



INTERNATIONAL FOOD POLICY
RESEARCH INSTITUTE
sustainable solutions for ending hunger and poverty
A member of the CGIAR consortium

IFPRI Discussion Paper 01220

October 2012

Change and Diversity in Smallholder Rice–Fish Systems

Recent Evidence from Bangladesh

Madan M. Dey

David J. Spielman

A.B.M. Mahfuzul Haque

Md. Saidur Rahman

Rowena A. Valmonte-Santos

Environment and Production Technology Division

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

The International Food Policy Research Institute (IFPRI) was established in 1975 to identify and analyze national and international strategies and policies for meeting the food needs of the developing world on a sustainable basis, with particular emphasis on low-income countries and on the poorer groups in those countries. IFPRI is a member of the CGIAR Consortium.

PARTNERS AND CONTRIBUTORS

IFPRI gratefully acknowledges the generous unrestricted funding from Australia, Canada, China, Denmark, Finland, France, Germany, India, Ireland, Italy, Japan, the Netherlands, Norway, the Philippines, South Africa, Sweden, Switzerland, the United Kingdom, the United States, and the World Bank.

AUTHORS

Madan M. Dey, University of Arkansas at Pine Bluff

Professor, Department of Aquaculture and Fisheries
mdey@uaex.edu

David J. Spielman, International Food Policy Research Institute

Senior Research Fellow, Environment and Production Technology Division

A.B.M. Mahfuzul Haque, The WorldFish Center

Bangladesh Office

Md. Saidur Rahman, Bangladesh Agricultural University

Department of Agricultural Economics

Rowena A. Valmonte-Santos, International Food Policy Research Institute

Senior Research Analyst, Environment and Production Technology Division

Notices

IFPRI Discussion Papers contain preliminary material and research results. They have been peer reviewed, but have not been subject to a formal external review via IFPRI's Publications Review Committee. They are circulated in order to stimulate discussion and critical comment; any opinions expressed are those of the author(s) and do not necessarily reflect the policies or opinions of IFPRI.

Copyright 2012 International Food Policy Research Institute. All rights reserved. Sections of this material may be reproduced for personal and not-for-profit use without the express written permission of but with acknowledgment to IFPRI. To reproduce the material contained herein for profit or commercial use requires express written permission. To obtain permission, contact the Communications Division at ifpri-copyright@cgiar.org.

Contents

| | |
|-------------------------------|----|
| Abstract | v |
| Acknowledgements | vi |
| 1. Introduction | 1 |
| 2. Data and Data Sources | 3 |
| 3. Results and Discussions | 4 |
| 4. Conclusion | 17 |
| Appendix: Supplementary Table | 18 |
| References | 20 |

Tables

| | |
|--|----|
| 3.1—Area (hectares) under various crop–fish systems in Bangladesh, 2011 | 10 |
| 3.2—Area (hectares and percentage) covered by various rice–fish systems in Bangladesh, 2011 | 11 |
| 3.3—Area (hectares) converted from rice fields to fishponds, by division and land use, Bangladesh, 2006–11 | 12 |
| 3.4—Cost and return to different farming systems in Bangladesh, 2000–11 | 13 |
| 3.5—Factor shares in fish farming by different rice–fish farming systems in Bangladesh, 2010/11 | 14 |
| 3.6—Labor utilization of different rice and fish-based farming systems | 15 |
| A.1—Selected studies on rice–fish farming in Bangladesh | 18 |

Figures

| | |
|--|---|
| 3.1—A calendar of rice–fish systems in Bangladesh | 5 |
| 3.2—Relative price of fish and rice in Bangladesh, 2005–10 | 7 |

ABSTRACT

Efforts to unlock the genetic potential of both rice and fish, when combined with efforts to improve the management of rice–fish systems, have considerable proven potential for increasing agricultural productivity and food security. In Bangladesh, estimates suggest that the country’s potential rice–fish production system encompasses between two and three million hectares of land. Despite three decades of research on biophysical and technical aspects of rice–fish systems, this potential has not been realized fully due to insufficient attention given to the social, economic, and policy dimensions of system improvement. This paper provides a characterization of the diverse and changing nature of rice–fish systems in Bangladesh by combining data from a novel *upazilla*-level (sub-district-level) survey of fishery officers with household surveys, focus group discussions, and a meta-review of the literature on aquaculture in the country. The resulting analysis sheds new light on the economic viability of different rice–fish systems and recommends policy and investment options to further improve the development and delivery of rice–fish technologies. Findings indicate that in addition to concurrent rice–fish systems, alternating rice–fish systems and collectively managed systems offer considerable potential for increasing productivity and farm incomes in Bangladesh. Findings also suggest that although the emergent innovation system around these rice–fish systems is fairly dynamic, there is a need for more supportive policies and investments—and analysis of the intended and unintended impacts of these policies and investments.

Keywords: rice–fish systems; productivity; income; policies; Bangladesh

ACKNOWLEDGEMENTS

The authors thank M. A. Sattar Mandal, Mahbub Hossain, Mahbubur Rahman Khan, Md. Syed Arif Azad, Md. Golam Hossain, Md. Idris Ali Miah, Md. Abdul Wahab, Akhter Ahmed, Mark Rosegrant, Jagadish Timsina, Md. Khairul Bashar, Md. Hazrat Ali, Sk. Mustafizur Rahman, Farida Begum, Md. Fazlur Rahman, Md. AHM Kohinoor, Ben Belton, Shakuntala Thilsted, William Collis, Benoy Barman, and Mohammad Mahfujul Haque for their input. The authors also thank participants at stakeholder workshops held in Dhaka in December 2010 and Mymensingh in July 2011, as well as respondents from Comilla and Mymensingh. Thanks are also given to the dean's office and the Bureau of Socio-Economics Research and Training at Bangladesh Agricultural University; Deputy Directors, District Fisheries Officers, and *Upazilla* Fisheries Officers of the Department of Fisheries; and Sabnam Mustary, Ayesha Siddiqa, A. Prodip Basu, Zakaria Noyon, Michael Go, and Lorena Danessi. Funding for this study was provided by the Bill and Melinda Gates Foundation and the United States Agency for International Development as part of the Cereal Systems Initiative for South Asia. Any and all errors are the sole responsibility of the authors.

1. INTRODUCTION

Many Asian countries are described as *rice–fish societies* because consumption is largely dependent on rice as the staple crop and fish (inclusive of finfish and crustaceans) as the main source of animal protein. In these countries, food security and prosperity long have been associated with the availability and diversity of both rice and fish. The rice and fish production systems on which these societies depend are quite varied and greatly influenced by seasonal rainfall and flood inundation patterns, particularly in river floodplains and deltaic lowlands. Many traditional systems in Asia are based on concurrent cultivation of rice and fish, whereas other systems alternate between rice cultivation in one season and fish culturing in the other. Still other systems—especially those in more commercialized rural economies—rely on separate and permanent fish culturing systems.

Efforts to improve concurrent and alternating rice–fish systems through improvements in genetic potential and management practices can potentially contribute to increasing agricultural productivity and food security. This is particularly relevant in Bangladesh, where estimates show that the country’s potential rice–fish production system encompasses between two and three million hectares of land (Asian Development Bank 2005; Dey and Prein 2006; Ahmed and Garnett 2010) and where the average size of operational holdings is only 0.5 hectares (Joshi et al. 2007). The importance of both rice and fish in Bangladeshi life is captured in the popular saying *Mache bhate Bangali*, which roughly translates into “Rice and fish make a Bengali.”

Traditionally, many Bangladeshi farmers catch large quantities of fish from their rice fields, primarily from stocks of naturally occurring small indigenous fish used primarily for their own consumption. But the intensification of rice cultivation in Bangladesh during the past three decades has significantly transformed many of Bangladesh’s traditional rice–fish systems. Since the mid-1980s, farmers in the medium highlands, medium lowlands, and shallow flooded areas of Bangladesh have shifted into intensive cultivation of high-yielding *boro* rice varieties during the dry season (typically January to June) with the help of modern inputs and irrigation from shallow/deep tubewells and have continued to cultivate *amon* rice during the wet season, typically July to December (see Hossain 2010). Farmers in the lowlands and deep flooded areas also have shifted into *boro* rice cultivation during this period but tend to leave their fields fallow during the wet season.

As a result of the intensification of *boro* rice production, critical dry-season fish habitat has diminished, and traditional fish catches have declined (Halls, Hoggarth, and Debnath 1998; Hoggarth et al. 1999; Shankar, Halls, and Barr 2004), thereby reducing the availability of an important source of both nutrition and income for many small farmers. At the same time, more permanent forms of inland pond culturing for homestead and commercial purposes have emerged (Belton et al. 2011).

But inland pond culturing is not the only option for intensifying aquaculture in Bangladesh. Many of the country’s agroecologies offer suitable environments and habitats for rice, fish, and crustaceans. Bangladesh’s main rice production systems—irrigated, rainfed lowland, and flood-prone/deepwater systems—are all suitable for both rice cultivation and aquaculture. Approximately 2.5 million hectares of land under rice cultivation in Bangladesh are flooded to a depth of more than 50 centimeters during the wet season, remaining submerged for between four and six months. The abundance of both flora and fauna in these submerged fields can support fish and crustacean populations concurrently, or in rotation, with rice.

In an effort to address the changes brought about by *boro* rice intensification, Bangladesh’s agricultural research and extension system has explored a variety of alternative aquaculture practices since the mid-1980s. The Bangladesh Fisheries Research Institute (BFRI), Bangladesh Rice Research Institute, Bangladesh Agricultural University (BAU), Department of Fisheries (DOF), and WorldFish Center have all conducted extensive research on the topic. Various nongovernmental organizations, private companies, rural entrepreneurs, and others also have invested in innovative approaches to culturing in Bangladesh’s rice–fish systems.

Many of the improved fish culturing practices introduced by these organizations in recent decades rely on the deliberate stocking of fish, either concurrently with, or subsequent to, rice cultivation. Many practices also rely on the stocking of improved fish breeds, including exotic breeds, in tandem with specific recommended practices on the management of land, water, feeding, health maintenance, and harvesting. Thousands of Bangladeshi farmers have experimented since with various forms of rice–fish culture and have developed practices to suit their farming environments and resource endowments (Halwart and Gupta 2004). To date, however, these fish culturing systems (including not only floodplain and rice–fish systems but also cages and oxbow lakes) account for only an estimated 2 percent of total aquaculture production in Bangladesh (Belton et al. 2011).

Part of the problem has been that the research conducted to date has focused on biological and technical issues related to what we term here *concurrent* and *alternating* rice–fish systems (the latter system is also referred to in the literature as an *alternate*, *rotating*, or *rotational* rice–fish system), both of which will be described in greater detail below. Studies tend to deal with location- and season-specific biophysical and technical feasibility of rice or fish technologies rather than feasibility at a system level or across an entire agricultural year.

Related to this is the paucity of research on the social and economic dimensions of rice–fish systems, for example, management practices for community-based fish culturing, comparative economic returns to rice–fish technologies, or gendered impacts of improved rice–fish technologies. Apart from several exceptional studies reviewed in greater detail below (see also Kumar and Quisumbing 2011 for a study of the long-term impacts of early adoption of pond-based fish polyculture on well-being in Bangladesh), the social and economic research on rice–fish systems is relatively limited given the magnitude of the system’s traditional importance in rural Bangladeshi livelihoods and given its potential importance as a means of improving agricultural production and rural livelihoods. Furthermore, policy research on rice–fish systems—on the public policies and investments needed to foster more substantive growth in Bangladeshi aquaculture, especially for small-scale, resource-poor farmer-fishers—is largely absent.

In an effort to partly address this knowledge gap, this paper examines the diverse and changing nature of rice–fish systems in Bangladesh and policy options that might support greater pro-poor development of the country’s rice–fish systems. Specifically, by combining data from a novel nationwide *upazilla*-level (sub-district-level) survey of fishery officers with household surveys and focus group discussions in two districts and a meta-review of the literature on fisheries and aquaculture in the country, this paper (1) characterizes the diverse nature of rice–fish systems in freshwater areas of Bangladesh, (2) examines the economic viability of alternative systems, and (3) recommends policy and investment options to further improve the development and delivery of rice–fish technologies.

Important to note, the methods, analysis, and recommendations set forth in this paper provide a framework for examining similar systems and systemic challenges in other Asian rice–fish societies. By examining rice–fish systems in an integrated manner, the paper aims to move beyond crop-specific approaches (that is, just rice or just fish) and incorporate the complex interactions between agroecological diversity, smallholder farming systems, and public policy. The paper also demonstrates how, in the absence of sufficient policy support from government, farmers nonetheless experiment and innovate—often in unexpected ways—to improve their livelihoods. This is an illustration of the properties of an innovation system (see, for example, Malerba 2002; Rycroft and Kash 1999; Edquist 1997; Lundvall 1992) in the context of developing-country agriculture (see, for example, Biggs 2007; Spielman 2006; Clark et al. 2003) where emergent and self-organizing characteristics are particularly relevant (see, for example, Ekboir 2012; Douthwaite et al. 2006). In effect, the paper marries the farming systems and innovation systems literature to capture a snapshot of the complex dynamics within Bangladesh’s rice–fish systems.

2. DATA AND DATA SOURCES

This paper draws on a study of rice–fish systems conducted in 2010/11 in Bangladesh. The study was a joint undertaking of DOF, Bangladesh, BAU, and the International Food Policy Research Institute (IFPRI). The study’s research questions and priorities were identified at a meeting held at the DOF headquarters in Dhaka on December 19–20, 2010, at which 28 experts from 11 national and international agencies were in attendance. Draft results were discussed in a meeting held at BAU in Mymensingh on July 5–6, 2011, and again at a policy conference held in Dhaka on October 4–5, 2011.

Data for this study were collected from both primary and secondary sources. The main source of primary data is a nationwide *upazilla*-level survey conducted in 2011 jointly by DOF, BAU, and IFPRI (referred to hereafter as the 2011 DOF/BAU/IFPRI Survey). The aim of this survey was to better understand exactly which types of rice–fish culturing systems were being practiced across Bangladesh. The 2011 DOF/BAU/IFPRI Survey queried DOF officers in 475 *upazillas* across the country about the primary crop cultivation and fish culturing practices by farmers in their respective *upazillas*. No other survey or statistical gazette provides this information at a national level, making the survey a unique contribution to our understanding of farming practices in Bangladesh.

As part of this survey, primary data were also collected from a series of focus group discussions and household surveys conducted in two key freshwater rice–fish producing districts, Mymensingh and Comilla. The former district was chosen due to the prevalence and growth of fish culturing in permanent fishponds and anecdotal reports of disadoption and disinvestment in these ponds by poorer households due to high input costs, credit constraints, and risks associated with both production and markets. The latter district was chosen because of the well-documented interventions of Shishuk, a nongovernmental organization, in promoting collectively managed aquaculture in seasonal floodplain areas (see Belton et al. 2011; Toufique and Gregory 2008).

For household surveys, we first interviewed local DOF officials and nongovernmental organization representatives to collect information on the nature and extent of fish and rice–fish culture in the respective areas and to develop sampling frames. We found that there were 108 community-based fish culture operations in Comilla district from which we selected 30 community-based operations from two *upazillas* (Daudknadi and Titas) using stratified random sampling. Based on the concentration of fish culture in various villages, we purposively selected four sample villages of Muktagacha *Upazilla* (Mymensingh district) and then randomly selected 30 sample households from the four villages. The interviews were conducted by trained enumerators, with help from local DOF and nongovernmental organization officials, from March to November 2011 based on two location-specific questionnaires.

Secondary data were garnered from various sources. First, data on rice and fish prices, rice–fish research efforts, and agricultural and fisheries policies were collected from various government organizations in Bangladesh. Second, data on the economics of rice–fish systems in Bangladesh—profitability, sustainability, and other measures—were extracted from an extensive literature review exercise. In this exercise, a total of 29 published articles and unpublished reports from across the academic and nonacademic grey literature were examined (see Appendix Table A.1 for details about these studies).

3. RESULTS AND DISCUSSIONS

Rice–Fish Systems, Policies, and Trends

Before discussing the findings that emerged from the study described above, this section aims to provide a more complete description of Bangladesh’s rice–fish systems. Specifically, this section characterizes the main features and attributes of these systems, the intricacies of Bangladesh’s fish markets and supply chains, and research on new fishery and aquaculture technologies and practices. The section then examines the policy landscape and its influence on productivity growth in Bangladesh’s rice–fish systems.

Rice–Fish Systems

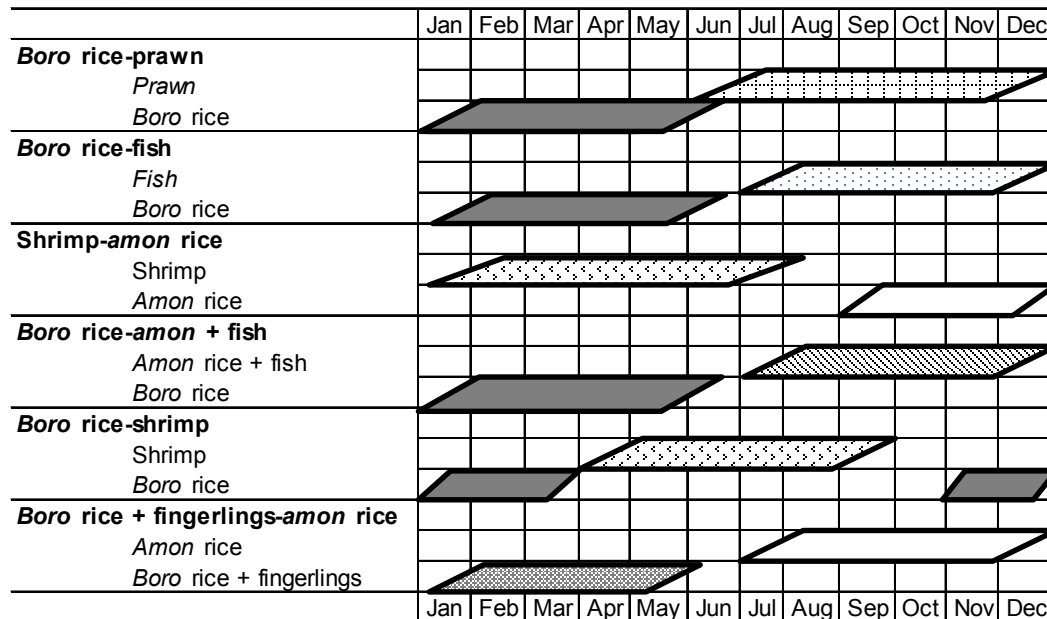
Broadly speaking, there are numerous inland or freshwater fish culturing systems in Bangladesh including (1) permanent, yearlong fishponds; (2) permanent and seasonal prawn and shrimp ponds; (3) traditional culturing of fish within the standing rice crop (the concurrent system mentioned earlier); and (4) seasonal rotations between rice and fishponds (the alternating system mentioned earlier).

The first system can be further divided into homestead pond culture, entrepreneurial pond culture, and commercial semi-intensive carp culture. These forms of inland pond culture account for 86 percent of aquaculture production in Bangladesh (Belton et al. 2011).

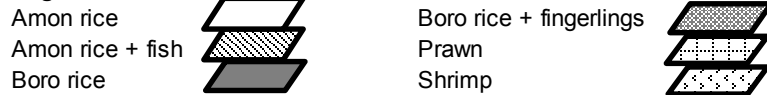
The second system is found in the southern part of Bangladesh. Here, rice cultivation and fish culturing are commonly practiced in polders locally known as *gher*, which essentially describes an enclosed area characterized by an encirclement of land. These polders or *gher* were constructed in the early 1960s as coastal embankments to protect agricultural lands in coastal areas from tidal waves and saline water intrusion. Since the 1970s, farmers have started growing shrimp in polders within the embanked areas by allowing the entry of saline water into the enclosed areas. There are two types of *gher* farming in the country: (1) brackish water–based shrimp farming and (2) freshwater based rice–prawn farming. This first farming system is common to the saline coastal *gher* and is based on the rotation of shrimp culturing during the dry season followed by *amon* rice in the wet season when water salinity is lowered by rainfall. In less saline areas, some farmers grow shrimp in rotation with an early *boro* rice crop. The second farming system was developed by farmers in the mid 1980s and is widely practiced in the nonsaline environments of southwestern Bangladesh. In this system, farmers usually grow *boro* rice on *gher chatal* (the land inside the *gher*) during the dry season followed by prawn in the wet season.

The third and fourth systems listed above are the main methods of culturing fish in rice fields and are the focus of this paper. Concurrent rice–fish systems are based on the practice of culturing fish simultaneously with the cultivation of rice within the same plot. Concurrent culture is practiced in the wet season because rains and flooding provide a favorable environment for both *amon* rice varieties as well as both endemic and exotic fish breeds (see Figure 3.1). Evidence suggests that concurrent rice–fish systems can improve rice yields by as much as 10–20 percent, possibly due to better mulching of rice paddies, fertilization of soils through fish waste, and better weed control (Dey et al. 2005; Lightfoot, van Dam, and Costa-Pierce 1992). However, concurrent culture of fish and *boro* rice in the dry season is generally not economical: Maintaining adequate water levels for a rice field stocked with fish during the dry season would incur significant additional costs associated with operation of electric or diesel tubewells.

Figure 3.1—A calendar of rice–fish systems in Bangladesh



Legend



Source: Authors.

Notes: Jan = January; Feb = February; Mar = March; Apr = April; Jun = Jun; Jul = July; Aug = August; Sep = September; Oct = October; Nov = November; Dec = December.

Alternating rice–fish systems rotate between rice cultivation and fish culturing on a seasonal basis (see Figure 3.1). In alternating systems, *boro* rice is cultivated during the dry season, and fish is cultured during the wet season. As in the concurrent system, there is heterogeneity within the alternating systems as to the stocking of endemic and exotic fish breeds. The alternating system is particularly popular in noncoastal flood-prone areas where farmers previously cultivated deepwater *amon* rice varieties during the wet season followed by a wide range of crops—pulses, oil seeds, and vegetables—during the dry season. With the increased availability of irrigation equipment and machinery during the late 1980s, the dominant cropping pattern in the noncoastal flood-prone environments changed dramatically to *boro* rice cultivation in the dry season. Because of a late harvest period in May/June, this cropping pattern does not allow for the establishment of *amon* rice in the subsequent wet season. But it does allow for fish culturing during the wet season.

The choice of fish or crustacean species cultured in these systems is dependent on the water resources (freshwater, saline/brackish, or low-saline), available biodiversity, household consumption preferences, and signals from local, national, or export markets. In alternating rice–fish systems, finfish species are most common in the floodplains, with prawn found more commonly in the low/nonsaline coastal areas and shrimp in the saline coastal areas. Traditionally people used to capture endemic fish species (also referred to as small indigenous species [SIS]) from flooded rice fields. More modern rice–fish systems include the stocking of both endemic and exotic breeds such as rohu carp (*Labeo rohita*), catla carp (*Catla catla*), common carp (*Cyprinus carpio*), silver barb (*Barbonymus gonionotus*), and tilapia (*Oreochromis mossambicus*, *O. niloticus*) in rice fields, with standing rice crop or in rotation with rice crop. The stocking of fish breeds in certain freshwater floodplains has not been shown to reduce the

capture of nonstocked SIS (Dey et al. 2005; Sheriff et al. 2010; Rahman 2010). Polyculturing practices—for example, the culturing of SIS along with other finfish and prawn in both alternating and concurrent rice–fish systems—also have proven technically feasible and economically viable (Kunda et al. 2008; Kunda, Wahab, et al. 2009; Kunda, et al. 2009). Permanent, commercial fishponds tend to culture various carp species, tilapia, climbing perch (*Anabas testudineus*, also known as *koi* in local Bengali language), and pangasius (*Pangasianodon hypophthalmus*), a species of catfish introduced from Thailand in 1989 and similar to the native pangasius (*Pangasius pangasius*) that is found in the freshwater rivers of Bangladesh.

Another way to classify fish culturing in Bangladesh is to categorize by production-intensity levels. In Bangladesh, fish culturing can be classified into three systems: (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, concentrated feeds and fertilizers. Concurrent rice–fish culture is basically an extensive system that relies mainly on organic matter in the field to sustain the fish population, in some instances supplemented with easily available farm feeds such as rice bran, wheat bran, or mustard oilcake. Alternating rice–fish systems tend to be semi-intensive systems as they often rely on commercially manufactured pellet feed in addition to farm feeds.

Necessarily, fish yields are higher in the semi-intensive alternating rice–fish systems than in the extensive concurrent system. Studies suggest that in freshwater areas, fish yields are usually about 0.25 to 0.50 tons per hectare per season under concurrent rice–fish systems compared to about 1.00 to 1.50 tons per hectare per season under alternating rice–fish systems (Ahmed, Zander, and Garnett 2011; Dey et al. 2005).

Input and Commodity Markets

Both the concurrent and the alternating rice–fish systems are highly dependent on a functioning supply chain for fish culturing inputs and marketable fish. On the input side, fingerlings, feeds, and fertilizers are vital to productivity in the semi-intensive and intensive alternating systems. Although feed and fertilizer markets are imperfect and quality issues abound (see, for example, Belton et al. 2011), many farmers are nonetheless able to purchase these inputs in local markets. Fingerlings reared from fish seed, on the other hand, are a more problematic input.

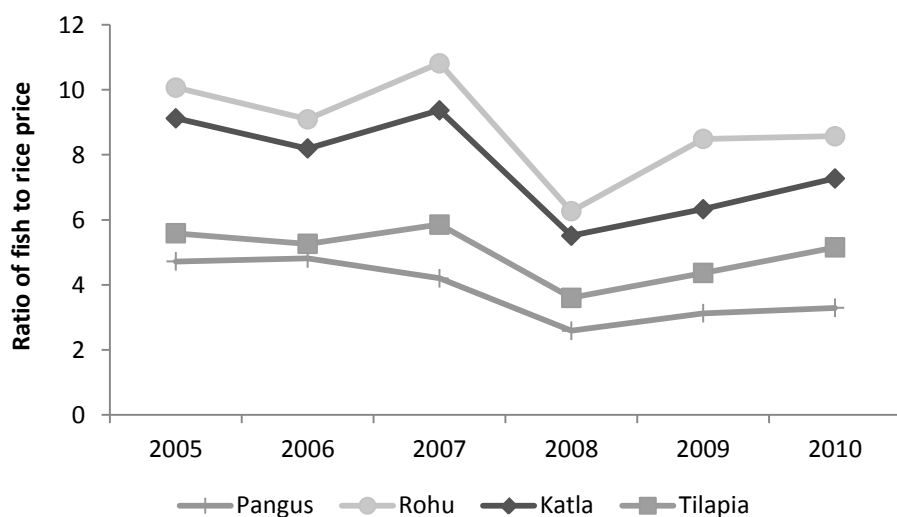
Fingerling production from fish seed in irrigated rice fields is a relatively new practice in Bangladesh. It is not a particularly input-intensive activity, nor is it especially detrimental to the environment, unlike shrimp culturing. Fingerlings can be used directly for fish culturing in subsequent seasons or as natural feed for larger fish in that same season. Alternatively, fingerlings can be marketed through local sales and bartering or sold directly to fry traders and food fish producers. See Haque (2007), Barman and Little (2006), and Haque et al. (2010) for details about fingerling production and marketing.

Yet although Bangladesh hosts an extensive network of finfish seed traders who link hatcheries and nurseries to smallholders, many studies indicate that fingerling quality is a persistent problem. Hatcheries face problems related to the poor selection of fish broodstocks, indiscriminate hybridization, and inbreeding. The fingerling problem is more acute for prawn and shrimp: About 15 percent of prawn and shrimp fry still depends on wild fry catches that can have significantly negative spillover effects on environmental health and biodiversity (Environmental Justice Foundation 2004; Selim 1994). On the marketing side, households that sell their fish production (as opposed to using it for their own consumption) generate income from two main sources: the sales of fish and the sales of fingerlings for stocking purposes. Such sales are conducted in local markets or via traders who supply more distant markets. Poor market infrastructure, roads, cold storage trucks, and other necessities of a perishable commodity supply chain, and the inequitable distribution of market power between smallholders and traders are also acute problems (Dey, Alam, and Bose 2010; Ahmed, Zander and Garnett 2011).

Despite these constraints, several key economic indicators indicate that the market for fish continues to be robust in Bangladesh, particularly consumption indicators. Per capita fish consumption

increased in urban areas by 17.5 percent and in rural areas by 4.8 percent between 2000 and 2005, and 98.5 percent of households report consuming fish on at least one occasion per week (Belton et al. 2011). Demand for fish in Bangladesh is income elastic (Dey, Alam, and Paraguas 2011). Rising real incomes and urbanization have contributed to this increase in consumption, the effect of which has been a rapid rise in demand. This rise in demand has been partly offset by the growth of aquaculture production at more than 10 percent per annum over the last decade. In spite of this increase in supply, the real price of fish has remained somewhat stable with some upward pressure on real prices relative to rice in recent years (see Figure 3.2). Various recent studies have projected that the demand for various types of fish in the country will increase substantially over time due to increases in population and per capita income (Dey, et al. 2008a; Dey, et al. 2008b; Dey, Alam, and Paraguas 2011).

Figure 3.2—Relative price of fish and rice in Bangladesh, 2005–10



Source: Authors, based on data from the Department of Agricultural Marketing (2011) and Bangladesh Rice Research Institute (2010).

Note: Taka/kg = Bangladeshi Taka per kilogram. Trends are based on real fish and rice prices, 2005-10 using consumer price index (2005=100).

Rice–Fish Technology Development and Delivery

In an effort to boost fish productivity and returns to smallholders, various governmental and nongovernmental agencies in Bangladesh have been conducting research and promoting rice–fish farming since the 1980s. BAU, for example, began conducting on-farm rice–fish experiments in the 1980s, initially with an emphasis on concurrent systems that expanded in the 1990s to include alternating systems. Similarly, BAU and the Bangladesh Rice Research Institute have been conducting on-farm research to integrate fish in deepwater and irrigated rice fields since 1990.

Since the 1980s, BFRI has been conducting research on concurrent rice–fish systems, including a novel collaboration with other national and international agencies in 1988–2001 that combined on-farm experimentation around concurrent and alternating rice–fish systems with community-based fish management. One aspect of this novel work was carried out in several parts of the country (Dey et al. 2005). DOF has pursued similar work on community-based management of rice–fish systems in seasonal floodplains since 1989, including an action research project on community-based fish culture in six season floodplains in 2005–10 (Sheriff et al. 2010).

Many of these national agencies collaborate closely with the WorldFish Center—an international agricultural research center based in Penang, Malaysia, that hosts a significant presence in Bangladesh—

and a number of active national nongovernmental organizations. But in spite of overwhelming recognition by these organizations that more research on rice–fish systems is needed, and despite the strong sense of collaboration among those involved in research and development in this area, there are still persistent knowledge gaps.

The same is largely true on the delivery side, where public extension and private input supply systems have come up short for aquaculture. Murshed-E-Jahan and Pemsil (2011) examine this in the context of one particular initiative—the Development of Sustainable Aquaculture Project coordinated by the WorldFish Center—by examining the impact of short-term training, long-term training, and small grants to farmers on integrated agriculture-aquaculture approaches from 2002/03 to 2005/06. Their findings indicate that sustained and participatory approaches to learning can have a significantly positive effect on farmers’ technical efficiency, total factor productivity, and net incomes for the rice–fish systems and technologies being examined here.

Still, research and extension priorities have focused on concurrent rice–fish systems and on biotechnical issues associated with these systems, thus overlooking the wider, largely self-organizing innovation system forming around rice–fish systems in Bangladesh. There is increasing (although in many cases anecdotal) evidence that farmers, farmer organizations, private suppliers of seed and feed, fish traders, and civil society groups are collaborating in novel ways to expand production and productivity in concurrent and alternating rice–fish systems. But research on this innovation system—specifically, on the socioeconomic, policy, and institutional aspects of rice–fish systems in Bangladesh—has been limited, thus limiting the analytical understanding of constraints and opportunities to further development of fish as a source of nutrition and income for smallholders and consumers in Bangladesh.

Part of the problem may be long-standing skepticism about the viability of rice–fish systems. Despite favorable market signals for fish production in Bangladesh, the biotechnical challenges still discourage many from investing in solutions. One such key challenge is the risks associated with seasonal flooding that cause fish to escape from fields (Belton et al. 2011). Socioeconomic challenges are, for example, concerns about increased household or hired labor requirements associated with rice–fish systems and the difficulties of organizing collective action (Nabi 2008). Still other challenges relate to the national policy landscape, explored in more detail below. But despite these challenges, innovation systems have emerged around rice–fish systems, and more socioeconomic, policy, and institutional analysis is needed to better understand the pros and cons of these systems.

The National Policy and Investment Landscape

This limited body of socioeconomic, policy, and institutional analysis is worrisome given the large number of government policies aimed at supporting rice–fish systems in Bangladesh and given the potential magnitude of the intended and unintended consequences of such policies. Key policies range from national strategic planning (for example, the national five-year plans since 1973 and the Country Investment Plan of 2011) to poverty-reduction strategies (for example, the National Strategies for Accelerated Poverty Reduction approved in 2004 and 2008), to commodity-specific policies (for example, the Protection and Conservation of Fish Act of 1950, amended in 1982; the Fish and Products [Inspection and Quality Control] Ordinance of 1983; the National Fisheries Policy of 1998; and the aquaculture substrategy of 2006), to broader sectoral and resource policies that influence rice–fish systems (for example, the National Water Policy of 1999, the National Agricultural Policy of 1999, and the National Land Use Policy of 2001), to directives on implementation (for example, the New Agricultural Extension Policy of 1996).

Although the labyrinth of these strategies, policies, regulations, and directives maintains a common emphasis on promoting rice–fish systems to increase fish production and rural incomes in Bangladesh, it also forms an incomplete patchwork of incentives. Policies such as the National Agricultural Policy of 1999, for example, address efforts to improve agricultural input markets but do not cover fish feed and seed. Meanwhile, the responsibilities for execution of such policies are fragmented among the government of Bangladesh’s various line departments: The land, water, crop, and fish sectors

in Bangladesh are managed by four entirely separate ministries, whereas the Bangladesh Agricultural Research Council (BARC) establishments working in these areas do not have control over their own resource allocations (Rahija et al. 2011; Beintema and Kabir 2006). In effect, neither policy formulation nor policy implementation in Bangladesh is appropriate to the essential systems nature of a livelihood strategy that combines rice cultivation and fish culturing that is so prevalent in Bangladesh.

Partly as a result of this, public investment in agricultural research has endured at least a decade of volatile and erratic funding. In 2009, public spending on agricultural research in Bangladesh totaled US\$120 million (measured in constant [2005] purchasing power parity terms; all dollars are US dollars), which is actually a slight decrease from 2000 spending levels estimated at \$135 million and also masks two dramatic funding declines in 2000–03 and 2007–09 (Rahija et al. 2011). Between 2000 and 2009, the number of full-time-equivalent researchers allocated to work on fisheries increased from an estimated 110.6 to just 124.5 (Rahija et al. 2011; Beintema and Kabir 2006). Their capacity to work, however, was likely limited because research expenditures on fisheries remained fairly stagnant and were largely allocated to salaries (for example, accounting for roughly 60 percent of BFRI’s spending in 2009), with little left over for operations (less than 25 percent at BFRI in 2009).

Although private investment in the fisheries sector is fairly extensive in Bangladesh, the amount of research conducted by the private sector is negligible. Just a handful of firms are involved in research tied to large-scale production, input supply, or processing (Rashid, Ali, and Gisselquist 2011), and there is limited evidence to suggest that these research activities—possibly apart from some work on fish genetic improvement—spill over to smallholder aquaculture.

Bangladesh’s current strategic planning document—the Country Investment Plan of 2011—takes aim at these problems to a certain extent. The plan emphasized the development of small-scale aquaculture with commitments to increasing access to quality inputs, advice, and skills; improving the management of fisheries resources; developing public–private partnerships in support of infrastructure and services development; promoting sustainable, community-based rice–fish management systems; and encouraging greater collaboration among key public and private players in the sector (FPMU 2011). The plan identifies donor funding needs—in addition to the government’s available budgetary resources—for fisheries and aquaculture development on the order of \$356 million during the sixth five-year plan period (2011–15), with “first priority requirements” within this amount totaling \$212 million. Important to note, the plan also identifies the need for a more stakeholder-driven approach to fisheries and aquaculture development that relies increasingly on farmers’ organizations and the private sector to sustainably intensify fish culturing throughout the country.

Key Findings

Rice–Fish Systems and Production Environments

Given the dynamism of markets, technologies, and policies in Bangladesh, it is not surprising that these systems have been undergoing significant change in recent years. However, since many of these changes are insufficiently documented, some semblance of order is needed to analyze the consequences of change or, at the least, to frame the changes in a way that will elicit further research on their impacts. To this end, we report here findings from the 2011 DOF/BAU/IFPRI Survey. As shown in Table 3.1, *upazilla*-level data aggregated to the division level identifies a fairly diversified set of rice–fish and other crop–fish systems practiced in Bangladesh. These systems are, in order of prevalence, as follows:

1. *Boro* rice cultivation during the dry season followed by prawn (often polyculture with fish) during the wet season (column 2)
2. *Boro* rice cultivation during the dry season followed by fish culturing (or fish/prawn polyculturing) during the wet season (column 3)
3. Shrimp cultivation during the dry season followed by *amon* rice during the wet season (column 4)

4. *Boro* rice cultivation during the dry season followed by concurrent *amon* rice cultivation and fish culturing (or fish/prawn polyculturing) during the wet season (column 5)
5. *Boro* rice cultivation during the dry season followed by shrimp during the wet season (column 6)
6. Concurrent *boro* rice cultivation and fingerling production during the dry season followed by *amon* rice during the wet season (column 7)
7. Crop production (potato or pulses) during the dry season followed by fish culturing in the wet season (column 8)
8. Salt production between November and May and shrimp culturing between May and November, practiced only in the southeastern coastal areas (column 9)

Table 3.1—Area (hectares) under various crop–fish systems in Bangladesh, 2011

| Division | Area of Crop–fish System (Hectares) | | | | | | | |
|------------|---|--|-----------------------------|--|-----------------------------|--|---|-----------------|
| | <i>Boro</i> Rice– Prawn ^a | <i>Boro</i> Rice– Fish ^b | Shrimp– <i>Amon</i> Rice | <i>Boro</i> Rice– <i>Amon</i> Rice + Fish ^b | <i>Boro</i> Rice– Shrimp | <i>Boro</i> Rice + Fingerlings– <i>Amon</i> Rice | Pulses or Potato– Fish ^b | Salt– Shrimp |
| Dhaka | 0 | 22,944 | 0 | 2,533 | 0 | 205 | 79 | 0 |
| Chittagong | 5,145 | 6,437 | 2,994 | 4,751 | 0 | 85 | 0 | 400 |
| Rajshahi | 0 | 9,897 | 0 | 965 | 0 | 125 | 0 | 0 |
| Khulna | 40,461 | 8,775 | 36,882 | 16,175 | 3,804 | 538 | 0 | 0 |
| Sylhet | 0 | 965 | 0 | 404 | 0 | 19 | 187 | 0 |
| Barisal | 7,523 | 83 | 73 | 1,100 | 172 | 22 | 0 | 0 |
| Rangpur | 0 | 3,692 | 0 | 2,974 | 0 | 504 | 813 | 0 |
| Total | 53,129 | 52,794 | 39,949 | 28,902 | 3,976 | 1,497 | 1,078 | 400 |

Source: Authors, based on data from the 2011 Department of Fisheries/Bangladesh Agricultural University/International Food Policy Research Institute Survey.

Notes: ^a Prawn culturing here is characterized by either exclusive prawn culturing or prawn and finfish polyculturing.

^b Fish culturing is characterized here by either exclusive finfish culturing or finfish and prawn polyculturing.

Findings show that alternating rice–fish systems (*boro* rice cultivation during the dry season followed by prawn culturing, fish culturing, or both during the wet season or shrimp culturing during the dry season followed by *amon* rice cultivation during the wet season) are the most prevalent systems in Bangladesh, accounting for an area of about 146,000 hectares in 2011 (see Table 3.1). Alternating *boro* rice cultivation during the dry season followed by polyculture of fish and shrimp during the wet season is common across the country except in the very deep-flooded Sylhet region and coastal Barisal region. Findings further show that in the southern coastal regions of Barisal, Khulna, and Chittagong, farmers practice two alternating systems widely: (1) *boro* rice cultivation during the dry season followed by prawn culturing during the wet season under low-saline conditions and (2) shrimp culturing during the dry season followed by *amon* rice cultivation during the wet season under saline conditions. Findings also show that about 70 percent of the alternating rice–fish areas in Bangladesh are located in flood-prone environments with more than 90 centimeters’ flooding during the rainy season (see Table 3.2).

Table 3.2—Area (hectares and percentage) covered by various rice–fish systems in Bangladesh, 2011

| Rice–fish Farming System | Total Area (Hectare) | Area at Different Flood Depths (%) | | | |
|--|----------------------|------------------------------------|-----------|------------|---------|
| | | <90 cm | 90–180 cm | 180–300 cm | >300 cm |
| Concurrent rice–fish culture | | | | | |
| Fish for consumption/sale | 28,902 | 71.18 | 22.88 | 4.23 | 3.07 |
| Fingerling/fish seed production | 1,497 | 69.45 | 25.78 | 4.71 | 0.06 |
| Alternating rice–fish cultivation | | | | | |
| Fish for consumption/sale | 149,848 | 29.41 | 54.50 | 13.03 | 1.71 |

Source: Authors, based on data from the 2011 Department of Fisheries/Bangladesh Agricultural University/International Food Policy Research Institute Survey.

The survey reveals several additional findings. First is the popularity of fingerling production concurrently with *boro* rice cultivation. Data from the 2011 DOF/BAU/IFPRI Survey indicate that the practice is used on some 1,500 hectares of land. Although the practice is well understood, its extensive use was not sufficiently documented as a major element of rice–fish systems in Bangladesh.

Second, concurrent rice–fish systems in Bangladesh are fairly limited, covering only about 30,000 hectares as of 2011 and concentrated in medium highland or shallow-flooded areas, where farmers cultivate *amon* rice and fish together during the wet season. This low prevalence is in stark contrast to the strategic emphasis placed on improving concurrent systems by Bangladesh’s main public research organizations mentioned earlier.

Third, findings show that collective action can play a significant role in boosting fish yields, particularly in flood-prone areas. During the rainy season when individual land boundaries (bunds) are submerged from view, fields become de facto common pool resources. Collective management of these resources and the endemic or exotic fish cultured in these aggregated fields can provide communities with a significant source of fish for consumption and sale. Estimates from the 2011 DOF/BAU/IFPRI Survey found that average fish yields under collective management of the alternating rice–fish system in Daudkandi (Comilla *Upazilla*) amounted to four tons per hectare per season, which is substantially more than the average yields of 0.25 to 0.50 tons per hectare per season under concurrent rice–fish systems or 1.00 to 1.50 tons per hectare per season under alternating rice–fish systems reported earlier. If landless households are included in the management of such resources—based on their traditional access to flooded areas for fishing—then the benefits are potentially even more significant.

Fourth, findings indicate that during the past five years about 30,000 hectares of land traditionally used for rice cultivation have been converted to permanent ponds across Bangladesh (see Table 3.3). This phenomenon is particularly noticeable in freshwater areas with easy access to the terminal Dhaka market (such as the Mymensingh district of the Dhaka region), where farmers intensively culture fish (pangasius, tilapia, and climbing perch), and in the southwest (Khulna region), where farmers culture freshwater prawn, shrimp, or both. About two-thirds of these areas used to be double- or triple-cropped areas, primarily owned by smallholders (see Table 3.3).

Table 3.3—Area (hectares) converted from rice fields to fishponds, by division and land use, Bangladesh, 2006–11

| Land Use | Division | | | | | | | Total |
|----------------|----------|------------|----------|--------|--------|---------|---------|--------|
| | Dhaka | Chittagong | Rajshahi | Khulna | Sylhet | Barisal | Rangpur | |
| Single cropped | 2,013 | 601 | 1,247 | 3,590 | 125 | 204 | 562 | 8,341 |
| Double cropped | 4,009 | 1,507 | 1,288 | 10,606 | 434 | 1,678 | 848 | 20,370 |
| Triple cropped | 197 | 426 | 144 | 6 | 92 | 91 | 42 | 997 |
| Total | 6,219 | 2,534 | 2,679 | 14,202 | 651 | 1,973 | 1,452 | 29,709 |

Source: Authors, based on data from the 2011 Department of Fisheries/Bangladesh Agricultural University/International Food Policy Research Institute Survey.

Fifth, findings indicate that about 0.18 million hectares of land are under rice–fish systems—a figure that is much lower than the potential area recognized by the government of Bangladesh. This raises the issue of whether the returns to and adoption of technologies and practices for improving rice–fish systems are being adequately examined in the context of continued public investment in research on both concurrent and alternating rice–fish systems.

Returns to Technologies and Practices

Findings from the meta-review of literature on rice–fish farming in Bangladesh provide a fairly good picture of the economic returns to various rice and fish enterprises of concurrent and alternating rice–fish systems under farmer conditions (see Table A.1 in the appendix). We conducted surveys in the Comilla and Mymensingh districts to collect information about *amon* and *boro* rice farming and two more recent farming systems: (1) privately managed *boro* rice farming during the dry season followed by collectively managed fish culture during the wet season and (2) yearlong pangasius or climbing perch farming in land traditionally used for rice farming. Following a system approach across an entire agricultural year, we have integrated the findings of previous studies with those of the 2011 DOF/BAU/IFPRI Survey and have reported the economic feasibility of different farming systems on a yearly basis in Table 3.4. For details about the individual studies, see Dey et al. (2005); Dey et al. (2008c); Kunda et al. (2008); Wahab (2008); Kunda et al. (2009); Kunda et al. (2009); Ahmed and Garnett (2010); Rahman (2010); Sheriff et al. (2010); and Murshed-E and Pemsil (2011). We have converted all cost and return data to 2010 prices for ease of comparison.

An analysis of data from the survey, combined with focus group discussions and a meta-review of the literature, reveals a high level of variability on the returns to technologies and practices associated with different rice–fish systems in Bangladesh. Although the figures in Table 3.4 are generally drawn from studies that used differing sampling frames and analytical methodologies and that as a result may obscure variations between localities, regions, and systems, they do provide an indicative ranking of the returns to different farming systems. Note that the returns to fish farming (that is, with no other crop rotation), alternating rice–fish systems, and concurrent rice–fish systems are all higher than traditional rice–rice systems, largely indicative of the rising price of fish relative to rice in the Bangladesh market. Even the least profitable rice–fish system (for example, *boro*-concurrent *amon* rice plus fish or *boro*-extensive fish farming) is more profitable than the traditional rice–rice system in favorable environments (such as in Mymensingh). Also note that returns to fish farming and permanent fishponds for pangasius and climbing perch farming are highly lucrative investments, as are the other high-input use systems.

Table 3.4—Cost and return to different farming systems in Bangladesh, 2000–11

| Farming System (Dry Season—Wet Season) | Total Cost (2010 US dollars/hectare) | Net Return | Data Sources |
|--|---|-------------------|--------------------------------------|
| Boro rice—amon rice | 1,478 | 290 | Dey, Bose, et al. (2008) |
| Boro rice—amon rice (Mymensingh, favorable environment) | 1,636 | 550 | 2011 DoF/BAU/IFPRI Survey |
| Pond polyculture (low input use), yearlong | 772 | 1,025 | Jahan et al. (2011) |
| Pond polyculture (high input use), yearlong | 1,294 | 1,148 | Dey, Bose, et al. (2008) |
| Pangasius fish farming, yearlong | 27,481 | 9,455 | 2011 DoF/BAU/IFPRI Survey |
| Climbing perch fish farming, yearlong | 13,042 | 11,459 | 2011 DoF/BAU/IFPRI Survey |
| Boro rice—concurrent amon rice + fish (traditional system) | 788 | 844 | Dey et al. (2005) |
| Boro rice—fish (low input use, collective management) (2000) | 789 | 1,142 | Dey et al. (2005) |
| Boro rice—fish (low input use, collective management) (2009) | 721 | 871 | Sheriff et al. (2010), Rahman (2010) |
| Boro rice—prawn (small farmer, low input use) | 2,130 | 1,598 | Ahmed and Garnett (2010) |
| Boro rice—prawn (large farmer, high input use) | 2,495 | 2,120 | Ahmed and Garnett (2010) |
| Boro rice—fish (semi-intensive input use, collective management) | 3,545 | 2,634 | 2011 DoF/BAU/IFPRI Survey |

Source: Authors, based on data and analysis from sources cited in the last column.

But between these low- and high-return systems lie several diversified rice–fish systems that may be preferential for risk-averse smallholders who choose to maintain a diversified farming system inclusive of rice cultivation for own consumption. These include low-input use systems and, most significantly, the alternating *boro* rice–fish system under collective management. Estimates from the 2011 DOF/BAU/IFPRI Survey found that average fish yields under collective management of the alternating rice–fish system in Daudkandi (Comilla *Upazilla*) cited above demonstrate the magnitude of a low-intensity, collectively managed land allocated to fish culturing.

A closer look at several of these farming systems provides further insight into their economic viability. An analysis of factor shares, for example, illustrates how input intensity and input prices influence the costs and returns to different systems (see Table 3.5). Estimates from the 2011 DOF/BAU/IFPRI Survey identify labor and fingerling as the two most costly inputs in traditional extensive systems, whereas semi-intensive systems are much more intensive in feed and fingerlings; intensive fish farming systems are relatively more intensive in feed. These factor shares are of particular importance when considering appropriate systems and technologies for credit-constrained smallholders with limited access to input markets and suggest that semi-intensive fish culturing may have significant unexploited potential.

Table 3.5—Factor shares in fish farming by different rice–fish farming systems in Bangladesh, 2010/11

| Farming System (Dry Season—Wet Season) | Factor Share of Gross Margin (%) | | | Factor Share of Total Cost (%) | | | Data Source |
|---|----------------------------------|------|-------|--------------------------------|------|-------|--|
| | Fingerlings | Feed | Labor | Fingerlings | Feed | Labor | |
| <i>Boro</i> rice– extensive fish culturing | 17.8 | 0.0 | 23.6 | 32.5 | 0.0 | 43.1 | Sheriff et al. (2010), Rahman (2010) |
| <i>Boro</i> rice–semi- intensive fish culturing | 7.7 | 25.9 | 2.8 | 13.9 | 46.7 | 5.0 | 2011 DoF/BAU/IFPRI Survey |
| Pangasius fish farming | 5.7 | 54.5 | 8.2 | 7.7 | 73.2 | 7.4 | 2011 DoF/BAU/IFPRI Survey |
| Climbing perch fish farming | 6.3 | 41.3 | 1.6 | 11.9 | 77.6 | 3.0 | 2011 DoF/BAU/IFPRI Survey |

Source: Authors, based on data and analysis cited in the last column.

Note: 2011 DoF/BAU/IFPRI Survey = 2011 Department of Fisheries/Bangladesh Agricultural University/International Food Policy Research Institute Survey.

It also is worth taking a closer look at labor use in both rice cultivation and fish culturing (see Table 3.6), especially given that many rice–fish systems in their entirety are significantly labor-intensive production systems. In a traditional double rice crop system, total labor requirements are estimated at 240 person-days per hectare, which is much lower than the labor requirements of *boro* rice’s semi-intensive fish culturing system at 352 person-days per hectare. During the rainy season, fish culturing in semi-intensive alternating systems actually generates more demand for labor (234 person-days/hectare) than rice cultivation during the same season in a rice–rice system (100 person-days/hectare). Some of the activities in semi-intensive fish farming (such as low-cost feed preparation, feeding, and guarding) require a little less drudgery compared to rice farming and are a source of employment for women. It is important to note that employment opportunities in the agricultural sector during the rainy season are limited and that the wage rate is much lower than in the dry season. *Amon* rice cultivation and fish farming are the only two main farming activities during the rainy season. Farmers in deep-flooded areas cannot even successfully grow *amon* rice during the rainy season and often keep their land fallow during the season. Semi-intensive fish culture during the wet season generates much-needed employment opportunities for smallholders in Bangladesh, who often have surplus labor during the rainy season. Findings from this study also indicate that labor requirements of intensive pangasius or climbing perch farming are high, at 824 and 734 person-days per hectare, respectively. These intensive farming activities are good employment opportunities for agricultural laborers but are too capital intensive for smallholder farmers.

Table 3.6—Labor utilization of different rice and fish-based farming systems

| Farming System (Dry Season—Wet Season) | Person-days/ha | | | Cost of Labor (US Dollars) | Data Source |
|--|----------------|------------|-------|----------------------------|--------------------------------------|
| | Dry Season | Wet Season | Total | | |
| Rice–rice system | 140 | 100 | 240 | 688 | 2011 DoF/BAU/IFPRI Survey |
| Pangasius fish farming, yearlong | | | 824 | 2,038 | 2011 DoF/BAU/IFPRI Survey |
| Climbing perch fish farming, yearlong | | | 734 | 1,908 | 2011 DoF/BAU/IFPRI Survey |
| <i>Boro</i> rice–extensive fish culturing | 98 | 36 | 134 | 321 | Sheriff et al. (2010), Rahman (2010) |
| <i>Boro</i> rice–semi-intensive fish culturing | 128 | 234 | 352 | 574 | 2011 DoF/BAU/IFPRI Survey |

Source: Authors, based on data and analysis cited in the last column.

Note: 2011 DoF/BAU/IFPRI Survey = 2011 Department of Fisheries/Bangladesh Agricultural University/International Food Policy Research Institute Survey.

Ultimately, the net benefit of rice–fish systems—primarily, the semi-intensive and collectively managed alternating systems described above—is the additional income from fish that is earned by smallholders without a significant loss of income or food security from forgone rice cultivation. Smallholders can meet many of their basic food staple needs (in the form of own-consumption or surplus marketing) from *boro* rice (or other cash crop) cultivation during the dry season and supplement that income with fish culturing (or with concurrent *amon* rice cultivation and fish culturing in relatively less flood-prone areas) in the rainy season. Data from our 2011 DOF/BAU/IFPRI Survey indicate that farmers get a good net return of \$2,141 per hectare from fish culturing in the wet season and a net return of \$493 per hectare from *boro* rice cultivation during the dry season.

What remains to be understood is the suitability of these various rice–fish systems to the smallholder household that is credit constrained, risk averse, or otherwise unable to access input and commodity markets. Results of our surveys and focus group discussions indicate that common biophysical and technical constraints to adoption include the limited or absent availability of component technologies within different rice–fish ecologies; quality fingerlings; postharvest processing, storage, transportation, and infrastructure; and climate variability. The main social and economic constraints to adoption include small farm size and nonscale neutrality of certain technologies or practices, conflicts about land ownership and use, issues in managing collective action around community-based fish culturing, elite influence and capture, and prohibitively high prices for quality feed. See, for example, studies by Nabi (2008), Taufique and Gregory (2008), Ahmed, Zander and Garnett (2011), and Rahman, Barmon, and Ahmed (2011) for detailed discussions about constraints to rice–fish farming.

Our findings also suggest that despite the lucrative nature of permanent fish culturing (that is, pangasius and climbing perch fish farming) that has been a main driver of conversion of rice land to fishponds, the cost of feed that is purchased on credit for this particular activity makes it unaffordable for many smallholders. In fact, anecdotal evidence gathered during focus group discussions suggests that even larger farmers who leased or purchased land for permanent intensive farming in freshwater (pangasius) and coastal (shrimp/prawn) areas have diversified into alternating rice–fish systems due to high feed prices, operational difficulties, and variable returns to their original investments.

Rice–fish systems in Bangladesh are undergoing a process of change, and more evidence is needed to guide scientists to the right research questions and policymakers to the right investment choices. The evidence presented here has several important implications for future research, policy design, and investment. First, both concurrent and alternating rice–fish systems have the potential to improve smallholder income and welfare, particularly when compared to rice–rice cultivation. Second,

among the most promising systems is the cultivation of *boro* rice and the culturing of fingerlings in the dry season and the cultivation of *amon* rice, fish, and/or prawns in the rainy season. This system has the added advantage of addressing the challenge of fingerling quality, quantity, and cost that constitutes a significant factor cost for many smallholders.

Third, variations on both the concurrent and the alternating rice–fish system that involve crops other than *boro* rice are also potentially beneficial to smallholders, as are variations that incorporate prawn and shrimp culturing for shallow-flooded, coastal, and saline areas. Fourth, there is evidence to suggest that the net returns to certain rice–fish systems are particularly high under collective management models such as those used in Daudkandi, Comilla.

The ecological sustainability of rice–fish systems in Bangladesh is closely linked to the intensity at which these systems are used, and their economic viability depends on good science, sufficient infrastructure, and efficient markets. The sustainable intensification of rice–fish systems and the improvement of smallholder welfare in Bangladesh will require careful policy design and implementation to address these related challenges. There is a need to further prioritize investments in scientific research and market development to capitalize on the sustainability and profitability of concurrent and alternating rice–fish systems that favor the poor in Bangladesh. Specifically, the national agricultural research system in Bangladesh needs to step up its applied research, particularly on the alternating rice–fish system. Researchers, extension agents, and nongovernmental organizations should prioritize an integrated approach that is cognizant of the interactions between rice cultivation, other crop cultivation, and fish culturing in smallholder livelihood strategies. The continued pursuit of singular commodity- and technology-driven research will not likely succeed in serving smallholders effectively.

The Country Investment Plan of 2011 recognizes the need for such integration. What remains to be seen is whether Bangladesh’s line ministries and departments can collaborate with each other, with civil society, and with the private sector to further realize the potential for growth in the aquaculture sector. In addition to this is the challenge of effectively executing rules and regulations (for example, the Fish Quality 2010 Ordinance) that can positively influence the quality and quantity of feed and fish in the market.

To date, analysis of the social, economic, and policy aspects and trends in Bangladesh’s rice–fish systems has been limited. There is an immediate need for further research on issues such as improved technologies and practices for rice–fish systems, fish value chains, the distribution of economic value within those value chains, and the policy interventions that can encourage efficiency and equity.

There is also a need for greater effort to support emergent and self-organizing innovation systems around rice–fish systems in Bangladesh. Given that many such networks have emerged at the local level around rice–fish system improvement, there is an opportunity to capitalize further on progress to date. But care must be taken to avoid tendencies toward provide support through project-driven compartmentalization or centrally managed administration. Rather, to encourage innovation systems, public research, and extension, agents may want to pursue best practices such as eschewing formal organizational or project structures and instead supporting more decentralized civil society–led experiments—an approach that has had much traction in Bangladesh through its vibrant civil society and many community-based development initiatives. Public policymakers may want to pursue greater efforts to strengthen the hardware and software of market infrastructure—better farm-to-market road networks and better enforcement of seed and feed quality ordinances—rather than provide immediate subsidies for inputs. And finally, policymakers, researchers, and extension agents may want to jointly invest in closer collaboration with the private sector—input suppliers, traders, and others in the value chain—to build innovative capacity and problem-solving skills that can catalyze and accelerate rice–fish system improvement.

4. CONCLUSION

This paper attempts to provide a snapshot of those changes by combining a meta-level assessment of the existing literature on rice–fish systems with data from a recent survey of aquaculture across Bangladesh. The paper characterizes the diverse and changing rice–fish systems in freshwater areas of Bangladesh, examines the economic viability of alternative systems, and explores policy and investment options to further improve the development and delivery of rice–fish technologies. Findings indicate that in addition to concurrent rice–fish systems, alternating rice–fish systems and collectively managed alternating systems offer considerable potential for increasing the overall agricultural productivity and farm incomes in Bangladesh. The potential embodied in these farming systems—along with the interactions between farmers, market agents, researchers, and policymakers that underlie them—suggests scope for further encouraging the already emergent properties of Bangladesh’s rice–fish innovation system. These findings are particularly relevant to the country’s freshwater ecosystems and indicate the need for greater research on the design and execution of pro-poor policies and investments and greater inquiry into the intended and unintended impacts of these policies and investments.

APPENDIX: SUPPLEMENTARY TABLE

Table A.1—Selected studies on rice–fish farming in Bangladesh

| Author (Year) | Research Question | Methods and Data | Geographical Focus | Farming System Focus | Seasonal Focus |
|-------------------------------|--|--------------------------------|---|-----------------------------------|----------------------|
| Nabi (2008) | Adoption of technology | Review based on secondary data | Bangladesh | Concurrent rice–fish | Dry season |
| Toufique and Gregory. (2008) | Distributional impacts | PRA and FGD ^a | Comilla | Alternating rice–fish | Rainy season |
| Kunda, Wahab, et al. (2009) | Technological effects | Experiment | Mymensingh | Alternating rice–fish | Rainy season |
| Haque, Little et al. (2010) | Adoption process | Survey-based primary data | Northwest Bangladesh | Concurrent rice–fingerlings | Dry season |
| Haque (2007) | Impacts on rural livelihoods | Survey-based primary data | Northwest Bangladesh | Concurrent rice–fingerlings | Dry season |
| Kunda (2008) | Technology assessment | On-farm experiment | Mymensingh | Alternating rice–fish | Rainy season |
| Ahmed, Brown, and Muir (2008) | Status of prawn farming | Survey-based primary data | Southwest Bangladesh | Alternating rice–fish | Rainy season |
| Ahmed and Luong-Van (2009) | Farming system and food security | Survey-based primary data | Mymensingh | Alternating rice–fish | Rainy season |
| Biswas (2007) | Impact of rice–fish integration on pesticides | Survey-based primary data | Northwest Bangladesh | Concurrent rice–fish | Dry season |
| Halwart and Gupta (2004) | Food security and poverty alleviation | Review based on secondary data | Asia and others countries | Concurrent, alternating rice–fish | Dry and rainy season |
| Uddin and Takeya (2006) | Different variation of integrated farming | Review based on secondary data | Bangladesh, India, Thailand, Philippines, and Vietnam | Concurrent rice–fish | Dry season |
| Kunda et al. (2008) | Technological effects | On-farm experiment | Mymensingh | Alternating rice–fish/prawn | Rainy season |
| Wahab et al. (2008) | Technological feasibility | On-farm experiment | Mymensingh | Concurrent rice–fish | Dry season |
| Kunda, Azim, et al. (2009) | Effect of technology | On-farm experiment | Mymensingh | Alternating rice–fish | Rainy season |
| Mustafa and Brooks (2009) | Technical and economic approach | Comparative analysis | Comilla | Alternating rice–fish | Rainy season |
| Rahman (2010) | Technological interventions | On-farm experiment | Rajshahi, Rangpur, and Mymensingh | Alternating rice–fish | Rainy season |
| Ahmed and Garnett (2010) | Assessment of sustainability | Survey-based primary data | Southwest | Alternating rice–fish | Rainy season |
| Ito (2002) | Investigation of the changes in agrarian structure | Review based on secondary data | Southwestern Bangladesh | Alternating rice–fish | Rainy season |

Table A.1—Continued

| Author (Year) | Research Question | Methods and Data | Geographical Focus | Farming System Focus | Seasonal Focus |
|-------------------------------------|--|-------------------------------|--|-----------------------------|-----------------------|
| Ahmed (2009) | Examination of fresh water prawn farming | Survey-based primary data | Southwest Bangladesh | Alternating rice–fish | Rainy season |
| Dey et al. (2005) | Economic feasibility of community-based fish culture | On-farm experiment and survey | Mymensingh, Kishorganj, Narail, and B. Baria | Alternating rice–fish | Rainy season |
| Rabbani (1999) | Profitability analysis | Survey-based primary data | Bhaluka, Mymensingh | Alternating rice–fish | Rainy season |
| Roy (2005) | Economic analysis | Survey-based primary data | Dinajpur | Concurrent rice–fish | Dry season |
| Islam (1996) | Economic analysis | Survey-based primary data | Mymensingh | Concurrent rice–fish | Dry season |
| Gupta et al. (1998) | Adoption and impact study | Survey-based primary data | Mymensingh | Concurrent rice–fish | Dry season |
| Dewan (1992) | Overview of rice–fish farming system | Review | Mymensingh | Concurrent rice–fish | Dry season |
| Dey and Prein (2006) | Productivity of floodplain | Action research | Mymensingh, Kishorganj, Narail, and B. Baria | Alternating rice–fish | Rainy season |
| Ahmed, Zander, and Garnett (2011) | Socioeconomic aspects | Survey-based primary data | Mymensingh | Concurrent rice–fish | Dry season |
| Rahman, Heidhues, and Becker (2005) | Impact | Survey-based primary data | Mymensingh | Concurrent rice–fish | Dry season |
| Haque, Visser, and Dey (2011) | Institutional aspects | Action research | Rajshahi, Rangpur, and Mymensingh | Alternating rice–fish | Rainy season |

Source: Authors.

Notes: ^a PRA = “participatory rural appraisal”; FGD = “farmer group discussions.”

REFERENCES

- Ahmed, N. 2009. "The Sustainable Livelihoods Approach to the Development of Fish Farming in Rural Bangladesh." *Journal of International Farm Management* 4 (4): 1–18.
- Ahmed, N., J. H. Brown, and J. F. Muir. 2008. "Freshwater Prawn Farming in Gher Systems in Southwest Bangladesh." *Journal of Aquaculture Economics and Management* 12 (3): 207–223.
- Ahmed, N., and S. T. Garnett. 2010. "Sustainability of Freshwater Prawn Farming in Rice Fields in Southwest Bangladesh." *Journal of Sustainable Agriculture* 34 (6): 659–679.
- Ahmed, N., and J. Luong-Van. 2009. "Can Rice–fish Farming Provide Food Security in Bangladesh?" *Aquaculture Asia Magazine* 14 (1): 18–23.
- Ahmed, N., K. K. Zander, and S. T. Garnett. 2011. "Socioeconomic Aspects of Rice–fish Farming in Bangladesh: Opportunities, Challenges and Production Efficiency." *Australian Journal of Agricultural and Resource Economics* 55:199–219.
- Asian Development Bank. 2005. *An Evaluation of Small-scale Freshwater Rural Aquaculture Development for Poverty Reduction*. Manila, Philippines.
- Bangladesh Rice Research Institute. 2010. *Rice Statistics in Bangladesh*. Gazipur, Bangladesh: Bangladesh Rice Knowledge Bank (BRKB).
- Barman, B. K., and D.C. Little. 2006. Nile Tilapia (*Oreochromis Niloticus*) Seed Production in Irrigated Ricefields in Northwest Bangladesh-an Approach Appropriate for Poor Farmers? *Aquaculture* 261:72-79.
- Beintema, N. M., and W. Kabir. 2006. *Bangladesh*. ASTI Country Brief No. 34. Washington, DC; Dhaka, Bangladesh: International Food Policy Research Institute; Bangladesh Agricultural Research Council.
- Belton, B., M. Karim, S. Thilsted, K. J. Murshed-e, W. Collis, and M. Phillips. 2011. *Review of Aquaculture and Fish Consumption in Bangladesh*. Studies and Reviews 2011-53. Penang, Malaysia: WorldFish Center.
- Biggs, S. 2007. "Building on the Positive: An Actor Innovation Systems Approach to Finding and Promoting Poor Natural Resources Institutional and Technical Innovations." *International Journal of Agricultural Resources Governance and Ecology* 6 (2): 144–164.
- Biswas, N. R. 2007. Impacts of Rice–fish Integration on Pesticide Use at Community Level in Northwest Bangladesh. MSc Thesis, Institute of Aquaculture, University of Stirling, UK.
- Clark, N., A. Hall, R. Sulaiman, and G. Naik. 2003. "Research as Capacity Building: The Case of an NGO Facilitated Post-harvest Innovation System for the Himalayan Hills." *World Development* 31 (11): 1845–1863.
- Dewan, S. 1992. "Rice–fish Farming in Bangladesh: Past Present and Future." In *Rice–Fish Research and Development in Asia*, ICLARM Conference Proceedings 24, edited by C. R. dela Cruz, C. Lightfoot, B. A. Costa-Pierce, V. R. Carangal, and M. P. Bimbao, 11–16. Manila, Philippines: ICLARM.
- Department of Agriculture Marketing. 2011. *Price Information*. Available [online]: <<http://www.dam.gov.bd>>. [Accessed September 2011]. Department of Agriculture Marketing, Government of Bangladesh, Dhaka.
- Dey, M. M., M. F. Alam, and M. L. Bose. 2010. "Demand for Aquaculture Development: Perspectives from Bangladesh for Improved Planning." *Reviews in Aquaculture* 2 (1): 1–17.
- Dey, M. M., M. F. Alam, and F. J. Paraguas. 2011. "A Multistage Budgeting Approach to the Analysis of Demand for Fish: An Application to Inland Areas of Bangladesh." *Marine Resources Economics* 26 (1): 35–58.
- Dey, M. M., R. M. Briones, Y. T. Garcia, A. Nissapa, U. P. Rodriguez, R. K. Talukder, A. Senaratne, I. H. Omar, S. Koeshendrajana, N. T. Khiem, T. S. Yew, M. Weimin, D. S. Jayakody, P. Kumar, R. Bhatta, M. S. Haque, M. A. Rab, O. L. Chen, L. Li, and F. J. Paraguas. 2008a. *Strategies and Options for Increasing and Sustaining Fisheries and Aquaculture Production to Benefit Poorer Households in Asia*. WorldFish Center Studies and Reviews No. 1823. Penang, Malaysia: WorldFish Center.

- Dey, M. M., Y. T. Garcia, P. Kumar, S. Piumsombun, M. S. Haque, L. Li, A. Adam, A. Senaratne, N. T. Khiem, and S. Koeshendrajana. 2008b. "Demand for Fish in Asia: A Cross-country Analysis." *Australian Journal of Agricultural and Resource Economics* 52 (3): 321–338.
- Dey, M. M., M. L. Bose, and M. F. Alam. 2008c. Recommendation Domains for Pond Aqua-culture. Country Case Study: Development and Status of Freshwater Aquaculture in Bangladesh. WorldFish Center Studies and Reviews No. 1872. Penang, Malaysia: WorldFish Center.
- Dey, M. M., and M. Prein. 2006. "Community Based Fish Culture in Seasonal Floodplains." *NAGA, WorldFish Center Quarterly* 29 (1/2): 21–27.
- Dey, M. M., M. Prein, A. B. M. Haque, P. Sultana, N. C. Dan, and V. van Nguyen. 2005. "Economic Feasibility of the Community Based Fish Culture in Seasonally Flooded Rice Fields in Bangladesh and Vietnam." *Aquaculture Economics & Management* 9:65–88.
- Douthwaite, B., A. Carvajal, S. Alvarez, E. Claros, and L. A. Hernandez. 2006. "Building Farmers' Capacities for Networking (Part I): Strengthening Rural Groups in Colombia through Network Analysis." *KM4D Journal* 2 (2): 4–18.
- Edquist, C., ed. 1997. *Systems of Innovation Approaches: Technologies, Institutions and Organizations*. London: Pinter.
- Ekboir, J. 2012. "How to Build Innovation Networks." In *Agricultural Innovation Systems Sourcebook*, edited by World Bank. Washington, DC: World Bank.
- Environmental Justice Foundation. 2004. *Desert in the Delta: A Report on the Environmental, Human Rights and Social Impacts of Shrimp Production in Bangladesh*. London.
- Food Planning and Monitoring Unit 2011. Bangladesh Country Investment Plan: A Road Map Towards investing in Agriculture, Food Security and Nutrition. Updated Version June, 2011. Food Planning and Monitoring Unit, Ministry of Food and Disaster Management, Government of the People's Republic of Bangladesh, Dhaka.
- Gupta, M. V., J. D. Sollows, M. A. Mazid, A. Rahman, M. G. Hussain, and M. M. Dey. 1998. *Integrating Aquaculture with Rice Farming in Bangladesh: Feasibility and Economic Viability, Its Adoption and Impact*. ICLARM Technical Report 55. Manila, Philippines: ICLARM.
- Halls, A. S., D. D. Hoggarth, and K. Debnath. 1998. "Impact of Flood Control Schemes on River Fish Migrations and Assemblages in Bangladesh." *Journal of Fish Biology* 53: 358–380.
- Halwart, M., and M. V. Gupta, eds. 2004. *Culture of Fish in Rice Fields*. Penang, Malaysia: FAO and WorldFish Center.
- Haque, A. B. M., L. E. Visser, and M. M. Dey. 2011. "Institutional Arrangements in Seasonal Floodplain Management under Community-based Aquaculture in Bangladesh." *Asian Journal of Agriculture and Development* 8 (1): 1–18.
- Haque, M., D. C. Little, B. Barman, and M. A. Wahab. 2010. "The Adoption Process of Rice field-based Fish Seed Production in Northwest Bangladesh: An Understanding through Quantitative and Qualitative Investigation." *Journal of Agricultural Education and Extension* 16 (2): 161–177.
- Haque, M. M. 2007. "Decentralised Fish Seed Networks in Northwest Bangladesh: Impacts on Rural Livelihoods." PhD Thesis, Institute of Aquaculture, University of Stirling, Scotland, UK.
- Hoggarth, D. D., V. J. Cowan, A. S. Halls, M. Aeron-Thomas, C. J. Caraway, A. I. Payne, and R. L. Welcomme. 1999. *Management Guidelines for Asian Floodplain River Fisheries. Part 2: Summary of DFID Research*. FAO Fisheries Technical Paper 384/2. Rome: United Nations Food and Agriculture Organization (FAO).
- Hossain, M. 2010. "Shallow Tubewells, Boro Rice, and their Impact on Food Security in Bangladesh." In *Proven Successes in Agricultural Development*, edited by D. J. Spielman and R. Pandya-Lorch. Washington, DC: International Food Policy Research Institute.

- Islam, N. M. 1996. "An Economic Study of Integrated Rice–fish Culture in Some Selected Areas of Mymensingh District." MS Thesis, Department of Agricultural Finance, Bangladesh Agricultural University, Mymensingh.
- Ito, S. 2002. "From Rice to Prawns: Economic Transformation and Agrarian Structure in Rural Bangladesh." *Journal of Peasant Studies* 29 (2): 47–70.
- Joshi, P., A. Gulati, and R. Cummings Jr., 2007. Agricultural diversification in South Asia: Beyond food security. In Joshi, P., A. Gulati, and R. Cummings Jr., (eds.) 2007. Agricultural diversification and smallholders in South Asia. New Delhi: Academic Foundation.
- Kumar, N., and A. R. Quisumbing. 2011. "Access, Adoption, and Diffusion: Understanding the Long-term Impacts of Improved Vegetable and Fish Technologies in Bangladesh." *Journal of Development Effectiveness* 3 (2): 193–219.
- Kunda, M. 2008. *The Potential of Inclusion of Freshwater Prawn and Mola in Rice-fish Culture Systems*. PhD dissertation submitted to the Department of Fisheries Management, BAU, Mymensingh.
- Kunda, M., M. E. Azim, M. A. Wahab, S. Dewan, M. A. Majid, and S. H. Thilsted. 2009. "Effects of Including Catla and Tilapia in a Freshwater Prawn-mola Polyculture in a Rotational Rice–fish Culture Systems." *Journal of Aquaculture Research* 40:1089–1098.
- Kunda, M., M. E. Azim, M. A. Wahab, S. Dewan, N. Roos, and S. H. Thilsted. 2008. "Potential of Mixed Culture of Freshwater Prawn (*Macrobrachium rosenbergii*) and Self-recruiting Small Species Mola (*Amblypharyngodon mola*) in Rotational Rice–fish/prawn Culture Systems in Bangladesh." *Journal of Aquaculture Research* 39:506–512.
- Kunda, M., M. A. Wahab, S. Dewan, M. Asaduzzaman, and S. H. Thilsted. 2009. "Effects of All-male, Mixed-sex and All-female Freshwater Prawn in Polyculture with Major Carps and Molas in the Fallow Rice Fields." *Journal of Aquaculture Research* 41:103–110.
- Lightfoot, C., A. van Dam, and B. Costa-Pierce. 1992. "What's Happening to Rice Yields in Rice–fish Systems?" In *Rice–fish Research and Development in Asia*, edited by R. dela Cruz, C. Lightfoot, B. A. Costa-Pierce, V. R. Carangal, and M. P. Bimbao. ICLARM Conference Proceedings 24. Manila, Philippines: ICLARM.
- Lundvall, B. 1992. *National Systems of Innovation*. London: Pinter.
- Malerba, F. 2002. "Sectoral Systems of Innovation and Production." *Research Policy* 31:247–264.
- Murshed-E-Jahan, K., and D. E. Pems. 2011. "The Impact of Integrated Aquaculture–agriculture on Small-scale Farm Sustainability and Farmers' Livelihoods: Experience from Bangladesh." *Agricultural Systems* 104:392–402.
- Mustafa, M. G., and A. C. Brooks. 2009. "A Comparative Study of Two Seasonal Floodplain Aquaculture Systems in Bangladesh." *Water Policy* 11 (Supp. 1): 69–79.
- Nabi, R. 2008. "Constraints to the Adoption of Rice–fish Farming by Smallholders in Bangladesh: A Farming Systems Analysis." *Aquaculture Economics and Management* 12:145–153.
- Rabbani, M. G. 1999. "An Economic Study on Alternate Rice–fish Culture in Selected Areas of Mymensingh District." MS Thesis, Department of Agricultural Economics, Bangladesh Agricultural University, Mymensingh.
- Rahija, M., S. M. M. Hossain, M. M. Rahman, and G.-J. Stads. 2011. *Bangladesh: Recent Development in Public Agricultural Research*. ASTI Country Note. Washington, DC; Dhaka, Bangladesh: International Food Policy Research Institute; Bangladesh Agricultural Research Council.
- Rahman, A. R., F. Heidhues, and K. Becker. 2005. *Socio-economic Impact of Rice-cum-fish Culture in Bangladesh*. The Global Food & Product Chain—Dynamics, Innovations, Conflicts, Strategies Conference Proceedings. Available [online]: www.tropentag.de/2005/proceedings/proceedings.pdf. Accessed September 2011. Stuttgart-Hohenheim, Germany: University of Hohenheim.

- Rahman, F. 2010. "Technological Interventions in Seasonal Floodplains under Community Based Fish Culture and Its Impact on Livelihood of the Beneficiaries in Bangladesh." PhD diss., Department of Fisheries Management, Bangladesh Agricultural University, Mymensingh.
- Rahman, S., B. K. Barmon, and N. Ahmed. 2011. "Diversification Economies and Efficiencies in a 'Blue-green Revolution' Combination: A Case Study of Prawn-Carp-Rice Farming in the 'Gher' System in Bangladesh." *Journal of Aquaculture International* 19:4665.
- Rashid, R., M. Ali, and D. Gisselquist. 2011. "Private Innovation and R&D in Bangladesh Agriculture: Description, Impact, and Policy Options." Mimeo, International Food Policy Research Institute; Rutgers University, Washington, DC; New Brunswick, NJ.
- Roy, N. 2005. "An Economic Analysis of Rice Fish Farming under the Northwest Fisheries Extension Project in Some Selected Areas of Dinajpur District." MS Thesis, Department of Agricultural Economics, Bangladesh Agricultural University, Mymensingh.
- Rycroft, R. W., and D. E. Kash. 1999. *The Complexity Challenge: Technological Innovation for the 21st Century*. New York: Cassell.
- Selim, N. M. 1994. *Development of "Bagda" Hatchery as a Strategy for Acceleration of Shrimp Aquaculture as an Industry in Bangladesh*. Dhaka: Bangladesh Frozen Foods Exporters Associations (BFFEA) Special Bulletin.
- Shankar, V., A. Halls, and J. Barr. 2004. "Fish versus Fish Revisited: On the Integrated Management of Floodplain Resources in Bangladesh." *Natural Resources Forum* 28:91–101.
- Sheriff, N., O. Joffre, M. C. Hong, B. Barman, A. B. M. Haque, F. Rahman, J. Zhu, H. van Nguyen, A. Russell, M. van Brakel, R. Valmonte-Santos, C. Werthmann, and A. Kodio. 2010. *Community-based Fish Culture in Seasonal Floodplains and Irrigations Systems*. Challenge Program on Water and Food (CPWF) Final Project Report No. CP35. Penang, Malaysia: WorldFish Center.
- Spielman, D. J. 2006. "A Critique of Innovation Systems Perspectives on Agricultural Research in Developing Countries." *Innovation Strategy Today* 2 (1): 25–38.
- Toufique, K. A., and R. Gregory. 2008. "Common Waters and Private Lands: Distributional Impacts of Floodplain Aquaculture in Bangladesh." *Journal of Food Policy* 33:587–594.
- Uddin, M. T., and H. Takeya. 2006. "Comparative Study on Integrated Farming in Bangladesh and Other Countries." *Bangladesh Journal of Agricultural Economics* 29 (1/2): 81–82.
- Wahab, M., M. Kunda, M. Ekram Azim, S. Dewan, and S. H. Thilsted. 2008. "Evaluation of Freshwater Prawn–Small Fish Culture Concurrently with Rice in Bangladesh." *Journal of Aquaculture Research* 39:1524–1532.

RECENT IFPRI DISCUSSION PAPERS

For earlier discussion papers, please go to www.ifpri.org/pubs/pubs.htm#dp.
All discussion papers can be downloaded free of charge.

1219. *Is MERCOSUR's external agenda pro-poor?: An assessment of the European union-MERCOSUR free-trade agreement on poverty in Uruguay applying MIRAGE*. Carmen Estrades.
1218. *Heterogeneous pro-poor targeting in India's Mahatma Gandhi national rural employment guarantee scheme*. Yanyan Liu and Christopher B. Barrett, 2012.
1217. *The impacts of public investment in and for agriculture: Synthesis of the existing evidence*. Tewodaj Mogues, Bingxin Yu, Shenggen Fan, and Linden McBride, 2012.
1216. *What determines public expenditure allocations?: A review of theories, and implications for agricultural public investment*. Tewodaj Mogues, 2012.
1215. *Nonlinear dynamics of livestock assets: Evidence from Ethiopia*. Bjorn Van Campenhout and Stefan Dercon, 2012.
1214. *An overview of Chinese agricultural and rural engagement in Tanzania*. Deborah Bräutigam and Xiaoyang Tang, 2012.
1213. *The partially liberalized cocoa sector in Ghana: Producer price determination, quality control, and service provision*. Shashidhara Kolavalli, Marcella Vigneri, Haruna Maamah, and John Poku, 2012.
1212. *Structural change in Argentina, 1935-60: The role of import substitution and factor endowments*. Dario Debowicz and Paul Segal, 2012.
1211. *Traceability in a supply chain with repeated moral hazard*. Alexander E. Saak, 2012.
1210. *Managing transition in Yemen: An assessment of the costs of conflict and development scenarios for the future*. Clemens Breisinger, Olivier Ecker, Perrihan Al Riffai, Wilfried Engelke, and Abdulmajeed Al-Bataly, 2012.
1209. *Bangladesh rice trade and price stabilization: Implications of the 2007/08 experience for public stocks*. Paul A. Dorosh and Shahidur Rashid, 2012.
1208. *Analyzing intersectoral convergence to improve child undernutrition in India: Development and application of a framework to examine policies in agriculture, health, and nutrition*. Rajani Ved and Purnima Menon, 2012.
1207. *Branding and agricultural value chains in developing countries: Insights from Bihar, India*. Bart Minten, K.M. Singh, and Rajib Sutradhar, 2012.
1206. *Costly posturing: Relative status, ceremonies, and early child development in China*. Xi Chen and Xiaobo Zhang, 2012.
1205. *Should private storage be subsidized to stabilize agricultural markets after price support schemes are removed?: A general equilibrium analysis applied to European reforms*. Fabienne Femenia, 2012.
1204. *Mapping the contemporary fertilizer policy landscape in Malawi: A guide for policy researchers*. Noora-Lisa Aberman, Michael Johnson, Klaus Droppelmann, Eva Schiffer, Regina Birner, and Peter Gaff, 2012.
1203. *The economic consequences of excess men: Evidence from a natural experiment in Taiwan*. Simon Chang and Xiaobo Zhang, 2012.
1202. *The value of customized insurance for farmers in rural Bangladesh*. Daniel Clarke, Narayan Das, Francesca de Nicola, Ruth Vargas Hill, Neha Kumar, and Parendi Mehta, 2012.
1201. *Gender assessment of the agricultural sector in the Democratic Republic of the Congo*. Catherine Ragasa, Annie Kinwa-Muzinga, and John Ulimwengu, 2012.
1200. *Toward an integrated approach for addressing malnutrition in Zambia: A literature review and institutional analysis*. Jody Harris and Scott Drimie, 2012.
1199. *Review of input and output policies for cereal production in Bangladesh*. Hemant Pullabhotla and A. Ganesh-Kumar, 2012.
1198. *Onset risk and draft animal investment in Nigeria*. Hiroyuki Takeshima, 2012.
1197. *Farmer groups, input access, and intragroup dynamics: A case study of targeted subsidies in Nigeria*. Lenis Saweda Liverpool-Tasie, 2012.

**INTERNATIONAL FOOD POLICY
RESEARCH INSTITUTE**

www.ifpri.org

IFPRI HEADQUARTERS

2033 K Street, NW
Washington, DC 20006-1002 USA
Tel.: +1-202-862-5600
Fax: +1-202-467-4439
Email: ifpri@cgiar.org