustainable only if complemented with adequate support services. Training, extension, credit, skilled human resources and market infrastructure lay the groundwork for increasing productivity and competitiveness. As in other countries, support services in Bangladesh traditionally focused on capture fisheries. In recent years, they have been shifting to aquaculture.

4.2.1 INSTITUTIONAL ARRANGEMENTS, LAWS AND REGULATIONS

Government agencies have been heavily involved in the planning, research, promotion, development, management and regulation of the aquaculture sector. As many as 14 public organizations and departments (listed in Table 15) are involved in managing and developing the fisheries sector. However, private sector participation in aquaculture development has rapidly increased in recent years, with fish harvesting, marketing, processing and trade mainly in the private sector.

Institutional recognition of the fisheries sector started when the British imposed the Permanent Settlement Regulation in 1793, followed by the enactment of Private Fisheries Protection Act in 1889. Later, in 1908, the government established DoF for the first time in the undivided Bengal province of British India.

Until recently, capture fisheries were the main component of the fisheries sector policies and legislation in Bangladesh, and the major focus of fisheries development was resource conservation and protection. Four major sets of laws and regulations (acts, ordinances and rules) are available to protect and encourage the development of the fishery sector in Bangladesh (Habib 1999). These are the (1) Protection and Conservation of Fish Act of 1950 as amended in 1982, (2) Tank Improvement Act as amended in 1986, (3) Fish and Fish Products (Inspection and Quality Control) Ordinance of 1983 as amended in 1997, and (5) Marine Fisheries Ordinance and Marine Fisheries Rules of 1983.

4.2.2 RESEARCH, DEVELOPMENT AND EXTENSION

Sundar Lal Hora, director of fisheries in Bengal from 1932 to 1947, made the first successful attempt to culture fish

Table 15: Government departments and ministries involved in aquaculture development in Bangladesh

Department or ministry	Role in aquaculture development
Department of Fisheries	National aquaculture development, extension, training, conservation, quality control, law enforcement, policy advice and information collection
Bangladesh Fisheries Development Corporation	Management of culture fisheries in Kapti Lake and marketing and processing of fish
Bangladesh Fisheries Research Institute (BFRI)	National research on aquaculture and fisheries
Bangladesh Agricultural Research Council (BARC)	Coordination of aquaculture and fisheries research
Ministry of Land	Administration and leasing of public water bodies larger than 20 acres (about 8 hectares) for fishing and aquaculture
Upazila Parishad (sub-district government)	Administration of small water bodies of up to 20 acres for fisheries and fisheries extension
Ministry of Irrigation, Flood Control and Water Developmemt	Aquaculture and culture-based fisheries in irrigation systems
Ministry of Local Government, Rural Development and Cooperatives	Inclusion of aquaculture in rural development projects
Ministry of Industry	Licensing of fish-processing plants
Ministry of Commerce	Export of frozen fish
Ministry of Education	Coordination of aquaculture-related education and research
Ministry of Finance	Budget and administration of externally funded aquaculture projects
Nationalized banks	Provision of credit for aquaculture
Planning Commission	Planning of fisheries and aqauculture sector as part of overall national planning

in ponds in the British-ruled province. Aquaculture developed further momentum with the introduction of induced breeding of carps in 1967 (Banglapedia 2008d). DoF and some of the public universities (e.g., the Zoology Department of Dhaka University) first initiated fisheries research in the country in the early 1960s, focusing on basic studies in ichthyology. In 1967, Bangladesh Agricultural University in Mymensingh established the first faculty of fisheries on the Indian subcontinent, marking a significant milestone in fisheries research and education in Bangladesh. In response to declining production from capture fisheries, DoF established its first Aquaculture Experiment Station in 1977 at the campus of Bangladesh Agricultural University to conduct aquaculture research. BFRI was established in 1984 as a national research institute to conduct and perform aquaculture and fisheries research. Various public universities are currently involved in aquaculture research and education. Table 16 lists the detailed activities of BFRI and public universities involved in aquaculture and fisheries.

DoF is the government agency primarily responsible for developing the fishery sector, with its main focus on fisheries extension. It has offices down to the upazila (the lowest administrative unit) and local demonstration farms. Various NGOs are actively involved in aquaculture extension.

Table 16: Public sector fisheries research and educational institutes in Bangladesh

Bangladesh Fisheries Research Institute (BFRI): Freshwater Station, Mymensingh
The Freshwater Station in Mymensingh is BFRI's largest, covering an area of 40 hectares (ha). It is located at the Bangladesh Agricultural University. It has five laboratories for fish genetics and reproduction, fish feed and nutrition, water quality, fish disease and general fish biology. It has a large, circular tank; 6 wide, circular incubating systems; 16 large, cemented funnel incubators; many cemented tanks and cisterns; 118 drainable ponds including 20 mini earthen ponds; 52 nursery ponds of 0.1 ha each; and 16 grow-out or broodstock ponds of 1.6-2.6 ha each. The scientific staff numbers 26.

BFRI: Marine Fisheries and Technology Station, Cox's Bazar
The 4-ha Marine Fisheries and Technology Station was established in 1991 at Cox's Bazar. Although there are 65 scientific staff positions, only 27 scientists and 5 research staffers currently work at the station. It has 5 specialized laboratories, 2 cistern complexes, and other infrastructure for official and residential purposes. It has a marine research vessel and experimental farm complex. This station conducts research on marine fish and shrimp seed production, marine ecology, coastal environmental studies, production systems for marine finfish and shellfish, stock assessment and population dynamics of economically important species, oceanographic studies, disease diagnosis and control, the development of processing and preservation technologies, socioeconomic studies of marine and coastal fisherfolk, and quality control of marine products. The station has produced valuable technology for easily transporting live shrimp without water and oxygen, using forced hibernation.

BFRI: Brackishwater Station, Paikgacha, Khulna
The Brackishwater Station at Paikgacha, Khulna, was established in 1987. It is the only station that conducts research on brackish fisheries. It has 30.56 ha of land with 52 drainable experimental ponds. Its major activities include the assessment of shrimp seed and breeding ground resources; mangrove ecology; the development of breeding techniques for commercially important brackishwater finfish, shrimp, mud crab and other crustaceans and their nursery management; the semi-intensive and intensive culture of shellfish and finfish such as sea bass, mullet, etc.; the diagnosis and control of shellfish disease; and socioeconomic studies of brackish aquaculture. Altogether 16 scientists are deployed at this station, looking into reproductive physiology and genetics; nutrition, food and feed technology; pollution and disease diagnosis and control; brackish aquaculture; estuarine ecology and environment; soil, water and productivity management; and aquaculture engineering.

BFRI: Riverine and Floodplain Stations
The Riverine Station is located in Chandpur and covers 17.2 ha. It has 36 undrainable ponds with a total water area of 8.6 ha. The station has the primary responsibility to undertake research on riverine species. It has one carp, one catfish and one *Macrobrachium* hatchery and a number of specialized laboratories. The major thrusts of this station are stock assessment, limnology and open-water fisheries management, culture-based fisheries management, aquatic pollution and fish toxicology, biodiversity and fish genetic resources collection and conservation, fish behaviour analysis, and fishing technology development. The station has 25 scientists. There are two sub-stations attached to the Riverine Station. The Riverine Sub-station at Rangamati looks into the Kaptai Lake fishery by continuously monitoring biological productivity, assessing stocks and studying the population dynamics of various fishes, major carps in particular. The Floodplain Sub-station at Santahar, Bogra, looks into floodplain fisheries ecology, limnology and gear selectivity among five types of floodplain beels: open, closed, perennial, semi-closed and semi-open.

Public Universities
Four public universities conduct research on and teach about capture fisheries and aquaculture in Bangladesh. Each university has a fisheries faculty and/or a fisheries and aquaculture department. Chittagong and Khulna universities concentrate on brackish and marine fisheries, and Dhaka and Mymensingh universities concentrate on freshwater fisheries and aquaculture. Teachers from all universities are involved across ecosystems in fisheries and aquaculture research.

Sources: www.fri.gov.bd/index.php downloaded on 22 March 2008, Mazid 2002.

4.2.3 MARKETS AND VALUE CHAINS

Markets and the value chain are critical for the growth and development of the aquaculture sector. The value chain begins with input supply and extends through postharvest services, processing and marketing.

Input supply. A major impediment to aquaculture growth is the inadequacy of the input delivery system for fingerlings, feed and other inputs. Fish seed markets are competitive in Bangladesh, and fish farmers have a wide choice of seed suppliers (ADB 2005). Public investment in the fish seed industry during 1970s catalyzed the development of freshwater aquaculture in the country. However, over the past 2 decades, the private sector has increasingly taken over the role of supplying seed fish. At present, quantities of seed of freshwater finfish are adequate. In 2006, 412,650 kg of seed were produced by hatcheries and only 1,723 kg of seed were collected from natural sources (DoF 2007). Nursing fish larvae to the fry and fingerling stage is generally carried out in small-scale, private nurseries. Bangladesh has a good network of fish seed traders linking hatcheries and nurseries to fish farmers, but various studies indicated that the quality of fingerlings is a problem. Hatcheries face problems related to the poor selection of fish broodstocks, indiscriminate hybridization and inbreeding (Mazid and Hussain 1995, Hussain and Mazid 2001). Sarker et al. (2006) found that the lack of quality fry and fingerlings was a major setback in Muktagacha, Mymensingh.

Fish feed markets are competitive, providing farmers with a variety of choice. However, many of the feed ingredients are imported, and many small farmers cannot afford to buy fish feed (Alam and Thompson 2001, Sarker et al. 2006).

Fish markets and marketing. Fish marketing in Bangladesh is largely in the hands of the private sector (Dey et al. 2001). The government provides support in the form of roads and infrastructure and exercises quality control for the export marketing of aquaculture products (Faruque 2007). Most fish farmers do not face significant problems in selling their fish because market demand is high, but markets are localized in some areas, and fish farmers have limited ability to reach better alternative markets (ADB 2005).

Alam (2001), Dey et al. (2001) and Faruque (2007) discuss in detail the fish-marketing channels in Bangladesh, which can be broadly categorized as domestic and export. The four main types of domestic fish market are primary markets located near the source of production, secondary markets located usually in the upazila headquarters, higher secondary markets located in big cities and terminal markets.

In general, fish-marketing channels are long and complex with about 3-4 intermediaries (Alam 2001, Dey et al. 2001, ADB 2005, Ahmed et al. 2005 and 2007). The dominant domestic marketing channel of freshwater fish involves the farmer, *bepary* (fish trader), *aratdar* (commission agent), *paiker*[2]/retailers and finally the consumer. This channel covers the primary and secondary market levels up to the upazila. Beparies are local or other traders who handle a large volume of fish and sell their purchases to aratdars and paikers/retailers. Unlike aratdars, beparies generally do not hold trade licences. Some beparies get advance business loans from aratdars during lean periods on the condition that they sell their purchases through these aratdars. Further along the marketing channel, fish is brought down the market hierarchy, i.e., from the higher secondary markets to the towns and primary markets in the peripheral villages (the final consuming markets) through paikers/retailers.

The fish marketing margin (the difference between what consumers pay and what farmers receive) varies for different locations and species, ranging from 30% to 60% (Table 17). This indicates that the farmers' and fishers' share of the consumers' price

Table 17: Fish marketing margin in Bangladesh

Species	Location/district	Year	Marketing margin (%)	Sources
Freshwater fish	Mymensingh	1995	44	Mia 1996, Alam 2001
Hilsha (ilish)	Rajshahi	1981	44	Islam 1982, Alam 2001
Freshwater fish	Mymensingh	2003/04	35	Faruque 2007
Freshwater fish	Dinajpur	2003/04	31	Faruque 2007
Prawn	Mymensingh	2003/04	38	Ahmed et al. 2007
Hilsa	Patuakhali	2005	45	Ahmed 2007
Carp	Gazipur	2002	55-60	Ahmed et al.2005

2 A small-scale wholesaler who may perform retailing at the same time.

ranges from 40% to 70%. According to ADB (2005), the fish farmers' price at farm gate was no less than half of the retail market price.

The market structure is not the same for all market levels. Open auctioning of fish lots by the wholesalers to paikers/retailers makes the market competitive at the retailer level in the final consuming markets, but exploitation prevails from the farm gate to the higher secondary market level. The limited number of wholesalers and their collaborative bidding and close ties through associations negate the principles of competitive market structure at the wholesale level. In the primary market, the main constraints for fish farmers are the lack of bargaining power or market information and barriers to market entry. Inadequate competition at the aratdar level means that the beparies pay relatively higher commissions, and the cost of this is borne ultimately by the fish farmers and fishers, who get lower prices.

The lack of transport and equipment is another important constraint in some areas, preventing producers from sending their fish to higher markets. Other factors that weaken fish farmers' bargaining position are their dependence on exclusive credit arrangements and high rates of illiteracy. They often end up being paid lower prices by existing buyers, as the product cannot be kept for long periods because icing facilities are absent in almost all primary markets. Physical facilities and infrastructure in all types of markets are far from satisfactory but are worst at village and primary markets. Most of these markets do not have electricity, water, ice or shelter. Fish sellers in most rural and primary markets sit under the open sky. Secondary and higher-level markets have better facilities, but in general conditions in urban and retail markets are far from satisfactory with regard to stalls, parking, spacing, sanitation, drainage and management.

In a survey conducted in Muktagacha, Mymensingh, an area with a good road and communication network, Sarker et al. (2006) found that more than 80% of fish farmers consider lack of information and poor extension service as barriers to their entrepreneurial development. Coulter and Disney (1987) observed that "communication between the traders in different markets is generally good and takes place by telephone and this keeps wholesale prices in line throughout the country. The least-informed party is the fisherman and small-scale fish farmer, because of his physical isolation from the markets."

However, with the growth in commercial pond aquaculture, a new pattern is emerging in fish marketing that increasingly involves direct participation by farmers (Alam 2001, Faruque 2007). After their pond harvest, some fish farmers directly approach aratdars at the higher secondary market. The farmers bear the costs of transporting fish to the aratdars in the markets, and then aratdars arrange open bidding by the paikers/retailers. The aratdars get commissions worth 3-7% of the sale proceeds for providing fish landing sites and icing for some fish and for facilitating the fish sale (Alam 2001). This trend in direct marketing is due to (1) the shift from subsistence to commercial fish farming; (2) a changing social attitude towards fish selling, as it is no longer considered a dishonourable job; and (3) an improved road and transport network (Faruque 2007). In areas with better road and communication infrastructure, fish marketing chains are thus getting shorter (ADB 2005, Faruque 2007).

4.2.4 CREDIT SUPPORT

Credit support is essential for the development and growth of any industry. In Bangladesh, credit sources available for aquaculture production, processing and marketing are both formal (commercial banks, finance companies, and government-initiated institutions and schemes) and informal (money lenders, traders, relatives and others). As a policy incentive for the agriculture sector, including fisheries and aquaculture, GoB provides subsidized credit to investors and exporters of agricultural and fish products. There are no distinct credit or input incentives for fisheries.

By any measure, access to credit is very limited for the overwhelming majority of pond fish farmers, so most farming operations rely on the farmers' own limited capital. Small-scale aquaculture investors report difficulties in gaining access to formal credit. It was reported that only 20% of fish farmers in Bangladesh obtained institutional credit (Shang 1990). Alam and Thompson (2001) reported that about 16% of pond farmers could obtain credit from either public or private sources. Rahman and Ali (1986) also reported that fish farmers' access to institutional credit was very low. The perceived risks of fisheries/aquaculture investments vis-à-vis agricultural loans, along with inadequate collateral, are the two main reasons for this difficulty, especially for small loan applications. Poor fish farmers therefore remain dependent on informal credit, which is far easier to obtain but subject to hefty interest rates. Alam and Bashar (1996) reported that intermediaries providing production credit to farmers link the loan with marketing, whereby the fish farmers receiving credit are obliged to sell their produce to the credit supplier at prices below the prevailing market price. No insurance schemes exist to cover the loss of fish production.

Borrowers from the public sector are mostly large-scale farmers. Large firms and listed companies that have been drawn into the fish sector also have good access to bank borrowings in recent years.

4.3 OVERALL PUBLIC INVESTMENT AND DEVELOPMENT ASSISTANCE

Public funds are allocated each year for the development of fisheries. However, budgetary allocations are disproportionately low considering the sector's contribution to GDP. Table 18 presents inconsistencies between budgetary allocations and expenditures in fisheries during the different plan periods. While the funds allocated for fisheries increased significantly, this was not reflected in actual expenditures. It was only in the TYP, 2nd FYP, 5th FYP and TYRIP that the funds delivered exceeded 80% of the amount allocated. In all other periods, the utilization of the budgetary allocation was about 40%. Despite the shortfalls between allocated funds and actual expenditure, the trend toward achieving production targets gradually improved over the plan periods.

Table 18: Targets for and achievements of fish production and public investment during different plan periods in Bangladesh

Plan (period)	Targeted production (million t)	Achieved production (million t)	Budgetary funds allocated (million taka)	Actual expenditure (million taka)
1st FYP (1973-78)	1.020	0.643 (63.03[1])	485	190 (39.17)
2-year plan (1978-80)	0.808	0.636 (78.71)	440	386 (87.72)
2nd FYP (1980-85)	1.000	0.774 (77.40)	1,743	1,583 (90.82)
3rd FYP (1985-90)	1.000	0.847 (84.70)	3,500	1,400 (40.00)
4th FYP (1990-95)	1.200	1.172 (97.66)	7,490	2,978 (39.78)
5th FYP (1997-2002)	2.075	1.890 (91.08)	5,852	4,808 (82.0)
Three Year Rolling Investment Programme (TYRIP) (2003-06)	2.300	2.329 (101.26)	3,387	2,815 (83.11)

FYP = 5-year plan, t = tonne.
[1] Figures in parentheses indicate percentages of target achieved.
Sources: DoF 2001; GoB 2003, 2004 and 2005; MoF 2005.

The share of public expenditure directed to the fisheries sector declined over the years from 0.74% during FY1993-95 to only 0.51% during FY2004-06 (Table 19). Moreover, public investments are biased towards shrimp, which accounts for the bulk of the sub-sectors' foreign exchange earnings (WorldFish 2005). Of some concern is the extremely low investment in research and development (R&D) activities, as the ratio of aquaculture and fisheries R&D to aquaculture and fisheries GDP is only about 0.10%. This is much lower than in other Asian countries such as Thailand (0.41%) and Sri Lanka (0.55%) (WorldFish 2005).

Table 20 shows the public investment (expenditure) bias (IB) index for the aquaculture and fisheries sector in Bangladesh, estimated using formula given below (Huang and Li 2001, Hossain 2002).

$$IB_k = \frac{Sik}{Sgk} \text{ where}$$

Sik = share of k sector in total government investment,

Sgk = share of k sector in total GDP.

If IB = 1 (or 100%), the investment policy is considered neutral. If IB>1 (or more than 100%), the investment policy is encouraging or has a pro-sector bias. If IB<1 (or less than 100%), the investment policy has an anti-sector bias.

The estimate of the IB index shows that it was consistently well below 1 both for

Table 19: Annual public investment (development expenditure) in the Bangladesh fisheries and agriculture sector, FY1993 to FY2006

Fiscal year	Public expenditure on agriculture sector (million taka)	Public expenditure on fisheries sector (million taka)	Total public expenditure (million taka)	Share of public expenditure in agriculture (%)	Share of public expenditure in fisheries sector (%)
1993	4,415	525	65,500	6.740	0.802
1994	4,361	668	89,830	4.855	0.744
1995	5,858	712	103,030	5.686	0.691
1996	5,654	590	100,157	5.645	0.589
1997	6,048	497	110,410	5.478	0.450
1998	6,296	346	110,370	5.704	0.313
1999	6,080	431	125,090	4.861	0.345
2000	5,851	546	144,614	4.046	0.378
2001	6,674	854	162,053	4.119	0.527
2002	5,279	775	143,894	3.668	0.538
2003	5,609	866	153,700	3.649	0.563
2004	5,658	1,088	175,799	3.218	0.619
2005	4,819	798	187,596	2.569	0.425
2006	6,678	929	190,939	3.497	0.486

Sources: GoB, Planning Commission, Annual Development Programme (annual issues from FY2000 to FY2006).

agriculture and fisheries for all the years under study (Table 20). During FY1993 to FY2006, the estimated IB index varied from 0.115 to 0.239 for agriculture and from 0.055 to 0.163 for fisheries and aquaculture. This index shows how public investment policy is biased against the agriculture sector and even more so against the fisheries and aquaculture sector.

The recent aquaculture and export boom has prompted international and bilateral funding agencies such as the Asian Development Bank, World Bank, United States Agency for International Development, UK Department for International Development, and Danish International Development Agency to fund resource management, aquaculture development, and postharvest and processing projects in Bangladesh. During the period of FY1986-2005, various donor agencies provided $345 million for fisheries and aquaculture development in Bangladesh, about 60% of which went into aquaculture development (de Graaf and Latif 2002).

4.4 FUTURE CHALLENGES

Aquaculture policies, institutions and support systems have attempted to keep pace with the sub-sector's economic transformation and the changing global environment. Planning and policy setting have in general terms recognized the importance of aquaculture to Bangladesh.

The future of fish exports from Bangladesh to developed countries will likely depend mainly on compliance with new health safety standards and other technical measures that are being made progressively more stringent by the major fish-importing developed countries. One of the challenges

Table 20: Sectoral share of agriculture and fisheries to GDP and investment bias index in Bangladesh, FY1993 to FY2006

Fiscal year	Sectoral share of gross domestic product at constant prices in		Investment bias index for	
	agriculture	fisheries	agriculture sector	fisheries sector
1993	28.21	4.93	0.239	0.163
1994	27.30	5.10	0.178	0.146
1995	26.02	5.21	0.219	0.133
1996	25.68	5.36	0.220	0.110
1997	25.87	5.48	0.212	0.082
1998	25.34	5.67	0.225	0.055
1999	25.28	5.93	0.192	0.058
2000	24.61	5.86	0.164	0.064
2001	24.11	5.31	0.171	0.099
2002	23.09	5.20	0.159	0.104
2003	22.61	5.06	0.161	0.111
2004	22.15	4.90	0.145	0.126
2005	22.27	5.00	0.115	0.085
2006	21.77	4.86	0.161	0.100

Sources: DoF 2007; BBS. 1999. Statistical Year Book of Bangladesh; MoF. 1990 to 2000 (annual issues). Economic Survey of Bangladesh; MoF. 2006 and 2007. Bangladesh Economic Review.

facing Bangladesh exports of fish and fish products is progressively stricter food safety requirements, particularly in major markets such as the EU, USA and Japan. Investment is needed in postharvest facilities and to train fish farmers and processors and build up processing enterprises to meet higher quality standards.

Fish production exists in the wider economic context of a supply-and-value chain beginning with inputs and extending through postharvest services, processing and marketing. Although constraints to growth occur all along the chain, marketing infrastructure has so far received less attention from planners and is generally little developed in many areas. Downstream producers and traders are plagued by primitive infrastructure and weak links in a long supply chain.

5. CONSUMPTION AND DEMAND FOR FISH

To assess the impact that technological change, infrastructure development and economic policies will have on food security and the distribution of fish, information is needed on current and past fish-consumption patterns and how they are likely to change as production, prices and incomes change. This section examines the trends and current consumption patterns and their sensitivity to changes in production, prices and income.

5.1 TRENDS IN FISH CONSUMPTION

Food fish plays a major role in human nutrition in Bangladesh by supplying about 66% of total animal protein intake, which constitutes about 14% of a person's total protein intake (BBS 2007b). Annual consumption of fish per capita from all sources has increased substantially in Bangladesh over the past 2 decades (Table 21). There is a strong relationship between higher per capita fish consumption and faster growth in freshwater aquaculture production (Table 21 and Figure 12). The contribution of freshwater fish is directly related to the expansion and intensification of freshwater aquaculture production. The growth in per capita fish consumption (about 2.4% per year during 1980-2000) is accompanied by growth in per capita freshwater fish consumption (about 2.5% during the same period). Figure 12 shows the relationships between annual fish consumption per capita and fish production from freshwater aquaculture (x_1) and inland capture fisheries production (x_2). Estimated regression coefficients for freshwater aquaculture confirm the positive and significant relationship between aquaculture production and per capita fish consumption.

In many developing countries, official national statistics on per capita fish consumption are commonly based on the total availability of commercial fish in the country and do not include the consumption of many small and non-commercial fish species obtained from artisanal and subsistence fisheries. It is generally assumed that actual per capita fish consumption is higher than the national average reported in official databases (FAO

Table 21: Trends in per capita annual fish consumption by source in Bangladesh

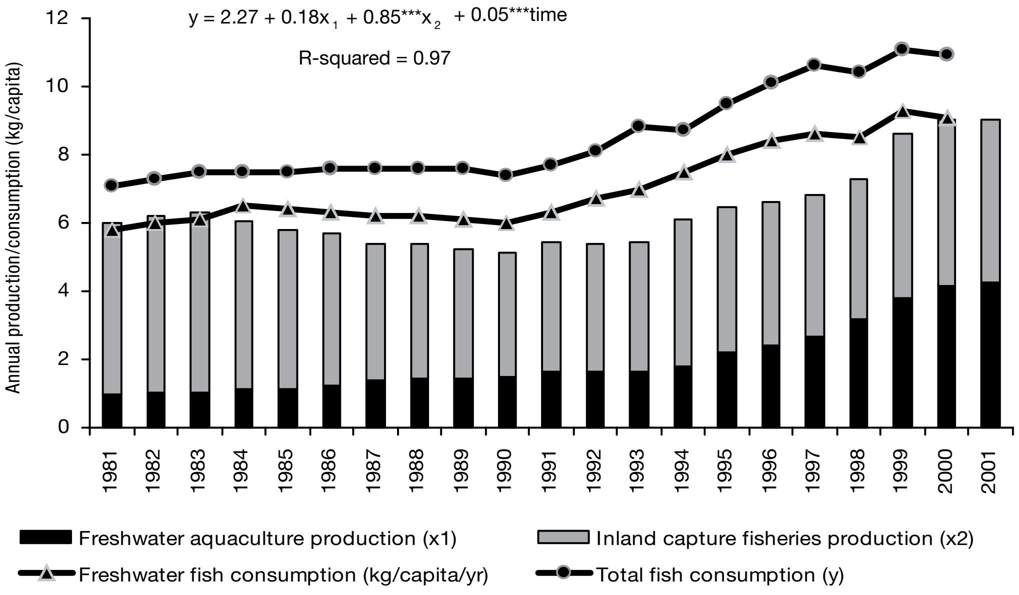
Source of fish	Average fish consumption (kilogram/capita/year)			Annual growth rate[1] of per capita average fish consumption			Share to total consumption (%)		
	1981-90	1991-2000	2000	1981-2000	1981-90	1991-2000	1981-90	1991-2000	2000
Freshwater fish	6.2	7.9	9.1	2.46 ***	0.21	4.26 ***b	82.7	81.4	83.5
Demersal fish	0.3	0.4	0.4	0.37	-3.84 ***	2.09 b	4.0	4.1	3.7
Pelagic fish	0.4	0.3	0.3	-1.4 ***	-0.17	-0.87 a	5.3	3.1	2.8
Other marine fish	0.4	0.3	0.4	-1.81 *	0.7	-1.56	5.3	3.1	3.7
Crustaceans	0.2	0.7	0.7	16.15 ***	20.93	9.28 ***	2.7	7.2	6.4
Molluscs	0	0.1	0	12.44	25.12	-8.37	0.0	1.0	0.0
Total	7.5	9.7	10.9	2.43 ***	0.47 **	4.14 ***b	100	100	100

Source: Adapted from Dey et al. 2005b.
Data source: FAO 2003 Food Balance Sheet, available at www.fao.org/ (May 2003).

1 Growth rates (β_1 * 100) are computed by estimating a regression model of the form $LnYt = \beta_o + \beta_1 t + \varepsilon_t$; where Ln refers to natural logarithm, Y is annual per capita fish consumption and t refers to time (year). Level of significance of the coefficient are shown by * marks. * significant at $\alpha = 0.10$; ** significant at $\alpha = 0.05$; *** significant at $\alpha = 0.01$.

2 Chow test (F-statistic) has been used to examine whether the coefficient vectors are the same between the periods 1981-90 and 1991-2000. a and b are levels of significance at 5% and 1%, respectively.

Figure 12: Relationship between inland freshwater fish production and per capita fish consumption in Bangladesh, 1981-2001



kg = kilogram.
Source: Modified from Dey et al. 2005b.

1999 and 2002, Welcome 2001, Ahmed et al. 1996, Dey et al. 2005b). The national average fish consumption in Bangladesh, as reported by FAO and other official databases (e.g., data published by BBS and DoF), also fails to include the consumption of fish unofficially imported from neighbouring countries. Based on a year-round survey of 720 households conducted from July 1998 to August 1999, ICLARM (2001) estimated annual fish consumption per capita to be 22.2 kg/year, which is more than double the reported official figure (Tables 21 and 22). Other micro-level surveys of fish consumption recently conducted in Bangladesh report much higher per capita fish consumption, at about 31 kg/capita/year (Thompson et al. 2004, Sultana and Thompson 2000).

5.1.1 FISH CONSUMPTION BY CONSUMERS' INCOME CLASS AND FISH TYPE

There is wide variation in annual fish consumption per capita among various economic groups (Table 22). It increases consistently with higher income. Pair-wise comparison across quartile groups using Duncan's multiple range test shows that the difference in average per capita fish consumption between the poorest quartile (I) and the richest quartile (IV), or even between income quartiles I and III, is statistically significant. An average consumer in the poorest quartile consumes around 39% of the quantity of fish consumed by an average consumer in the richest quartile.

The share of fish expenditure in total food expenditure and the share of fish expenditure in total animal protein expenditure by income class indicate the relative importance of fish in the diet of people of different income classes (Table 22). Poorer households tend to devote more of their food expenditure on fish than do richer families. Richer families spend less of their budget for animal protein on fish than do lower-income groups, though they consume more fish and meat. This shows that fish is an especially important source of animal protein for poorer households in Bangladesh.

Lower-income groups spend more on low-value fish than do higher-income groups. Although the expenditure shares on assorted small fish, rohu, river shad (hilsha) and catla are relatively high across all income groups, lower-income groups tend to consume more low-value species like silver carp, tilapia and assorted small fish (Table 23).

Table 22: Annual per capita expenditure on fish and its share of total expenditure on food and animal protein in Bangladesh

Income quartile	Annual fish consumption per capita (kilogram)	Annual fish expenditure per capita ($)	Expenditure on fish as a share of total food expenditure (%)	Expenditure on fish as a share of total animal protein expenditure (%)
I	13.05	15.97	26.1	77.87
II	19.20 [a]	23.51 [a]	26.8	73.91
III	22.92 [ab]	28.06 [a]	25.4	71.92
IV	33.64 [b]	41.19	23.9	68.94
All	22.20	27.19	25.2	71.89

Source: Adapted from Dey et al. 2005b, based on field survey data collected in 1998/99 (ICLARM 2001) of fish consumers in inland areas of Bangladesh by the WorldFish Center and Bangladesh Agricultural University.

Note: The Duncan's Multiple Range Test mean separation test was conducted to examine pair-wise differences between average per capita consumption of different quartile groups. Figures with the same letters in the superscripts [(a,b)] are not pair-wise statistically significant at the 5% level of significance.

Table 23: Expenditure on specific fish types in Bangladesh as a share (%) of total fish expenditure, by income class, in 1998/99

Fish type	Income quartile				
	Average	I	II	III	IV
Rohu	11.8	11.2	12.5	12.1	11.4
Catla	7.7	7.0	6.9	7.9	8.3
Mrigal	4.6	4.4	4.7	4.5	4.7
Silver carp	9.3	11.5	10.3	9.7	7.7
Silver barb	3.8	3.0	3.6	4.1	4.0
Other (exotic) carp	5.8	4.7	5.6	5.5	6.5
Tilapia	1.9	2.7	2.4	1.9	1.4
River shad	12.9	14.1	14.6	12.0	12.2
Live fish	16.0	14.0	13.4	15.3	18.5
Other high-value fish	9.5	9.1	9.4	10.5	9.2
Assorted small fish	16.7	18.2	16.6	16.5	16.1

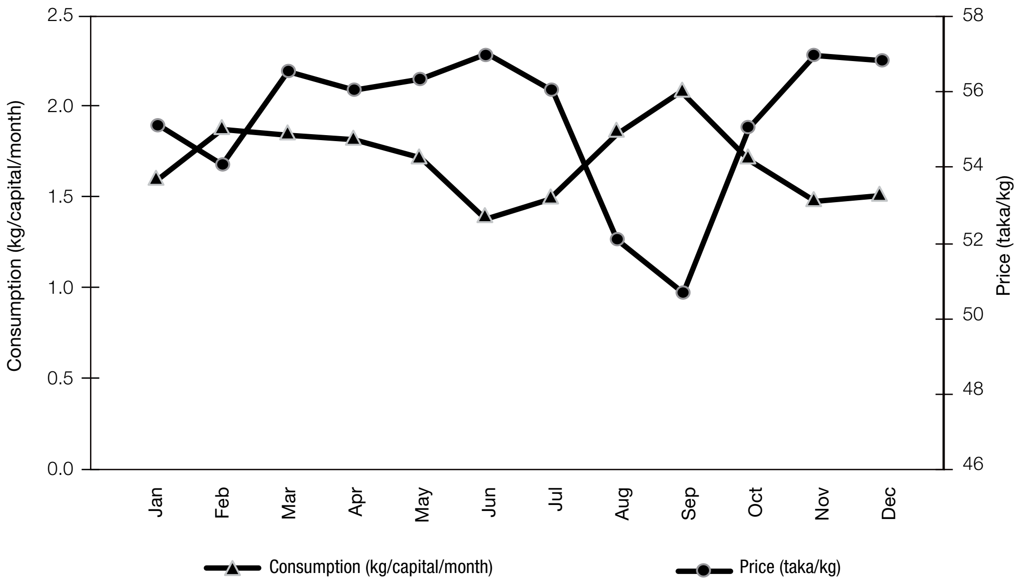
Source: Adapted from Dey et al. 2005b, based on field survey data collected in 1998/99 (ICLARM 2001) of fish consumers in inland areas of Bangladesh by the WorldFish Center and Bangladesh Agricultural University.

5.1.2 SEASONALITY IN FISH CONSUMPTION

Figure 13 shows that seasonality of per capita fish consumption is in inverse relation to the weighted average price of fish. This relationship and pattern could be attributable to the seasonality of fish supply. During the first quarter of the year (January-March), open waters like rivers, canals and beels dry up, and the fish catch from open water increases, as does fish availability in markets. During the third quarter (July-September), cultured fish attain marketable size and the market supply increases.

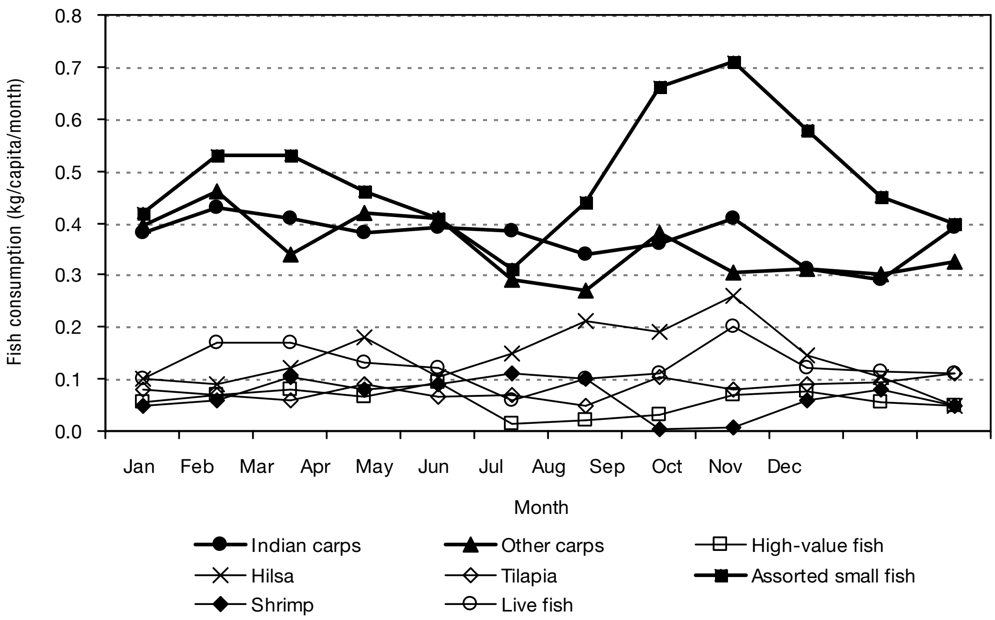
An analysis by species is presented in Figure 14. Except for shrimp, all species similarly follow the seasonal pattern. The assorted small fish, which are mostly from freshwater capture fisheries, seem to be the major driving factor for this seasonality pattern, followed by cultured Indian carps and exotic carps.

Figure 13: Seasonality of fish consumption and price in Bangladesh



kg = kilogram.
Source: Modified from Dey et al. 2005b.
Note: In 1999, $1 = 49 taka

Figure 14: Seasonality of fish consumption by species group



kg = kilogram.
Source: Modified from Dey et al. 2005b.

5.2 DEMAND ELASTICITIES

Studies on elasticities of demand for fish (i.e., how fish demand responds to changes in price and income) are generally scanty in Asia and particularly so in Bangladesh. The earlier studies on demand for fish in Bangladesh treated fish as one of the commodity groups in their demand models and analyzed aggregate fish demand (Ahmed and Shams 1994, Goletti 1992, Hossain 1988, Pitt 1983, Razzaque et al. 1997, Shahabuddin and Zohir 1995, Talukder 1993). Dey (2000b) estimated disaggregated demand for fish based on limited household expenditure data collected by BBS, where consumption data were collected over a period of a week. Ali (2002) used survey data collected in 1994 and analyzed demand for fish in four aggregated fish categories (low-price, medium-price, high-price and dried fish). ICLARM (2001) and Dey et al. (2008b) improved upon the previous research efforts by using weekly data collected throughout the year to capture the seasonality of fish consumption, including geographical representation of the country, and disaggregating the analysis by eight different types of fish and four quartile groups of consumers.

Available estimates of income and own-price elasticities of fish demand are provided in Table 24. Estimated elasticities vary substantially across studies due to differences in the source and type of data used (cross section, time series or both), the model used, and the estimation procedure followed. The magnitudes of elasticities vary across different species and quartile groups, indicating the relevance of estimation specific to species and quartiles.

Table 24: Own-price and income elasticities of fish in Bangladesh

Authors/ source	Sample period	Estimating model	Data source	Description	Uncom-pensated own price elasticity	Income/ expenditure elasticity
Pit (1983)	1973/74	Tobit demand model	Household expenditure survey	Percentile 25 expenditure (high income)	-0.97	1.02
				Percentile 90 expenditure (low income)	-0.66	0.50
Hossain (1988)	1982	Working-Leser Engel function, modified by Hazell and Roëll	Field source	Underdeveloped village		1.19
				Developed village		1.22
Goletti (1992)	1988/89	Tobit demand system	Household expenditure survey	Rural quartile 1	-1.81	1.18
				quartile 2	-1.45	0.45
				quartile 3	-1.13	0.29
				quartile 4	-1.26	0.40
				All	-1.42	0.90
				Urban quartile 1	-1.29	1.05
				quartile 2	-1.15	0.79
				quartile 3	-1.44	0.56
				quartile 4	-0.79	0.13
				All	-1.16	0.61
Talukder (1993)	1981/82	Food -specific demand equations	Household expenditure survey	All rural		1.34
				All urban		1.10
Ahmed and Shams (1994)	1991/92	Almost ideal demand system	Field survey	All rural	-0.71	1.48

Table 24: Own-price and income elasticities of fish in Bangladesh (cont'd)

Authors/ source	Sample period	Estimating model	Data source	Description	Uncom-pensated own price elasticity	Income/ expenditure elasticity
Shahabuddin and Zohir (1995)	1981/82 to 1988/89	Multistage budgeting	Published household expenditure survey data 1981/82, 1983/84, 1984/85, and 1988/89	Rural expenditure quantile 1		0.74
				quantile 2		0.90
				quantile 3		0.91
				quantile 4		0.91
				quantile 5		0.62
				All		0.71
				Urban expenditure quantile 1		0.99
				quantile 2		0.88
				quantile 3		0.75
				quantile 4		0.57
				quantile 5		0.23
				All		0.62
Dey (2000b)	1988	Multistage budgeting	Published household expenditure survey data	Hilsha, quartile 1	-1.22	1.76
				quartile 2	-1.20	1.27
				quartile 3	-1.18	1.01
				quartile 4	-1.17	0.75
				Live fish, quartile 1	-1.56	2.13
				quartile 2	-1.41	1.53
				quartile 3	-1.37	1.20
				quartile 4	-1.27	0.83
				Carp, quartile 1	-2.90	1.77
				quartile 2	-2.82	1.32
				quartile 3	-2.46	1.03
				quartile 4	-2.07	0.74
				Assorted small fish, quartile 1	-1.00	1.44
				quartile 2	-0.99	0.97
				quartile 3	-0.99	0.76
				quartile 4	-1.00	0.55
				Shrimp, quartile 1	-0.60	1.26
				quartile 2	-0.53	0.71
				quartile 3	-0.29	0.37
				quartile 4	-0.47	0.33
				Dried fish, quartile 1	-1.32	1.32
				quartile 2	-1.47	0.70
				quartile 3	-1.50	0.50
				quartile 4	-1.81	0.15
Ali (2002)	1994	Linear approximated almost ideal demand system	Field survey	Aggregate fish	-0.74	1.37
				Low-price fish	-0.83	0.98
				Medium-price fish	-0.67	1.90
				High-price fish	-1.24	2.27
				Dry fish	-0.97	0.17

Table 24: Own-price and income elasticities of fish in Bangladesh (cont'd)

Authors/ source	Sample period	Estimating model	Data source	Description	Uncompensated own price elasticity	Income/ expenditure elasticity
Dey et al. (2008b)	1999/2000	Multistage budgeting	Field Survey, nine districts	HV freshwater fish, lowest quintile	-1.61	2.23
				HV freshwater fish, highest quintile	-1.12	0.9
				LV freshwater fish, lowest quintile	-1.32	1.4
				LV freshwater fish, highest quintile	-0.97	0.7
				HV marine fish, lowest quintile	-2.78	3.07
				HV marine fish, highest quintile	-1.49	1.00
				LV marine fish, lowest quintile	-1.04	1.25
				LV marine fish, highest quintile	-0.80	0.85
				Shrimp, lowest quintile	-0.98	0.80
				Shrimp, highest quintile	-1.04	0.47
				Dried fish, lowest quintile	-0.40	1.38
				Dried fish, highest quintile	-0.40	0.78

HV = high-value; LV = low-value.

The negative values of all the own-price elasticities indicate an inverse relationship between prices of a commodity and demand for it. Low-priced fish such as assorted small fish and dried fish have lower own-price elasticity in absolute terms than high-value marine and freshwater fish. Low-priced fish types have average elasticities that are less than 1 in absolute value, meaning that demand for these types of fish is generally inelastic. This result suggests that Bangladeshi households consider low-priced species a necessity.

The own-price elasticities of the various fish categories were generally found to be lower for the highest income group than for the lowest income group. This suggests that poorer households tend to respond more to changes in fish price than do richer households. It also suggests that price elasticity moves from elastic to inelastic with increased household income. This result is important as it suggests the flexibility in fish demand by the Bangladeshi poor absorbs potential supply expansion in the market. This observation is consistent with most demand studies for various food commodities, including rice (Senauer 1990), rice and cassava (Timmer and Alderman 1979), and fish (Park et al. 1996).

Income elasticities of demand (that is, how fish demand responds to an increase in income) for all the fish types are positive (Table 24), suggesting that fish (whether fresh or processed) is considered a common good in Bangladesh by all households, whether rich or poor. Income elasticities differ considerably across income quartiles and fish types. In general, low-priced fish types have lower income elasticities than their high-priced counterparts. Income elasticities for expensive fish, such as live fish, high-value species, hilsha and to some extent carps are elastic (i.e., >1). As is the case with price elasticities, income elasticities shift from elastic to inelastic as households occupy higher income brackets. This suggests that fish consumption among poorer households responds more to income changes than is true among the richer households. Moreover, poorer households treat fish as a luxury food (with elastic income elasticity), while the richer households deem it a basic food necessity (inelastic income elasticity). Hilsha, shrimp, live fish and other high-value fish appear to be luxury commodities among the lower-income groups, but they are considered necessities among the higher-income groups.

5.3 POLICY IMPLICATIONS

Elasticities of demand for fish in Bangladesh vary substantially across species and income groups. Income elasticities of demand for fish are positive, indicating that fish is a commonly available commodity. The estimated price and income elasticities for all fish types are higher among poorer people than among the more affluent members of the society. This implies that poorer households often consider fish a luxury commodity, especially the high-value species, while the rich consider it a basic food item.

These results have important policy implications. The analysis showed that per capita income and population growth in Bangladesh will be accompanied by a tremendous increase in fish demand, which is expected to come mostly from poorer people. The absence of a commensurate increase in fish supply will create pressure for fish prices to rise, which will likely hurt consumers. This has worrisome consequences on protein intake, particularly among the poor. A way to circumvent this problem is to expand fish production, which can realistically be achieved only through expanded aquaculture.

6. PROFILE AND ECONOMICS OF FRESHWATER FISH FARMING

The adoption of a technology depends on the characteristics and preferences of the individual, the technology, and the environments within which an individual adopts the technology (Rogers 2003). This section discusses the profile of pond fish farmers and the economics of pond aquaculture technologies to provide an insight on the future adoption of freshwater fish faming in Bangladesh. The analysis is based on several rounds of recent surveys conducted in Bangladesh by the WorldFish Center and others.

6.1 SOCIOECONOMIC PROFILE OF POND FISH FARMERS

Recent surveys reveal that a typical pond fish producer's household consists of about six members and that the average age of fish farmers is around 40 years (Table 25). The results show that relatively younger people are engaged in pond fish culture in Bangladesh. Fish farmers are, on average, reasonably well educated, with around 8 years of schooling. However, Dey et al. (2008a) found in a 2002 survey that only 23% of farmers were trained in modern fish culture.

Table 25: Socioeconomic profile of freshwater pond fish farmers in Bangladesh

Indicator	Year				
	1998/99	2002	2003	2003	2005
Household size	5.5	5.2	5.5	6.1	6.6
Educational attainment (yr)	8.0	7.5	7.2		
Age of farmer (yr)	45.0	40.0	37.2	34.3	39.4
Fish culture experience (yr)	13.0		9.1		
% of farmers with aquaculture training		23			47
Average farm size (ha)		0.51	1.02	1.44	
Average pond area (ha)	0.20	0.25	0.11	0.12	1.39
Pond productivity (kg/ha)	3,262	2,160	2,789	2,531	
Per capita income ($/yr)	293	404	287	253	
Per capita net income from aquaculture ($/yr)	44	108	25	34	326
Share of fish farming in total farm income (%)	15	27	9	13	
Survey locations	Bogra, Comilla, Jessore and Mymensingh	Bogra, Comilla, Jessore and Mymensingh	Representa-tive upazilas covering the whole country	Representa-tive upazilas covering the whole country	Mymensingh
Sources of information	ICLARM 2001, Dey et al. 2001	Dey et al. 2008a	DSAP survey, WorldFish[1]	Fourth Fisheries Project, DoF[2]	Sarker et al. 2006

DoF = Department of Fisheries, DSAP = Development of Sustainable Aquaculture Project, ha = hectare, ICLARM = International Center for Living Aquatic Resources Management (the WorldFish Center), kg = kilogram, yr = year.

[1] data set from DSAP survey conducted by WorldFish in 2002/03.

[2] data set used from Fourth Fisheries Project coordinated by DoF.

Although various surveys show similar socio-demographic characteristics of pond fish farmers in Bangladesh, they also show substantial variation in farmers' economic conditions across regions and within any region (Tables 25 and 26). On average, pond fish farmers in Bangladesh tend to be poor, earning an annual per capita income of less than $365 (below the poverty line of $1/day that is used by the World Bank for cross-country comparisons) and work a farm smaller than 1.5 ha. However, average figures obscure large variations in household income within the sample. For example, Sarkar et al. (2006) found that many fish farmers in Mymensingh district have a larger pond area (averaging 1.39 ha, with a maximum of 9.0 ha) and higher annual per capita income from aquaculture (averaging $326, with a maximum of $2,154) (Table 26). While small-scale fish farmers are basically crop farmers for whom fish farming is a secondary activity, fish farming is the main occupation of commercial fish farmers. In some cases, income from fish farming can be as high as 60% of total household income (Dey et al. 2008a). These results show that small-scale fish farming coexists with commercial fish faming in Bangladesh. Socio-demographic characteristics such as farmers' age, formal education and family size do not appear to be main constraints for aquaculture development in Bangladesh. Sarker et al. (2006) found that the economic conditions of the farmers and poor extension service, which lacks information and training, are the main barriers to the entrepreneurial development of pond aquaculture.

6.2 COSTS AND RETURNS OF FRESHWATER POND AQUACULTURE

The costs and returns of freshwater aquaculture technologies are analyzed for different culture systems (e.g., monoculture, polyculture), species (e.g., carp, tilapia, freshwater prawn) and levels of intensity, following the definitions of Edwards (1993) and Dey et al. (2000a):

- Extensive systems rely on natural food produced in the water body without supplementary inputs.
- Semi-intensive systems supplement natural feed with additional feed and fertilizers.
- Intensive systems rely on nutritionally complete concentrates of feed and fertilizers.

Table 26: Regional differences in the socioeconomic profile of freshwater pond fish farmers in Bangladesh, 2003[1]

Category	Region				
	Dhaka	Chittagong	Rajshahi	Barisal	Jessore
Household size	5.74	5.48	5.37	5.63	5.20
Educational attainment (yr)	7.52	6.95	7.13	7.00	7.05
Age of farmer (yr)	38.30	41.71	35.65	35.90	35.66
Land area owned (ha)	0.96	0.73	1.33	0.72	1.02
Pond area (ha)	0.09	0.15	0.12	0.11	0.11

ha = hectare, yr = year.
[1] data set from DSAP survey conducted by WorldFish in 2002/03.

Information on variable costs was available in all studies and data sets reviewed, as listed in Table 27, but was not available for fixed costs. In freshwater aquaculture in Bangladesh, fixed costs are relatively unimportant (Dey et al. 2000a), so the gross margin (gross return minus variable costs) is a good measure of profitability. Another important indicator is cost-effectiveness,

Table 27: Costs and returns of freshwater pond aquaculture in Bangladesh

Culture pattern	Tilapia monoculture	Tilapia-carp polyculture in seasonal ponds	Carp polyculture	Carp polyculture	Carp polyculture	Freshwater prawn mono-culture	Freshwater prawn mono-culture
Culture system	Extensive to semi-intensive (average)	Extensive to semi-intensive (average)	Extensive	Semi-intensive	Extensive to semi-intensive (average)	Extensive	Semi-intensive
Yield (t/ha)	4.050	1.736	0.800	3.280	2.789	0.292	0.478
Gross return ($/ha)	1,863	1,531	512	2,184	1,902	1,679	2,699
Total variable Cost ($/ha)	453	422	381	1,019	878	836	1,197
Gross margin ($/ha)	1,410	1,109	131	1,165	1,014	843	1,502
Return over variable cost	3.11	2.63	0.34	1.14	1.14	1.01	1.25
Reference year	1991/92	1995/96	1998/99	1998/99	2002/03	2004	2004
Source of information	Dey and Bimbao 1998	Dey et al. 2000a	Dey et al. 2005c	Dey et al. 2005c	DSAP survey, WorldFish[1]	Ahmed et al. 2008	Ahmed et al. 2008

ha = hectare, t = tonne.
Note: cost and return are calculated on a per-crop-cycle basis, where only one cycle is practised per year.
[1] data set from DSAP survey conducted by WorldFish in 2002/03.

measured here by the ratio of the gross margin to variable costs (or return over variable costs), i.e., the net income that one dollar of current outlay is expected to earn within one production cycle. If cost-effectiveness is low, one needs a larger outlay to hit the same gross margin, which may be a problem if there are limits to expansion caused by, for example, credit constraints.

Analysis shows that freshwater pond aquaculture is a reasonably profitable enterprise (Table 27). Except for one case of extensive polyculture, the average annual gross margin per hectare of pond fish culture ranged from about $850/ha to about $1,500/ha. Return over variable costs ranged from 1.01 to 3.11 (except for one case of extensive carp polyculture). Semi-intensive aquaculture is more productive and profitable than extensive aquaculture. This indicates that fish production in Bangladesh can be increased through intensification, with fish farmers expected to increase their use of feed over time, if credit is available. However, it is important to note that increased intensity of feed use beyond a certain point may lead to environmental problems (Dey et al. 2005c).

Fingerlings, feed and labour are the major costs for freshwater pond aquaculture in Bangladesh (Table 28). In a survey conducted in Mymensingh district, Sarker et al. (2006) found that lack of quality fish fry and fingerlings was a barrier to aquaculture development, with 67% of those surveyed mentioning this as a major problem. Feed will likely become increasingly important as farmers move from extensive to semi-intensive and intensive systems, but many poor farmers may still be unable to afford to use economically optimal levels of feed (Dey et al. 2005c).

Table 28: Input cost as a percentage of the total variable costs for pond polyculture in Bangladesh

Category	WorldFish Carp-1 Project survey	WorldFish DSAP survey	WorldFish Fish Supply-Demand Project survey	WorldFish Carp-2 Project survey
Seed	14	35	27	14
Feed	20	21	20	38
Fertilizer	11	14	0	1
Labour	53	27	30	44
Lime	2	3	0	3
Reference year	1998/99	2002/03	2002	2004/05

Note: 0 indicates zero or very negligible use.

Freshwater fish farming is more profitable, as measured by net return and benefit-cost ratio, than rice farming in Bangladesh (Table 29), but rice farming offers more opportunity for employment. Results from comparative analysis of double-cropped rice culture and year-round fish culture show that the net return from fish culture is 3-5 times more than that from rice culture. Over the last decade, rice paddies are being converted into freshwater fishponds (Karim et al. 2006), and it is likely that more rice lands will be converted to fishponds in the future.

Table 29: Cost and return of rice double cropped with the varieties Pajam and BRRI 29 and fish culture per hectare per year in Bangladesh

Variables	Double-cropped rice culture[1]			Carp polyculture (per ha per year)	Freshwater prawn monoculture		
	BRRI 29 (per ha per season)	Pajam (per ha per season)	Total (per ha per year)		Extensive (per ha per year)	Semi-intensive (per ha per year)	Average (per ha per year)
Gross return ($)	875	522	1,397	1,930	1,679	2,699	2,189
Total cost ($)	703	464	1,167	1,022	1,070	1,559	1,314
Net return ($)	172	57	229	907	609	1,140	875
Benefit/cost ratio	1.24	1.12	1.19	1.89	1.57	1.73	1.67
Labour use (person-days)	149	159	308	247			
Labour cost ($)	235	204	439	310	137	189	163
Labour cost (% of total cost)	33	44	37	30	13	12	12
Reference year	2003	2002		2002	2004	2004	2004
Source of information	Rahim 2004	Anik 2003		Talukder 2004	Ahmed et al. 2008	Ahmed et al. 2008	Ahmed et al. 2008

ha = hectare.
[1] This pattern is one of the highest yielding and most profitable in double-cropped rice.

7. YIELD GAP, YIELD LOSS AND TECHNICAL INEFFICIENCY

7.1 CONCEPT OF YIELD GAP AND YIELD LOSS

Carp polyculture in ponds is the main freshwater aquaculture system in Bangladesh (Dey et al. 2005c). Various culture technologies and carp strains have been developed or introduced. However, the biophysical potential for pond aquaculture in Bangladesh has still not been realized. Gaps persist between the yields obtained at research stations and in farmers' fields. Large variation in production levels exists among farms. To meet the urgent need for increased aquaculture production in Bangladesh, the problems that affect fish yield must be clearly identified. Planners and policymakers need information on the relative importance of various problems so that they can design and implement strategies to solve them.

Yield gap analysis has long been used in agriculture to demonstrate how much farm yields are below the maximal potential yield for a particular technology and to suggest ways of improving production efficiency through the extension of currently available technology or by developing new technologies (IRRI 1977 and 1979, De Datta et al. 1978, Widawsky and O'Toole 1990 and 1996, Evenson et al. 1996, Dey et al. 1996). Three definitions of yield gap are commonly recognized (Figure 15). Yield gap I is the difference between the theoretical yield potential and highest experimental yield. It represents the potential increase in biological efficiency and is attributed to genetic and management improvement conceived but not yet developed or perfected. By definition, this yield gap cannot be measured. Yield gap II is defined as the difference between the yield observed on experimental stations and the best yield on farmers' fields. This yield gap is probably largely attributable to inherent differences, large and small, in the biophysical environments of the experimental station and typical farmers' field, which cannot be easily managed or eliminated. Production research or changes in socioeconomic conditions can do little to exploit yield gap II. Yield gap III is defined as the difference between actual and best-practice yields on farmers' fields for a particular technology and can be considered as comprising three components (Figure 15):

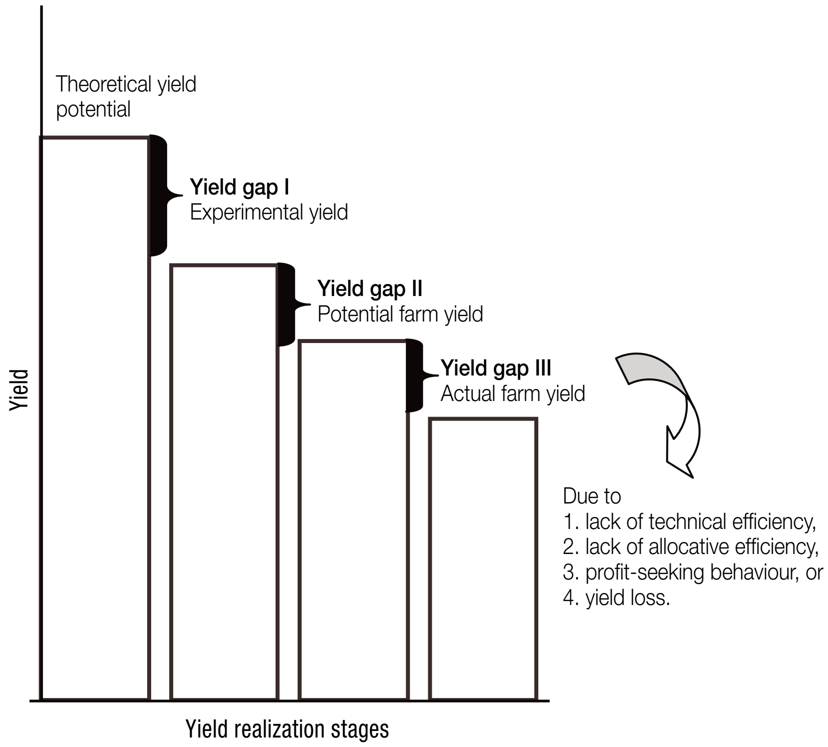
1. yield losses due to biotic and abiotic factors such as disease, problem soils, poor water quality, and adverse climate or weather;
2. lack of efficiency, both technical and allocative, such as lack of credit, poor knowledge, input unavailability, tradition and attitudes, and poor institutional support; and
3. farmers' profit-seeking behaviour.

In this monograph the focus is on yield gap III because it may be reduced through technological and policy interventions that overcome constraints. This chapter has as its objectives to (1) identify the gap between the potential and actual yield (the yield gap), (2) analyse how various technical constraints worsen the yield gap, and (3) assess the level and determinants of farm-level technical inefficiencies in the freshwater pond polyculture system in Bangladesh.

7.2 YIELD GAP ANALYSIS

The output of fish farmers practicing a particular aquaculture technology varies; some farmers produce close to the potential while others fall considerably short of it (Arjumanara 2002, Arjumanara et al. 2004, Dey et al. 2005e). Dey et al. (2005e) reported that the ratio of the average farm yield to the maximum farm yield of carp polyculture in Bangladesh is 0.46, the maximum yield being 7.13 t/ha and average farm yield being 3.26 t/ha (Table 30). Arjumanara (2002) showed that yield deviations from that of the highest-yielding fish producers ranged between 20% and 32%, with an average of 21%. This yield gap is considerably larger than the rice yield gaps estimated by the International Rice Research Institute (IRRI) and its partners in the early 1990s (Evenson et al. 1996, Dey et al. 1996). This may be because fish culture is more complex than rice cultivation and fish farming is more

Figure 15: Concept of yield gap



Sources: Yield gap concept as discussed in Evenson et al. 1996, Dey et al. 1996.

affected by environmental conditions than is rice cultivation.

Table 30 shows estimates of yield gaps for carp culture in ponds for different stocking intensities (Dey et al. 2005e). Although most fish farms in Bangladesh are semi-intensive, the sample farms were divided into three intensity levels (low, medium and high) to determine if the yield gap varies with intensity level. In general, higher-intensity farms have both a higher average yield and a wider yield gap, so the ratio of yield gap to the maximum farm yield is more or less constant at 52-54% across various intensity levels.

7.3 YIELD LOSS ANALYSIS

There are two kinds of technical constraints to fish production: abiotic (e.g., problems with water, soil, temperature, etc.) and biotic (e.g., pests, predators and disease). Dey et al. (2005e) estimated the financial losses caused by the different constraints based on surveys conducted with fish farmers. The results of this analysis are presented in Table 31. The annual financial loss caused by the various biotic and abiotic factors is estimated at about $243/ha, constituting about 14% of the total yield value. As the average yield gap III is about 54% of the maximum farm yield and about 119% of the average farm yield, the yield loss estimates in Table 30 explain only a small portion of yield gap III. This is because technical constraints account for only part of the total yield gap III. The yield loss estimates of Dey et al. (2005e) did not include losses caused by socioeconomic factors.

Dey et al. (2005e) also report that water quantity and quality in general — and flooding, high turbidity and low dissolved oxygen in particular — were perceived by fish farmers as the key abiotic factors contributing to yield loss (Table 31). Overall, abiotic constraints are more important than biotic constraints to freshwater aquaculture development in Bangladesh.

Table 30: Yield gap III for carp polyculture in ponds by intensity level in Bangladesh

Intensity level[1]	Low intensity	Medium intensity	High intensity	Overall
Number of farms	295	146	99	540
Maximum potential farm yield (t/ha)	6.31	6.69	8.45	7.13
Average actual farm yield (t/ha)	3.06	3.23	3.91	3.26
Yield gap III (t/ha)	3.25	3.46	4.54	3.87
Yield gap III as % of max farm yield	54.88	51.77	53.76	54.30

t/ha = tonnes per hectare.
[1] The sample farms were grouped into three intensity levels (low, medium and high) though most are semi-intensive.
Source: Adapted from Dey et al. 2005e.

Table 31: Yield loss caused by various abiotic and biotic factors in Bangladesh

Factor	Annual yield loss ($/ha)	% contribution to total yield loss
Water quality	170.98	70.29
High turbidity	109.28	44.92
Plankton bloom	21.17	8.70
Filamentous algae/weeds	4.52	1.86
Low dissolved oxygen	36.01	14.80
Pollution[1]		0.00
Water	55.74	22.91
Shortage of water	8.48	3.49
Flooding	47.26	19.43
Soil problem	8.42	3.46
Acidity[1]		0.00
Sedimentation[1]		0.00
Seepage	8.42	3.46
Disease	8.11	3.33
Viruses	2.58	1.06
Bacteria	5.53	2.27
Parasites[1]		0.00
Total loss ($/ha)	243.24	100.00
Average gross output ($/ha)	1,715.12	
Loss as % of yield	14.18	

Source: Adapted from Dey et al. 2005e.
[1] Not reported by farmers during survey, contrary to expectations.

7.4 TECHNICAL INEFFICIENCY IN FRESHWATER AQUACULTURE

Ever since the publication of Schultz's "poor but efficient" thesis (Schultz 1964), there has been continuous debate whether the best strategy for developing agriculture is (1) technology development and transfer or (2) more efficient use of available technology and resources at the farm level (Lipton 1968, Nair 1979, Adams 1986, Ali and Byerlee 1991). It has been argued on the one hand that, if farmers are not making efficient use of existing technology, efforts to improve that efficiency and so increase agricultural output are more cost-effective than introducing new technology (Shapiro 1983, Belbase and Grabowski 1985, Dey et al. 2000b). On the other hand, if farmers are reasonably efficient, then further productivity increase requires the development and adoption of new technologies (Ali and Byerlee 1991, Dey et al. 2000b).

The economic efficiency of a farm has two components: technical efficiency (TE), which reflects the ability of a farm to obtain maximum output from a given set of inputs and the technology available, and allocative efficiency, which reflects the ability of a farm to use inputs in optimal proportions, given their respective prices (Farrell 1957, Coelli 1995). Although several studies have been conducted in recent years on technical efficiency in Asian aquaculture (Gunaratne and Leung 1996 and 1997, Jayaraman 1998, Sharma and Leung 1998, Iinuma et al. 1999, Sharma 1999, Sharma et al. 1999, Bimbao et al. 2000, Dey et al. 2000b, ICLARM 2001, Sharma and Leung 2000a and 2000b, Irz and McKenzie 2003), estimates of economic efficiency for aquaculture are still relatively scarce compared with those for agriculture and other industries. Table 32 summarizes the technical efficiency estimates from various studies for fish farmers in Bangladesh.

The average TE of freshwater fish farmers in Bangladesh has been estimated at 70% (ICLARM 2001), putting the average level of inefficiency at 30%. Sharma and Leung (2000a) estimated that the average TE for carp polyculture in Bangladesh ranges from 40% to 48% among extensive farms and from 74% to 86% among semi-intensive farms. Estimates of TE for carp polyculture made by Arjumanara et al. (2004) are 86% for farmers who received training, 69% for farmers who received credit and 61% for farmers who received neither training nor credit. These findings suggest that training is an important factor, more so than availability of credit, for increasing fish production in Bangladesh.

Table 32: Summary results of estimated technical efficiency (TE) and influencing factors for pond aquaculture in Bangladesh

Source and year of study	Production system	Method of estimation	Technology	Mean TE	Factors influencing inefficiency
Sharma and Leung 2000a	Grow-out polyculture of carps in ponds	Stochastic production function, meta-production	Extensive Semi-intensive	47.5 73.8	Pond area, fish-management index, water-management index and feed-management index
		Stochastic production function, country specific	Extensive Semi-intensive	38.9 85.7	
ICLARM 2001	Grow-out polyculture of carp in ponds	Stochastic production function	Extensive to semi-intensive	70.0	Farmers' income and training
Arjumanra et al. 2004	Grow-out polyculture of carp in ponds	Stochastic production function	Extensive to semi-intensive Farmers who receive training Farmers who receive credit	86.0 69.0 61.0	Farmers' income, age and training

These results are consistent with the findings in other countries in the region, as reported by Sharma and Leung (2000a), who estimated TE of carp polyculture for ponds using a meta-production frontier model at the South Asia regional level and a country-specific production frontier model, to account for country-specific technologies, for Bangladesh, India, Nepal and Pakistan. Their estimate for semi-intensive farms in Nepal is 68%, India 79% and Pakistan 74% and for extensive farms in Nepal 60%, India 50% and Pakistan 62%. Earlier studies to estimate TE for carp production in Nepal (Sharma and Leung 1998), Pakistan (Sharma 1999) and India (Sharma and Leung 2000b) using slightly different model specifications but the same data sets yielded TE values ranging from 56% (Pakistan) to 69% (Nepal) for extensive farms; rather higher estimates ranged from 67% (Pakistan) to 81% (India) for semi-intensive farms.

The terms *productivity* and *efficiency* are often used interchangeably, but they do not have precisely the same meaning. Differences in productivity (that is, production per unit of area) across production units at a point in time, or over time, can be caused by differences in productive efficiency, the scale of operation and the state of the technology. Data collected by WorldFish and Bangladesh Agriculture University reveal that productivity rises with technical efficiency (ICLARM 2001). Table 33 shows that productivity is higher for those farms that are technically more efficient. Yields are lowest (501 kg/ha) on farms within the TE range of 20-30% and highest (6,034 kg/ha) on farms within the TE range of 90-100%. Obviously, yields vary considerably between fish farmers. Table 33 also shows that ponds with higher TE tend to be deeper and older. Interestingly, higher TEs are not necessarily achieved by stocking ponds with more fingerlings. For example, farms with a TE in the range 51-60% had, on average, lower stocking density than farms in the 31-40% TE range. This suggests that it is not necessary to increase stocking density to be efficient in fish production. Labour deployment was consistently higher on farms with a TE exceeding 60%, but for ponds with TEs of 60% or less there was no

Table 33: Characteristic features of carp farming according to technical efficiency

Variables	Technical efficiency range (%)							
	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100
Water depth (feet)	7.50	4.00	7.31	7.37	7.10	7.57	8.46	6.56
Age of pond (years)	2.00	29.40	32.00	36.00	34.00	44.00	41.00	45.00
Fingerling (no./ha)	2,910	14,826	11,700	8,561	9,840	11,521	11,684	26,289
Rice bran (kg/ha)	1,353	2,184	2,399	1,748	1,435	1,685	1,811	2,500
Oil cake (kg/ha)	271	579	480	623	537	659	697	1,590
Labour (person-days/ha)	205	190	271	218	328	357	405	617
Urea (kg/ha)	51	93	212	274	200	254	304	756
TSP (kg/ha)	34	77	120	106	94	148	171	463
Income ('000 taka)	264.50	35.97	57.71	83.76	72.20	80.73	86.56	62.08
Pond size (ha)	0.295	0.130	0.142	0.255	0.235	0.182	0.158	0.065
Yield (kg/ha)	501	1,853	1,898	2,033	2,786	3,580	4,366	6,034

ha = hectare, kg = kilogram, no. = number, TSP = triple super phosphate.
Source: Original data from ICLARM 2001.

direct relationship between labour input and TE. Application of the fertilizers urea and triple super phosphate showed a consistent and strong positive relationship with TE, with fertilizer applications higher on farms with higher TEs.

The foregoing discussion suggests that considerable inefficiency exists among pond aquaculture operators in Bangladesh. A good understanding of fish culture technology and proper application of pond inputs appear to be more important for improving TE than merely increasing input quantities, including of fingerlings. Inputs such as feed and fertilizer need to be appropriate mixes applied at the correct rates, and the correct number of fingerlings needs to be stocked. At the same time, the socioeconomic constraints causing inefficiency need to be overcome. Several studies on agriculture and aquaculture show empirically that human capital (age, education, experience and training received by farmers) affect TE, which in turn influences productivity.

8. OUTLOOK AND STRATEGIC DIRECTION

The importance of aquaculture to Bangladesh can hardly be overstated, and there is no doubt that the sector has started to take off. The contribution of aquaculture to total fish production in terms of output increased from a little over 18% in FY1986 to 38% in FY2006, and aquaculture is now recognized as an industry in its own right. It is time to steer this growth to meet industry and development objectives.

8.1 OUTLOOK

Continued population growth and rising demand for fish, coupled with stagnation in capture fisheries, have raised concerns that fish production will be unable to meet future global demand. The key questions arising from this concern are the prospects for the future availability of fish given existing trends in supply and demand and whether aquaculture can fill the gap in fish supplies. This chapter attempts to provide answers to these questions in the context of Bangladesh by analyzing fish supply and demand using the AsiaFish model recently developed by the WorldFish Center and its partner organizations for Bangladesh (Dey et al. 2008a). The AsiaFish model can be used to make detailed projections of the outlook for fish production, consumption and trade under alternative scenarios. Table 34 shows projections for Bangladesh over the period 2005-20 under four scenarios: (1) baseline, (2) productivity improvement in freshwater aquaculture, (3) productivity improvement in brackish aquaculture and (4) faster income growth. The baseline scenario is based on historical trends of exogenous variables such as income, prices of inputs and non-fish products, population growth, and productivity in aquaculture and fisheries.

For the baseline scenario, the projected aquaculture output growth of Bangladesh is spearheaded by brackish culture (i.e., for shrimp) and, to a lesser extent, by freshwater culture. For freshwater aquaculture, the model predicts diversification from the prevailing culture of Indian major carps toward tilapia and other carp species. For capture fisheries, projected output growth trends are highly uneven among various sub-sectors, i.e., high-value marine fish post robust growth, but other capture species decline. A similar story is reflected in demand projections, with uneven consumption growth among species groups. Retail fish prices are projected to grow more slowly than the projected inflation rate of 3.1%, except for hilsha and captured freshwater species. Interestingly, the fastest-growing freshwater fish sub-sector, other carps, is projected to undergo a steep fall in price. More importantly, it is predicted that shrimp exports will continue to grow rapidly, outpacing overall output, and decide the overall trends in fisheries exports because of its dominance there.

The scenario of increased productivity in freshwater or low-value aquaculture was explored by adding an increase in the technology index by 1 percentage point. The simulation results show that, compared to the baseline situation, the growth in both the production and consumption of freshwater aquaculture species will be faster, with a corresponding slower growth (or faster decline) of consumer price. There will be mild substitution away from captured species in general but almost none from brackish culture species. Exports will decline slightly as a result. In general, this experiment amplifies the effect of technological change in freshwater aquaculture observed in the baseline scenario. The productivity rise of 1 percentage point, as simulated, is not enough to overcome declining per capita consumption, as consumption growth remains lower than the population growth of 1.8% per year.

Meanwhile, the scenario of increased productivity in high-value brackish aquaculture was explored based on a similar increase of 1 percentage point in the relevant technology index. The results suggest effects that are similar to those of the baseline scenario, but of course higher growth in the production and export of shrimp.

Finally, sensitivity analysis was carried out for projected change in income by assuming an increase of 1 percentage point in the growth rate of per capita GDP. The simulation results show patterns similar to

Table 34: Projections of average annual growth rates (%) of aquaculture and income for 2005-2020 by fish type in Bangladesh

Indicator	Baseline	Productivity changes (+)		Income growth (+)
		Freshwater aquaculture	Brackish aquaculture	
Output	1.36	1.56	1.78	1.92
Total inland culture	1.63	2.02	1.66	2.39
Total inland capture	-2.12	-2.28	-2.16	-1.87
Total brackish culture	7.45	7.37	9.02	7.85
Total marine capture	-1.78	-1.82	-1.78	-1.82
Indian major carps culture	-0.89	-0.59	-0.07	1.42
Indian major carps capture	-2.78	-3.06	-2.48	-0.38
Other carps	5.03	5.79	4.85	4.84
Tilapia	1.27	0.78	0.50	1.18
Pangus	-0.28	0.57	0.19	1.15
Live fish	0.82	-0.15	0.69	0.63
Hilsha	-1.58	-1.58	-1.61	-1.59
Freshwater fish	-4.20	-4.09	-4.32	-3.88
Shrimp	7.45	7.37	9.02	7.85
High-value marine fish	6.02	5.40	4.71	3.38
Low-value marine fish	-2.14	-2.13	-2.04	-2.01
Demand				
Total quantity	0.22	0.50	0.27	0.95
Indian major carps	-1.11	-0.88	-0.36	1.21
Other carps	5.03	5.79	4.85	4.84
Tilapia	1.27	0.78	0.50	1.18
Pangus	-0.28	0.57	0.19	1.15
Live fish	0.82	-0.15	0.69	0.63
Hilsha	-4.67	-4.95	-5.04	-4.57
Freshwater fish	-4.20	-4.09	-4.32	-3.88
Shrimp	2.26	1.98	2.51	3.69
High-value marine fish	6.02	5.40	4.71	3.38
Low-value marine fish	-2.14	-2.13	-2.04	-2.01
Dried fish	-12.85	-7.42	-6.32	-8.28
Consumer price				
Indian major carps	0.87	0.69	0.81	1.99
Other carps	-0.54	-0.60	-0.67	0.31
Tilapia	2.23	2.32	2.36	3.57
Pangus	2.20	2.21	2.24	3.58
Live fish	-1.52	-1.51	-1.78	-0.88
Hilsha	3.90	4.40	4.51	6.36
Freshwater fish	9.61	9.78	9.77	11.39
Shrimp	0.36	1.18	0.41	1.78
High-value marine fish	1.22	1.26	1.46	2.84
Low-value marine fish	1.33	1.35	1.42	2.71
Dried fish	2.22	2.08	2.01	2.92
Exports				
Total quantity	8.68	8.63	9.98	8.89
Hilsha	6.96	6.77	6.91	6.94
Shrimp	8.76	8.76	10.36	9.02
Dried fish	17.01	17.55	19.87	16.39

Source: Adapted from Dey et al. 2008a.

those of the baseline scenarios, but with higher levels of output, consumption and price. However, the leading role of other carps does not occur; rather, Indian major carps continue to dominate production and consumption and even undergo an increase in price. The results suggest that Indian major carps may continue to be major contributors to freshwater aquaculture production in Bangladesh.

The results imply that maintaining the status quo in aquaculture technologies (the baseline scenario) or a mild increase in aquaculture productivity will see a slowing of aquaculture growth. The low average annual increase in aggregate consumption relative to population growth suggests that per capita consumption in Bangladesh is expected to decline over the projection period. Unless Bangladesh targets higher productivity growth in fish supply, the traditional role of fish as a source of animal protein for poor households will be increasingly undermined. The rapid growth of aquaculture achieved over the last decade will not be sustained unless strategic planning and concerted efforts, both public and private, are made to boost aquaculture production. Maintaining the high productivity of freshwater aquaculture is imperative for ensuring overall growth in fish production and improving food security.

8.2 STRATEGIES

The production of fish from freshwater aquaculture can be increased by (1) expanding the area for fish culture by bringing potentially productive water bodies under fish culture, (2) mitigating technical inefficiency in fish production, (3) shifting the production frontier through research and development, and (4) increasing the intensity of input use.

Expanding the area under fish culture is an obvious way of increasing fish production. Even if technology and productivity remain the same, expanded area can provide additional production. However, when the best areas are already in use, expansion into new areas that are not as well suited poses challenges that require new and different technologies and may bring a reduction in average productivity.

The second strategy aims to reduce the gap between actual and potential output and targets fish farmers who are not technically efficient. The studies reported in Chapter 7 reveal that, on average, pond fish farmers in Bangladesh operate at a 70% TE level, 30% below the potential level, and suggest that there is ample scope for improving the efficiency of the semi-intensive and extensive systems if farmers followed best practice more closely. Among the important reasons that farmers have not been able to benefit from aquaculture innovations with high potential are their lack of knowledge of fish-farming practices and fisheries extension work that is deficient in quality and quantity. As pointed out in Chapter 7, training constituted an important driving factor for elevating the TE of fish farmers. Radical changes to the quality of aquaculture extension services and the way they are provided to farmers can substantially narrow the productivity gap.

The third strategy is to generate new technologies and refine existing ones to further push the production frontier. The WorldFish Center and its research partners have successfully developed a strain of Nile tilapia known as genetically improved farmed tilapia (GIFT) through selective breeding. Dey (2000a) showed that the adoption of GIFT strains could increase production by 21.9% in Bangladesh. Hussain et al. (2002), reporting on the results of selective breeding for genetically improving silver barb, indicated average weight gains of 7.2% per generation across two generations of selection. This method of improving silver barb through several generations of genetic selection may also be a useful technique for other carp species in Bangladesh and elsewhere in Asia. Genetically improving carps and other freshwater species would help poor farmers in Bangladesh increase production of fish without spending more on inputs.

The fourth strategy calls for increasing pond inputs, which requires that farmers have more access to finance than is generally the case in Bangladesh. Unless the socioeconomic conditions of fish farmers are significantly improved and adequate credit facilities extended to poorer farmers, this option is unlikely to be effective. Furthermore, intensification may be appropriate only if farmers are currently using inputs below economically and environmentally optimal levels.

Differences in productivity and technical inefficiency across regions also merit attention. The large variation in aquaculture growth across regions reflects differing bio-physical and socioeconomic conditions. Boosting aquaculture production requires more strategic planning and appropriate targeting of aquaculture systems to the most suited areas. The development and dissemination of region-specific aquaculture technology packages would contribute to an increase in the area dedicated to aquaculture and improved aquaculture productivity.

9. REFERENCES

Adams J. 1986. Peasant rationality: Individuals groups, cultures. World Development 14:273-282.

ADB. 2005. An evaluation of small-scale freshwater rural aquaculture development for poverty reduction. Operations Evaluation Department, Asian Development Bank, Asian Development Bank Publications, ISBN 071-561-550-3, Manila, 164 p.

Ahmed AU, Shams Y. 1994. Demand elasticities in rural Bangladesh: An application of the AIDS model. The Bangladesh Development Studies 22:1-25.

Ahmed M, Rab MA. 1992. Feasibility of adopting aquaculture to increase resource productivity in existing Bangladesh farming systems. NAGA, WorldFish Center Quarterly 15(4):21-22.

Ahmed M, Rab MA, Bimbao MP. 1994. Sustainable aquaculture in small water bodies: Experiences from Bangladesh. Integrated Fish Farming, CRC Press, Wuxi, China.

Ahmed M, Tana TS, Thouk N. 1996. Sustaining the gifts of the Mekong: The future of freshwater capture fisheries in Cambodia. Watershed 1(3):33-38.

Ahmed MNU, Hossian MM, Humayun NM, Hossain MB, Haque MS, Talukder RK. 2004. Final country report: Bangladesh. Strategies and options for increasing and sustaining fisheries and aquaculture production to benefit poor households in Asia project. WorldFish Center, Penang, Malaysia.

Ahmed N. 2007. Value chain analysis for hilsa marketing in coastal Bangladesh. Aquaculture News, Stirling, UK, 33:14-20.

Ahmed N, Rahman MM, Rahman MM. 2005. A study of fish marketing in Gazipur in Bangladesh. Pakistan Journal of Biological Science 8:287-292.

Ahmed N, Ahammed F, Lecouffe C. 2007. Socioeconomic aspects of small-scale freshwater prawn marketing systems in Mymensingh, Bangladesh. Aquaculture Economics and Management 11(4):335-353.

Ahmed, N, Ahammed F, Brakel MV. 2008. An economic analysis of freshwater prawn, *Macrobrachium rosenbergii,* farming in Mymensingh, Bangladesh. Journal of World Aquaculture Society 39(1):37-50.

Alam MF, Bashar MA. 1996. An economic analysis of financing and organizing riverine fish production in Bangladesh. Department of Agricultural Finance, Bangladesh Agricultural University, Mymensingh.

Alam MF, Thompson KJ. 2001. Current constraints and future possibilities for Bangladesh fisheries. Food Policy 26:297-313

Alam S. 2001. Production, accessibility and consumption patterns of aquaculture products in Bangladesh. In: FAO. 2001. Production, accessibility and consumption patterns of aquaculture products in Asia: A cross country comparison. Food and Agriculture Organization, Rome.

Ali M, Byerlee D. 1991. Economic efficiency of small farmers in a changing world: A survey of recent evidence. Journal of International Development 3:1-27.

Ali MA, Islam MR. 2002. Standard in fisheries sector vis-à-vis international standard and its role for promoting export. Paper presented at the national workshop on sanitary and phytosanitary measures, May 2002, Tariff Commission, Dhaka, Bangladesh.

Ali Z. 2002. Disaggregated demand for fish in Bangladesh: An analysis using the almost ideal demand system. The Bangladesh Development Studies 28(1&2):1-45.

Anik AR. 2003. Economic and financial profitability of aromatic and fine rice production in Bangladesh. MS thesis. Department of Agricultural Economics, Bangladesh Agricultural University, Mymensingh, Bangladesh.

Arjumanara L. 2002. A study of yield gaps, production losses and technical efficiency of selected groups of fish farmers in Rajshahi district. MS Agri. Econ. (Finance) thesis submitted to the Department of Agricultural Finance, Bangladesh Agricultural University, Mymensingh, Bangladesh.

Arjumanara L, Alam MF, Rahman MM, Jabbar MA. 2004. Yield gaps, production losses and technical efficiency of selected groups of fish farmers in Bangladesh. Indian Journal of Agricultural Economics 59(4):808-818.

Banglapedia. 2008a. "Fish". http://Banglapedia.search.com.bd. Downloaded on 20 February 2008.

Banglapedia. 2008b. http://banglapedia.search.com.bd/HT/R_0207.htm. Downloaded on 20 February 2008.

Banglapedia. 2008c. http://banglapedia.search.com.bd/HT/F_0184.htm. Downloaded on 20 February 2008.

Bangladpedia. 2008d. http://banglapedia.org/HT/R_0052.htm. Downloaded on 20 February 2008.

Banglapedia. 2008e. http://banglapedia.search.com.bd/HT/F_0081.htm. Downloaded on 20 February 2008.

BARC. 1995. Electronic inventory database of agricultural land resources in Bangladesh maintained by the computer section of Bangladesh Agricultural Research Council, Ministry of Agriculture, Government of the People's Republic of Bangladesh, Dhaka.

BBS. 1980 to 2007a (various issues). Statistical yearbook of Bangladesh. Bangladesh Bureau of Statistics, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

BBS. 1993. Twenty years of national accounting of Bangladesh (FY1972/73 to FY1991/92) Bangladesh Bureau of Statistics, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

BBS. 1998. Household expenditure survey 1995/96. Bangladesh Bureau of Statistics, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

BBS. 1999. Agricultural and livestock census 1996. Bangladesh Bureau of Statistics, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

BBS. 2003a. Population census 2001, national report (provisional). Bangladesh Bureau of Statistics, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

BBS. 2003b. Monthly statistical bulletin Bangladesh, July 2003. Bangladesh Bureau of Statistics, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

BBS. 2003c. Household income and expenditure survey 2000. Bangladesh Bureau of Statistics, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

BBS. 2004a. Monthly statistical bulletin Bangladesh, March 2004. Bangladesh Bureau of Statistics, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

BBS. 2004b. Labour force survey FY2002/03. Bangladesh Bureau of Statistics, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

BBS. 2006. Report on labour force survey, 2005. Bangladesh Bureau of Statistics, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

BBS. 2007a (see BBS 1980 to 2007a above).

BBS. 2007b. Household income and expenditure survey 2005. Bangladesh Bureau of Statistics, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

BCA V.3.0 (undated). Bangladesh Country Almanac, BCA v.3.0. CD 1 and 2 personally collected from Computer Center, Bangladesh Agriculture Research Council, Dhaka, Bangladesh.

Belbase K, Grabowski R. 1985. Technical efficiency in Nepalese agriculture. Journal of Development Areas 19:515-525.

Bhattacharya D. 2002. Breaking the LDC barrier: 8pc GDP growth rate needed till 2020. www.cpd_bangladesh.org/media/press_210902.html.

Bimbao GB, Paraguas FJ, Dey MM, Eknath AE. 2000. Socioeconomics and production efficiency of tilapia hatchery operations in the Philippines. Aquaculture Economics and Management 4(1&2):31-46.

Bose ML. 2001. Optimum allocation of land under food crop for sustained agricultural development in Bangladesh: A macro-level analysis. Unpublished PhD thesis, Rabindra Bhariti University, Kolkata, India.

Bose ML, Dey MM. 2007. Food and nutritional security in Bangladesh: Going beyond carbohydrate counts. Agricultural Economics Research Review 20:203-225.

Breazley M. 1993. Wetlands in Danger. Reed International Books Limited, London.

Cato JC, Santos ALD. 1998. European Union 1997 seafood safety bans: The economic impact on Bangladesh shrimp processing. Marine Resource Economics 13:215–227.

Cato JC, Santos ALD. 2000. Costs to upgrade the Bangladesh frozen shrimp processing sector to adequate technical and safety standards and to maintain a HACCP program. In: Unnevehr L (ed.). The economics of HACCP: New studies of costs and benefits. Eagan Press, St. Paul, USA.

CDMP. 2008. www.cdmp.org.bd and http://banglapedia.search.com.bd/Maps. Downloaded on 20 February 2008.

Chowdhury MH, Maharjan KL. 2001. Pond fish production through people's participation in rural Bangladesh. Journal of Development and Cooperation 7(2):11-28.

Chowdhury MAK, Yakupitiyage A. 2000. Efficiency of the existing oxbow lake management systems in Bangladesh to introduce cage culture for resource poor fishers. Fisheries Management and Ecology 7(1-2):65-74.

CIA. 2008. The World Factbook, Bangladesh. www.cia.gov/library/publications/the-world-factbook/print/bg.html.

Coelli TJ. 1995. Recent developments in frontier modelling and efficiency measurement. Australian Journal of Agricultural Economics 39:219-245.

Coulter JP, Disney JG. 1987. The handling, processing and marketing of fish in Bangladesh. ODNRI Bulletin, No. 1.

Craig JF, Halls AS, Barr JJF, Bean CW. 2004. The Bangladesh floodplain fisheries. Fisheries Research 66:271-286.

De Datta SK, Gomez KA, Herdt RW, Barker R. 1978. A handbook on the methodology for and integrated experiment — Survey on rice yield constraints. International Rice Research Institute, Los Baños, Philippines. 59 p.

De Graaf G, Latif A. 2002. Development of freshwater fish farming and poverty alleviation: A case study from Bangladesh. Aquaculture Asia 7(2):5-7

Dey MM. 2000a. The impact of genetically improved farmed Nile tilapia in Asia. Aquaculture Economics and Management 4(1&2):107-124.

Dey MM. 2000b. Analysis of demand for fish in Bangladesh. Aquaculture Economics and Management 4:65-83.

Dey MM, Bimbao GB. 1998. Policy imperatives for sustainable aquaculture development in Asia: Lessons from Bangladesh, the Philippines and Thailand, pp 331-350. In: Network of Aquaculture Centers in Asia-Pacific (NACA). Proceedings of the regional study and workshop on aquaculture sustainability and the environment, 6-12 October 1995, Beijing, Asian Development Bank and NACA, Bangkok.

Dey MM, Miah MNI, Mastafi BAA, Hossain M. 1996. Rice production constraints in Bangladesh: Implications for further research priorities. pp 179-191. In: Evenson RE, Herdt RW, Hossain M. Rice research in Asia: Progress and priorities. CAB International, UK. 418 p.

Dey MM, Bimbao GB, Yong L, Regaspi P, Kohinoor AHM, Pongthana N, Paraguas FJ. 2000a. Current status of production and consumption of tilapia in selected Asian countries. Aquaculture Economics and Management 4(1&2):13-30.

Dey MM, Paraguas FJ, Bimbao GB, Regaspi PB. 2000b. Technical efficiency of tilapia growout pond operations in the Philippines. Aquaculture Economics and Management 4(1&2):33-47.

Dey MM, Paraguas FJ, Alam F. 2001. Cross county synthesis. In: FAO. 2001. Production, accessibility, marketing and consumption patterns of freshwater aquaculture products in Asia: A cross-country comparison. FAO Fisheries Circular No 973. Food and Agriculture Organization, Rome. 275 p.

Dey MM, Rab MA, Kumar A, Nisapa A, Ahmed M. 2005a. Food safety standard and regulatory measures: Implications for selected fish exporting Asian countries. Aquaculture Economics and Management 9(1&2):217-236.

Dey MM, Rab MA, Paraguas FJ, Piumsumbun S, Bhatta R, Alam MF, Ahmed M. 2005b. Fish consumption and food security: A disaggregated analysis by types of fish and classes of consumers in selected Asian countries. Aquaculture Economics and Management 9 (1&2):89-112.

Dey MM, Rab M, Paraguas FJ, Piumsombun S, Bhatta R, Alam MF, Koeshendrajana S, Ahmed M. 2005c. Status and economics of freshwater aquaculture in selected countries in Asia. Aquaculture Economics and Management 9(1&2):11-38.

Dey MM, Prein M, Haque ABMM, Sultana S, Dan NC, Hao NV. 2005d. Economic feasibility of community-based fish culture in seasonally flooded rice fields in Bangladesh and Vietnam. Aquaculture Economics and Management 9(1&2):65-88.

Dey MM, Alam MF, Weimin M, Piumsumbun S, Bhatta R, Koeshendrayana S, Paraguas FJ. 2005e. Constraints to higher yield in carp farming: Implications for future genetic research. In: Penman D, Gupta MV, Dey MM (eds.). Carp genetic resources for aquaculture in Asia. pp 114-120. WorldFish Center Technical Report 65, 152 p.

Dey MM, Briones RM, Garcia YT, Nissapa A, Rodriguez UP, Talukder RK, Senaratne A, Omar IH, Koeshendrajana S, Khiem NT, Yew TS, Weimin M, Jayakody DS, Kumar P, Bhatta R, Haque MS, Rab MA, Chen OL, Li L, Paraguas F. 2008a (in press). Strategies and options for increasing and sustaining fisheries and aquaculture production to benefit poorer households in Asia. WorldFish Center Studies and Reviews, Penang, Malaysia.

Dey MM, Garcia YT, with Kumar P, Piumsombun S, Haque MS, Li L, Radam A, Senaratne A, Khiem NT, Koeshendrajana S. 2008b (in press). Demand for fish in Asia: A cross-country analysis. Australian Journal of Agricultural and Resource Economics.

DoF. 1984 to 1996 (various issues). Fish catch statistics of Bangladesh. Department of Fisheries, Ministry of Fisheries and Livestock, Dhaka.

DoF. 1997 to 2007 (various issues). Fishery statistical yearbook of Bangladesh. Department of Fisheries, Ministry of Fisheries and Livestock, Dhaka.

DoF. 2006. National fisheries strategy and action plan for the implementation of the national fisheries strategy. Department of Fisheries, Ministry of Fisheries and Livestock, Dhaka.

DoF-BARC. 2001. Fisheries sector review and ten-year (2002-2012) production projection. Department of Fisheries, Ministry of Fisheries and Livestock, Dhaka.

Edwards P. 1993. Environmental issues in integrated agriculture-aquaculture and wastewater-fed fish culture systems. pp. 139-170. In: Pullin RSV, Rosenthal H, Maclean JL (eds.). Environment and aquaculture in developing countries. ICLARM conference proceedings 31. International Center for Living Aquatic Resources Management, Manila, Philippines.

European Commission. 2004. Commission decision of 13 April 2004 (2004=359=EC). Official journal of European Union, 20 April 2004, L 113, 47, pp 45-47.

Evenson RE, Herdt RW, Hossain M. 1996. Rice research in Asia: Progress and priorities. Cab International, UK. 418 p.

FAO. 1999. State of world fisheries and aquaculture 1999. Fisheries Department, Food and Agriculture Organization, Rome.

FAO. 2002. State of world fisheries and aquaculture 2002. Fisheries Department, Food and Agriculture Organization, Rome.

FAO. 2007. State of world fisheries and aquaculture 2006. Fisheries Department, Food and Agriculture Organization, Rome.

Farrell MJ. 1957. The measurement of productive efficiency. Journal of Royal Statistical Society, Series A (General) Part III. 120:253-281.

Faruque G. 2007. An exploration of impacts of aquaculture production and marketing of rural livelihoods in three regions in Bangladesh. PhD thesis submitted to the University of Stirling, UK, 318 p.

FDA. 2004. US Food and Drug Administration import refusal reports available at www.fda.gov/ ora/oasis/ora_oasis_det.html.

Future Fisheries. 2003. Findings and recommendations from the fisheries sector review and future developments study. In: Muir JF (ed.). The future for fisheries, findings and recommendations from the fisheries sector review and future development study. Evergreen Printing and Packaging, Dhaka.

GoB. 2003. Annual development programme 2003-2004. Planning Commission, Government of the People's Republic of Bangladesh, Dhaka.

GoB. 2004. Annual development programme 2004-2005. Planning Commission, Government of the People's Republic of Bangladesh, Dhaka.

GoB. 2005. Annual development programme 2005-2006. Planning Commission, Government of the People's Republic of Bangladesh. Dhaka.

Goletti F. 1992. The liberalization of the public food grain distribution system in Bangladesh. International Food Policy Research Institute, Washington, USA. (mimeo).

Gunaratne LHP, Leung PS. 1996. Asian black tiger shrimp industry: A productivity analysis. Paper presented at the Second Biennial George Productivity Workshop, University of Georgia Athens, Georgia, 1-13 November 1996. In: Leung PS, Sharma KR (eds.). 2001. Economics and management of shrimp and carp farming in Asia: A collection of research papers based on the ADB/NACA farm performance survey. Network of Aquaculture Centers in Asia-Pacific, Bangkok, Thailand. pp 55-68.

Gunaratne LHP, Leung PS. 1997. Productivity analysis of Asian shrimp industry: The case of Malaysian shrimp culture. World Aquaculture '97, 19-23 February, Seattle, Washington. In: Leung PS, Sharma KR (eds.). 2001. Economics and management of shrimp and carp farming in Asia: A collection of research papers based on the ADB/NACA farm performance survey. Network of Aquaculture Centers in Asia-Pacific, Bangkok, Thailand. pp 69-80.

Gupta MV, Rab MA. 1994. Adoption and economics of silver barb (*Puntius gonionotus*) culture in seasonal waters in Bangladesh. Manila, Philippines.

Gupta MV, Ahmed M, Bimbao M, Lightfoot C. 1992. Socioeconomic impact and farmers' assessment of Nile tilapia (*Oreochromis niloticus*) culture in Bangladesh. ICLARM Technical Report No 35. 50 p.

Gupta MV, Mazid MA, Islam MS, Rahman M, Hussain MG. 1999. Integration of aquaculture into farming systems of the flood prone ecosystem in Bangladesh: An evaluation of adoption and impact. ICLARM Technical Report No 56. 32 p.

Habib E. 1999. Management of fisheries, coastal resources and the coastal environment in Bangladesh: Legal and institutional perspectives. Working Paper No. 04, ICLARM, Manila.

Hasnath SA. 2006. The practice and effect of development planning in Bangladesh. Public Administration and Development 7(1):59-75.

Hossain M. 1988. Nature and impact of the green revolution in Bangladesh. IFPRI research report No 67. International Food Policy Research Institute, Washington, DC, and Bangladesh Institute of Development Studies, Dhaka.

Hossain M, Bose ML. 2000. Growth and structural changes in Bangladesh agriculture: Implications for strategies and policies for sustainable development. In: Mandal MAS (ed.). Changing rural economy of Bangladesh. Bangladesh Economic Association and Moushumi Printers, Dhaka. pp 1-20.

Hossain M, Sen B, Hossain ZR. 2000. Growth and distribution of rural income in Bangladesh: Analysis base on panel survey data. Economic and political weekly, XXXV (52&53), Mumbai, India. pp 1-24.

Hossain M. 2004. Rural non-farm economy in Bangladesh: A view from household surveys, CPD Occasional Paper Series, Paper 40, Dhaka. 31 p.

Hossain MB. 2002. Sources of growth, structural changes and the role of support services to fishery sector in Bangladesh. Bangladesh J. Polit. Econ. 17(2) (December).

Huang J, Li L. 2001. Analysis of policy, institutional environment and support services in China's fisheries. Centre for Chinese Agricultural Policy, Chinese Academy of Sciences. Paper presented in the first regional workshop held in Penang, Malaysia, 20-25 August 2001.

Hussain MG, Islam MS, Hossain MA, Wahid MI, Kohinoor AHM, Dey MM, Mazid MA. 2002. Stock improvement of silver barb (*Barbodes gonionotus* Bleeker) through several generations of genetic selection. Aquaculture 204 (2002):469-480.

Hussain MG, Mazid MA.. 2001. Genetic improvement and conservation of carp species in Bangladesh.

Bangladesh Fisheries Research Institute and International Center for Living Aquatic Resources Management, 74 p.

ICLARM. 2001. Genetic improvement of carp species in Asia: Final report. Asian Development Bank Regional Technical Assistance No 5711, WorldFish Center, Penang, Malaysia.

Iinuma M, Sharma KR, Leung PS. 1999. Technical efficiency of carp pond culture in peninsula Malaysia: An application of stochastic frontier and technical inefficiency model. Aquaculture 175:199-213.

IRRI. 1977. Constraints to high yield on Asian rice farms: An interim report. International Rice Research Institute, Los Baños, Philippines. 235 p.

IRRI. 1979. Farm level constraints to high rice yields in Asia: 1974-77. International Rice Research Institute, Los Baños, Philippines. 411 p.

Irz X, McKenzie V. 2003. Profitability and technical efficiency of aquaculture systems in Pampanga, Philippines. Aquaculture Economics and Management 7(3&4):195-211.

Islam MR. 1982. Hilsa fish marketing at Rajshahi, A project report. Submitted to the Department of Zoology, University of Rajshahi.

Islam S. 1993. The history of Bangladesh 1704-1971 (First part: political history). Asiatic Society of Bangladesh, Dhaka. 575 p.

Jayaraman R. 1998. Economics and technical efficiency in carp culture in Thanjavur district in Tamil Nadu, India. In: Eide A, Vassdal T (eds.). Proceedings of the 9th International Conference of the International Institute of Fisheries Economics and Trade in Tromsø, Norway, 8-11 July 1998. pp 71-82.

Karim M, Ahmed M, Talukder RK, Taslim MA, Rahman HZ. 2006. Dynamic agribusiness-focused aquaculture for poverty reduction and economic growth in Bangladesh. WorldFish Center Discussion Series No. 1. 44 p.

Khan MS, Haq E, Huq S, Rahman AA, Rashid SMA, Ahmed H. 1994. Wetlands of Bangladesh. Bangladesh Centre for Advanced Studies, Dhaka.

Lewis D. 1997. Rethinking aquaculture for resource poor farmers: Perspective from Bangladesh. Food Policy 22(6):533-546.

Lipton M. 1968. Theory of the optimizing peasant. Journal of Development Studies 4:325-351.

Mazid MA. 1999. Developmental needs and research priorities for fisheries in Bangladesh. In: Gupta MV, Macawaris-Ele N (eds.). Priorities in aquatic resources research in the Asia-Pacific region. ICLARM Conf. Proc. 62. 39 p.

Mazid MA. 2002. Development of fisheries in Bangladesh: Plans and strategies for income generation and poverty alleviation. Nasima Mazid, Dhaka.

Mazid MA, Hussain MG. 1995. Genetic problems in artificial breeding of fish in Bangladesh and mitigating measures. Bangladesh Fisheries Research Institute extension manual, 16 p.

Mia GF. 1996. A study of production and marketing of cultured fishes by the selected pond owners in Mymensingh district. Unpublished MS thesis, Department of Cooperation and Marketing, BAU, Mymensingh.

MoF. 1990 to 2000 (various issues). Economic survey of Bangladesh. Economic Advisor's Wing, Finance Division, Ministry of Finance, Government of the People's Republic of Bangladesh, Dhaka.

MoF. 2003. A national strategy for economic growth, poverty reduction and social development. Economic Relations Division, Ministry of Finance, Dhaka.

MoF. 2005. Three-year rolling investment program FY2005-07 (TYRIP). Ministry of Finance, Government of the People's Republic of Bangladesh, Dhaka.

MoF. 2006. Bangladesh economic review 2005. Economic Advisor's Wing, Finance Division, Ministry of Finance, Government of the People's Republic of Bangladesh, Dhaka.

MoF. 2007. Bangladesh economic review 2006. Economic Advisor's Wing, Finance Division, Ministry of Finance, Government of the People's Republic of Bangladesh, Dhaka.

MoFL. 1998. National fisheries policy 1998. Ministry of Fisheries and Livestock, Government of Bangladesh, Dhaka.

Muir J. 2005. Managing to harvest? Perspective on the potential of aquaculture. Philosophical Transactions of the Royal Society of Britain 360:191-218.

Nair K. 1979. In defence of the irrational peasant: Indian agriculture after the Green Revolution. University of Chicago Press, Chicago.

Muktada M. 1986. Poverty and inequality: Trends and causes. In: Islam R. Muktada M (eds.). Bangladesh: Selected issues in employment and development. International Labour Organisations, New Delhi.

Park J, Holcomb R, Raper K, Capps O. 1996. A demand systems analysis of food commodities by US households segmented by income. American Journal of Agricultural Economics 78:290-300.

PC. 1995. Participatory perspective plan for Bangladesh: 1995-2010. Planning Commission, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka. p. 38 of Document 2.

PC. 1998. Fifth-five year plan, 1997-2002. Planning Commission, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

PC. 2005. Unlocking the potential: National strategy for accelerated poverty reduction. Provisional final draft. Planning Commission, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

Pillay TVR. 1997. Economic and social dimensions of aquaculture development. Aquaculture Economics and Management 1(1&2):3-12.

Pitt MM. 1983. Food preferences and nutrition in rural Bangladesh. Review of Economics and Statistics 65:105-114.

Rahim MR. 2004. Profitability of some newly introduced rice varieties in selected locations of Bangladesh. MS thesis. Department of Agricultural Economics, Bangladesh Agricultural University, Mymensingh, Bangladesh.

Rahman ML, Ali MH. 1986. A study on the credit and marketing aspects of pond fisheries in two selected districts of Bangladesh. Report No 10. Bureau of Socio-economic Research and Training, Bangladesh Agricultural University, Mymensingh, Bangladesh.

Razzaque A, Khondoker BH, Mujeri MK. 1997. Elasticity estimates by occupational groups in Bangladesh: An application of food characteristics demand system. The Bangladesh Development Studies 25:1-41.

Rogers Everett M. 2003. Diffusion of innovations. 5th edition. Simon & Schuster International. 512 p.

Sarker MA, Chowdhury AH, Itohara Y. 2006. Entrepreneurships barriers of pond fish culture in Bangladesh: A case study from Mymensingh district. Journal of Social Sciences 2(3):68-78.

Schultz TW. 1964. Transforming traditional agriculture. Yale University Press, New Haven, USA.

Sen B. 2003. Drivers of escape and descent: Changing household fortunes in rural Bangladesh. World Development 31(3):513-534.

Senauer B. 1990. Household behavior and nutrition in developing countries. Food Policy 15:408-17.

Shahabuddin Q, Zohir S. 1995. Projections and policy implications of rice supply and demand in Bangladesh. Paper presented in the final workshop on Projections and Policy Implications of Medium and Long Term Rice Supply and Demand, held in Beijing, 23-26 April 1995, co-hosted by the International Rice Research Institute, International Food Policy Research Institute and China Center for Economic Research.

Shang YC. 1990. Socio-economic constraints of aquaculture in Asia. World Aquaculture 21(1):34-43.

Shapiro KH. 1983. Efficiency differentials in peasant agriculture and their implications for development policies. Journal for Development Studies 19:179-190.

Sharma KR. 1999. Technical efficiency of carp production in Pakistan. Aquaculture Economics and Management 3(2):131-141.

Sharma KR, Leung PS. 1998. Technical efficiency of carp production in Nepal: An application of the stochastic frontier production function approach. Aquaculture Economics and Management 2(3):129-140.

Sharma KR, Leung PS. 2000a. Technical efficiency of carp pond culture in South Asia: An application of a stochastic meta-production frontier model. Aquaculture Economics and Management 4(3/4):169-189.

Sharma KR, Leung PS. 2000b. Technical efficiency of carp production in India: A stochastic frontier production function analysis. Aquaculture Research 31:937-948.

Sharma KR, Leung PS, Hailiang C, Peterson A. 1999. Economic efficiency and optimum stocking densities in fish polyculture: An application of data envelopment analysis (DEA) to Chinese fish farms. Aquaculture 180:207-221.

Sultana P, Thompson PM. 2000. Community fishery management: Implications for food security and livelihoods. Proceedings of the Biennial Conference of the International Institute on Fisheries Economics and Trade (IIFET) 2000 in Wellington, New Zealand.

Talukder RK. 1993. Patterns of income induced consumption of selected food items in Bangladesh. The Bangladesh Development Studies 21:41-53.

Talukder RK. 2004. Socioeconomic profiles of the stakeholders of the aquaculture sector in Bangladesh. Paper presented at the final workshop on Strategies and Options for Increasing and Sustaining Fisheries and Aquaculture Production to Benefit Poor Households in Bangladesh, Manila, 17-20 March.

Task Force. 1991. Managing the development process: Bangladesh development strategies, Vol 2. University Press Limited, Dhaka.

Thilsted SH, Ross N, Hassan N. 1997. The role of small indigenous fish species in food and nutrition security in Bangladesh. NAGA, ICLARM quarterly (supplement) July-December. pp 13-15.

Thompson PM, Sultana P, Firoz Khan AKM. 2004. Aquaculture extension impacts in Bangladesh: A case study from Kapasia, Gazipur. WorldFish Center Technical Report 63.

Thompson PM, Sultana P, Nuruzzaman Md, Firoz Khan AKM. 2005. Aquaculture extension impacts in Bangladesh: A case study from Kapasia, Gazipur. WorldFish Center.

Timmer CP, Alderman H. 1979. Estimating consumption parameters for food policy analysis. American Journal of Agricultural Economics 61(5):982-987.

UNDP-FAO. 1988a. Land resources appraisal of Bangladesh for agricultural development. Report 2, United Nations Development Programme, New York, and Food and Agriculture Organization, Rome. Also available at BARC, Dhaka.

UNDP-FAO. 1988b. Land resources appraisal of Bangladesh for agricultural development. Report 3, Vol I and II. United Nations Development Programme, New York, and Food and Agriculture Organization, Rome. (Also available at BARC, Dhaka.)

Unnevehr LJ. 2000. Food safety issues and fresh food product exports from LDCs. Agricultural Economics 23:231-240.

Welcome RL. 2001. Inland fisheries: Ecology and management. Fishing New Books, Blackwell Science, Oxford.

Widawsky DA, O'Toole JC. 1990. Prioritizing the rice biotechnology research agenda for eastern India. Rockefeller Foundation, New York. 86 p.

Widawsky DA, O'Toole JC. 1996. Prioritizing the rice research agenda for Eastern India. pp 109-129. In: Evenson RE, Herdt RW, Hossain M (eds.). Rice research in Asia: Progress and priorities. CAB International, UK. 418 p.

World Bank. 1991. Bangladesh fisheries sector review. Agricultural Operations Division. Asia Country Department 1. Report No. 8830-BD. World Bank, Washington.

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 (main report). WorldFish Center, Penang, Malaysia. 235 p.

WorldFish Center. 2008. Aquatic region map generated by the Recommendation Domain Project of the WorldFish Center, Penang, Malaysia.

WorldFish-DoF. 2006. Upazila (sub-district) level data jointly collected by the WorldFish Center, Penang, Malaysia, and Department of Fisheries, Dhaka, Bangladesh, in 2006 for the recommendation domains project of the WorldFish Center.

This document describes the historical background, practices, stakeholder profiles, production levels, economic and institutional environment, policy issues, and prospects for freshwater aquaculture in Bangladesh. It is an output from a 3-year project that produced a decision-support toolkit with supporting databases and case studies to help researchers, planners and extension agents working on pond aquaculture. The purpose of the work, carried out in Cameroon and Malawi in Africa, and Bangladesh and China in Asia, was to provide tools and information to help practitioners identify places and conditions where freshwater pond aquaculture can benefit the poor, both as producers and as consumers of fish.

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