Universität für Bodenkultur Wien
University of Natural Resources
and Life Sciences, Vienna

Pathways towards organic aquaculture (shrimp): Challenges, potentials and risks under a livelihood perspective

Brojo Gopal Paul

Supervisor
Ao. Univ. Prof. Dr. Christian Reinhard Vogl

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Division of Organic Farming
Department of Sustainable Agricultural Systems

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Dedication

Dedicated to the sweet memories of my beloved grandmother

Late Jugal Dasi Paul – she blesses me from paradise

Declaration

I declare that this thesis is a presentation of my original research work, and has been composed entirely by myself, and no material in this thesis has previously been submitted to attain any other degree or qualification in any university.

To the best of my knowledge and belief, wherever contributions of others are involved, every effort is made to indicate this clearly and has specially been acknowledged by reference.

Brojo Gopal Paul

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Abstract

Increased international demand for seafood and the involvement of multinational corporations in the commercialization of organic seafood have greatly enhanced organic shrimp aquaculture practices in Bangladesh. Based on the example of organic shrimp farming in Bangladesh, this research examines whether conversion to an organic aquaculture system can be a viable option for improving the livelihoods of farmers. The shrimp industry employs approximately 1.2 million people in Bangladesh and provides livelihood for an estimated 4.8 million household members. Development agencies and companies are increasingly trying to utilize this potential by organizing organic farmers' groups, and linking them to the growing market demand in industrialized countries. The study was carried out in view of a sustainable livelihood approach of the Department For International Development, sustainability science defined by the World Commission on Environment and Development, and the diffusion of innovation theory developed by the rural sociologist Everett M. Rogers. Focus group discussions, transect walks, and questionnaire surveys were employed in 2009 with 144 organic, 60 conventional, and 60 integrated (with fish and rice) shrimp farmers. Negative criticisms such as mangrove destruction, salt water intrusion, water pollution, disease outbreak, low yield, high input cost, low price, market fluctuation, livelihood displacement, and social unrest have challenged and jeopardized the future growth of sustainable shrimp aquaculture. However, the results show that by substituting synthetic fertilizers and pesticides with locally available resources and family labor, organic shrimp farming in Bangladesh not only has the potential to improve natural resource management, but also to increase yield (320 kg ha^{-1} yr^{-1} in organic production compared to 226 kg ha^{-1} yr^{-1} in conventional production), to reduce production costs, and to obtain a better price for the produce (annually 10–20% higher in organic compared to conventional farmers). Surprisingly, organic shrimp farming did not require significantly more labor than conventional and integrated systems. Due to lower production costs and a price premium for "organic" food, the average annual gross margins from organic shrimp were higher (10–20%) than those of conventional and integrated systems. The greatest effect of organic aquaculture on the farm household was observed in income and employment. Lower production costs and higher incomes help organic shrimp farmers to minimize their vulnerability to uncertain causes such as occurrence of natural disaster, shrimp disease, and market demand fluctuations. The adoption of organic shrimp farming requires the farmer to acquire new knowledge and skills, and a change of attitude. The economic constraints of the conversion period emerged as an important entrance barrier to the adoption of organic shrimp farming, especially for small and medium scale farmers. Government, research organizations, development agencies, and multinational companies should work together to formulate integrated policies that will help organic shrimp farmers to reduce vulnerability, obtain certification, and overcome market fluctuations.

Key words: aquaculture, shrimp, organic farming, organic aquaculture land, income, input, Bangladesh.

Kurzfassung

Die zunehmende internationale Nachfrage nach Meeresfrüchten/Fisch, sowie der Einstieg internationaler Händler in die Vermarktung von ökologisch zertifizieren Meeresfrüchten/Fischen haben zu einer Ausdehnung der Flächen der ökologischen Aquakultur in Bangladesh geführt. Vor dem Hintergrund der boomenden Öko-Shrimp-Aquakultur in Bangladesh untersucht diese Doktorarbeit ob die Umstellung auf Öko-Shrimp ein gangbarer Weg für die Verbesserung der Lebenssituation (livelihood system) der lokalen Bevölkerung darstellen kann. Die Shrimp-Industrie beschäftigt in Bangladesh 1,2 Millionen Menschen direkt und stellt die Lebensgrundlage von weiteren 4,8 Millionen Menschen (Familienmitgliedern der direkt involvierten Personen) dar. Entwicklungsorganisationen und Unternehmen nutzen zunehmend das Potential der Öko-Shrimp-Aquakultur und helfen diese mit neuen Märkten und Abnehmern in Industrieländern zu vernetzen. Diese Dissertation nutzt den *sustainable livelihood approach* des Department For International Development, die Nachhaltigkeitsdebatte wie von der World Commission on Environment and Development erarbeitet und die Diffusionstheorie des Soziologen Everett M. Rogers als theoretische Grundlagen. Im Jahr 2009 wurde mit 144 ökologisch, 60 konventionell und 60 integriert arbeitetenden Aquakulturbauern und –bäuerinnen Fokus-Gruppen und *transect walks* durchgeführt sowie Fragebögen angewendet. Die Zerstörung der Mangrovenwälder, das Eindringen von Salzwasser , Wasserverschmutzung, das Ausbrechen von Krankeiten in Shrimpsbeständen, geringe Erträge, hohe Kosten für Betriebsmittel, geringe Marktpreise für Shrimp, sich laufend änderne Weltmarktpreise für Shrimp bis hin zu Vertreibung von Bauern und soziale Unruhen sind einige der in der Literatur wahrgenommenen Problemkreise rund um die herkömmliche Art der Shrimp-Produktion. Die eigenen Ergebnisse dieser Dissertation zeigen, daß die Substitution synthetischer Betriebsmittel (Dünger und Pestizide) durch lokal verfügbare Ressourcen und Familienarbeitskräfte nicht nur einem Schutz der natürlichen Ressourcen, sondern auch zu ansteigenden Erträgen (ökologische Produktion 320 kg ha^{-1} yr^{-1} im Vergleich zu 226 kg ha^{-1} yr^{-1} in konventioneller Produktion), abnehmenden Produktionskosten, und besseren Produktpreisen führt (jährlich 10-20% höhere Bruttogewinnspanne im Vergleich zu konventioneller Produktion). Unerwarteter Weise führte die Öko-Shrimpproduktion zu keinem signifikant höheren Arbeitskräftebedarf im Vergleich zu konventioneller oder integrierter Shrimp-Produktion. Durch geringere Produktionskosten und den Premium-Aufpreis für Öko-Ware war die durchschnittliche Gewinnspanne für Öko-Shrimp besser als jene für konventionelle oder integrierte Produktion. Den größten Effekt hatte die Öko-Shrimp-Produktion auf die Haushalte (Einkommen und Beschäftigungsrate) der Aquakultur-Bauern und –Bäuerinnen. Geringere Produktionskosten und ein höheres Einkommen führen zu einer Abnahme der Vulnerabilität gegenüber Naturkatastrophen, Produktionseinbußen durch Krankeiten in Shrimpsbeständen und Schwankungen der Preise am Markt. Die Umstellung auf Öko-Shrimp-Aquakultur forderte von den Bäuerinnen und Bauern die Aneignung neuen Wissens und neuer Fertigkeiten, sowie eine Veränderung ihrer Einstellungen. Die ökonomischen Herausforderungen in der Umstellung waren das zentrale Hindernis für eine Umstellung insbesondere bei Kleinbauern. Die Regierung, Forschungsinstitutionen, Entwicklungsorganisationen und multinationale Vermarkter sollten enger zusammenarbeiten und könnten mit aufeinander abgestimmten Schritten besser dazu beitragen die Vulnerabilität von Kleinbauern und Kleinbäuerinnen, die Shrimp produzieren, zu reduzieren, eine Öko-Zertifizierung zu erlangen und die Schwankungen der Preise am Markt auszubalancieren.

Schlagworte: Aquakultur, Shrimp, Meeresfrüchte, Ökologischer Landbau, Biologische Landwirtschaft, Ökologische Aquakultur, Einkommen, Betriebsmittel, Bangladesch.

List of Acronyms

AIDS	Acquired Immunodeficiency Syndrome
BFFEA	Bangladesh Frozen Food Exporters Association
BRAC	Bangladesh Rural Advancement Committee
CARE	Cooperative for Assistance and Relief Everywhere
CBRM	Community Based Resource Management
DANIDA	Danish International Development Agency
DFID	Department For International Development
DoF	Department of Fisheries
EC	European Commission
EEC	European Economic Community
EU	European Union
FAO	Food and Agriculture Organizations in the United Nations
FRI	Fisheries Research Institute
GDP	Gross Domestic Product
GMO	Genetically Modified Organisms
HIV	Human Immunodeficiency Virus Infection
IFOAM	International Federation of Organic Agriculture Movements
IMO	Institute for Market Ecology
IUCN	International Union for the Conservation of Nature
KRAV	Swedish Development Organization
MDG	Millennium Development Goals
NASAA	National Association for Sustainable Agriculture, Australia
NGO	Non Government Organization
OFDC	Organic Good Development and Certification Centre of China
OSP	Organic Shrimp Project
PRA	Participatory Rural Appraisal
SIPPO	Swiss Import Promotion Program
UN	United Nations
UNDP	United Nations Development Programs
USAID	United States Agency For International Development
USDA	United States Department of Agriculture
WCED	World Commission on Environment and Development
WWF	World Wildlife Fund

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Structure of the thesis

This thesis is presented in three parts. The background of the research is discussed in the first part and a general introduction to aquaculture is given. The importance and details of shrimp farming are discussed with respect to organic aquaculture principles, actors’ involvement, and current trends. The rationale for the study and the problems encountered in doing this type of research are described and the objectives of the study are stated. The theory and concepts of the research and the methodology involved are defined in the first part of the thesis as well. The second part presents the results of the studies which were compiled in four manuscripts published in peer reviewed journals. The third part of the thesis provides a general discussion of the study’s contributions to the field and the implications of the work to organic shrimp farming. A short overview of the outcomes of the study and recommendations for future research that will enrich farmers' knowledge and hopefully impact policy makers’ decisions concludes the thesis.

PART – 1

General Background, Research Topics and Theoretical Insights

1. General introduction

In September 2000, eight Millennium Development Goals (MDGs) were agreed upon at the United Nations (UN) Millennium Summit, and by 2002, 193 nations had adopted these goals (UNDP, 2012). In relation to the goals defined at the UN summit, Bangladesh has recorded impressive achievements in pulling people out of poverty, increasing enrolment in primary education, encouraging gender parity in primary and secondary education, reducing child and maternal mortality and improving immunization coverage, rolling back malaria and controlling tuberculosis, and improving drinking water supplies and sanitation. However, in a UN development report in 2012 (UNDP, 2012), it was observed that the areas in need of more attention are chronic hunger-poverty reduction and employment generation, increases in the primary school completion rate and adult literacy rate, creation of more decent wage employment for women, increases in the presence of skilled health professionals at child delivery, increases in correct and comprehensive knowledge of HIV/AIDS, increases in forest coverage and coverage of information and communication technology. Fisheries and aquaculture contribute to attaining the eight MDGs goals, both directly via specific goals and indirectly to all MDGs through enhancing livelihoods (World Fish Center, 2007).

Fisheries and aquaculture make conspicuous contributions to the world's well-being and prosperity. From 1961 to 2009, the global fish food supply underwent an average growth rate of 3.2% per year, outpacing the increase of 1.7% per year in the world's population (FAO, 2012). World per capita food fish supply has increased from an average of 9.9 kg (live weight equivalent) in the 1960s to 18.6 kg in 2010, which indicates that fish constitutes an important source of nutritious food and animal protein for much of the world's population (FAO, 2012). In the last three decades (1980–2010), world food fish production via aquaculture has expanded by almost 12 times, at an average annual rate of 8.8% (FAO, 2012). In addition, fisheries and aquaculture provided livelihoods and income for an estimated 54.8 million people engaged in the primary sector of fish production in 2010, of which an estimated seven million were occasional fishers and fish farmers (FAO, 2012). Considering both direct and indirect employment, fisheries and aquaculture share a significant portion of the world's population.

Fisheries and aquaculture play vital roles in alleviating protein shortage, providing jobs for unemployed youth, earning foreign currencies, and enhancing the socioeconomic development of Bangladesh. The fisheries sector contributes 4.43% to the national GDP and 22.21% to the agricultural GDP in Bangladesh (DoF, 2012). Fish alone constitutes about 60% of the animal protein in the daily dietary requirement (DoF, 2012). The country's export earnings from the fisheries sector was 2.73% in 2010–2011 (DoF, 2012). The average growth rate of this sector during the last three years was 6.11%. About 10% of the total population obtains a livelihood directly or indirectly from the fisheries sector (DoF, 2012). The fisheries resources of Bangladesh are divided into three groups: inland capture, marine capture, and inland culture (DoF, 2012). Inland capture fisheries resources consist of 4.0 million ha of open water which includes rivers, estuaries, beels (natural depressions), polders (enclosures) and flood plain, and 0.68 million ha of closed water which includes ponds, ditches, shrimp/prawn farms, and semi closed water bodies (DoF, 2012). The total fish and fisheries production in 2010–2011 was 3.0 million metric tonnes, of which 47.71% was from inland culture, 17.84% was from marine capture, and 34.45% was from inland capture fisheries (DoF, 2012). However, due to environmental degradation and increased fishing by a growing population, the harvest from inland capture fisheries had declined to about 34% of total fisheries production by 2011 and currently aquaculture has been replaced as a top fish producing source. Meanwhile, shrimp aquaculture has been promoted in Bangladesh with an increase of shrimp farm area from 0.14 million ha in 2002–2003 to 0.28 million ha in 2010–2011, which has resulted in an increase in shrimp farm production from 0.07 million metric tonnes in 2002–2003 to 0.18 million metric tonnes in 2010–2011 (DoF, 2012).

Shrimp is a high value, popular seafood commodity consumed mainly by the rich people in industrialized countries in Europe, North America, and Japan. Penaeid shrimps comprise around 80% of the total farmed shrimp production (FAO, 2009) and globally traded aquaculture products, while being one of the most emotive and politically polarizing production systems in coastal areas (Stonich and Bailey, 2000; Bene, 2005; Vandergeest, 2007). Shrimp is mainly cultivated in tropical areas of Asia and Latin America. Diverse species of shrimp are cultured in different countries. In eastern hemisphere especially Asian countries, black tiger shrimp (*Penaeus monodon*; Fabricius, 1798) is the main cultured species followed by white shrimp (*Penaeus merguiensis*, *Penaeus indicus, and Penaeus chinensis)* and fresh water giant prawn (*Macrobrachium rosenbergii*), whereas in western hemisphere countries the dominant cultured species is the white shrimp (*Penaeus vannamei and Penaeus penicillatus*). Green tiger shrimp (*Penaeus semisulcatus and Penaeus vannamei*) was recently introduced in Asia (China and Vietnam) (Rahman et al., 2006b). Shrimp is cultivated following the methods favored in the shrimp growing countries. Thailand, Indonesia, Philippines, and China produce shrimp using intensive cultivation with high input and realize high products per hectare and great economic gains per year. India and Vietnam follow semi-intensive shrimp farming using extensive and traditional methods. Semi-intensive shrimp farming was introduced in Bangladesh in the early 1990s, but the shrimp ponds of semi-intensive farms were abandoned after frequent crop failures due to virus attacks in the mid-1990s. Currently, many farmers in Bangladesh follow improved extensive shrimp farming with limited feed supply and water control systems, but a few of them also follow the traditional method of shrimp farming without many additional inputs. Farmers in some of the moderate salinity zones in the country practice shifting and mixed cultivation. They farm shrimp in the dry season in their ponds followed by rice, fin fish, and shrimp in the rainy season (Rahman et al., 2006b).

About 25 species of freshwater prawn and 36 species of marine shrimp can be found in Bangladesh (Rahman et al., 2006a). *Macrobrachium rosenbergii*, locally known as Galda, is the most important among the freshwater species and is cultivated commercially in Bangladesh. The most important marine/salt water shrimp is *Penaeus monodon*, locally called Bagda, the giant black tiger, and is the target species for brackish water farming in Bangladesh. Brackish water shrimp farming in the coastal region of Bangladesh, particularly in the southwest (Khulna region), has been practiced for centuries. Before 1960, shrimp farming was carried out for local consumption using earthen dyked areas called “bheri” in rice fields in the tidally inundated zone where juvenile shrimp entered *ghers* (shrimp ponds) through tidal flows. This type of shrimp farming was locally known as bheri culture and would take place from January to July followed by rice cultivation during the monsoon (Rahman et al., 2006a). In the past, one rice crop was grown in the tidally affected coastal zone and was often damaged by cyclones, tidal surges or unusual tidal movements, and high saline water. To diversify and to protect the agricultural crop from damage, the Bangladesh government constructed coastal embankments during the 1960s. This resulted in a change in the ecosystem of the coastal zone and traditional shrimp farming under the bheri system almost stopped (Rahman et al., 2006a).

After the liberation of Bangladesh in 1971, the high demand and high prices for shrimp in foreign markets motivated influential and wealthy people to start shrimp farming on a commercial basis. Their method was to trap shrimp larvae/fry entering the ponds with the tidal water by cutting embankments illegally and using indigenous wooden sluice gates. The culture system that resulted was rudimentary and traditional in nature. Farm size was large with no artificial feeding and fertilization, and production rate per hectare was very low. The government took several initiatives for technological development, management, and market promotion in the sector to increase production and export earnings. The government instituted special development projects for the improvement of farming technology and infrastructure to develop proper water supplies to shrimp farms, proper extension services, and supports for quality control of products for export. The government also took administrative measures to resolve social and other problems that arose out of shrimp farming in the coastal region. The government declared shrimp aquaculture an industry and gave tax holidays and financial support. Consequently, shrimp farming expanded rapidly in the coastal zone, particularly in Satkhira, Khulna, Bagerhat, and Cox's Bazar districts where suitable environments for shrimp farming (tidal inundation and saline water) existed (Rahman et al., 2006a).

The shrimp farming system can be classified into three types according to the cropping pattern (Rahman et al., 2006a):

(a) *Monoculture* (shrimp cultivation only): In high saline zones of Satkhira and Cox's Bazar, where salinity ranges from 5 to 18 ppt for 8–9 months of the year, only shrimp is cultivated for most of the year;

(b) *Shrimp alternating with rice and fish*: Common in Khulna, Bagerhat, and part of Satkhira districts where salinity is medium to low. Shrimp are grown from January/February to July when the salinity is favorable for shrimp farming, and transplanted rice (Aman) is grown from August to December when the salinity declines due to monsoon rainfall and upstream runoff. Farmers also cultivate fin fish with rice during the rainy season; and

(c) *Shrimp alternating with salt and fin fish*: This system of farming is practiced in Cox's Bazar where salinity is very high. The land is used for salt production from December to May and shrimp culture from June to September/October. Farmer's usually stock shrimp fry in the canals inside the farm during February/March and after salt production the land is inundated with tidal water. Many farmers in Cox's Bazar and in Satkhira also cultivate fin fish along with shrimp.

To explore the opportunities and to constitute an ethical sustainable shrimp production, an Organic Shrimp Project (OSP) was initiated in the southwest of Bangladesh in 2005. The OSP is a significant small holder project for organic shrimp production in the region of Satkhira in the southwest of Bangladesh. It was initiated by the Swiss Import Promotion Programme (SIPPO) and implemented in partnership with the local NGO Shushilan, with the goal of promoting small and medium enterprises through providing training and consultation services and facilitating trade. When in 2007 the focus of SIPPO shifted toward Europe, Africa, and Latin America, the service providing organization, Euro Centra (a member of the Wünsche business group), took over the responsibilities of the OSP but discontinued activities in 2007. As successor, the Germany based importing organization, WAB Trading International (Asia) Ltd. continued the OSP operations, with Gemini Sea Food Ltd. as the processor in Bangladesh. Organic shrimp farming in Bangladesh follows the criteria of the EU and other regulations to minimize adverse effects on the environment. This means: (i) protection of adjacent ecosystems; (ii) prohibition of the use of chemicals; (iii) natural treatment in case of disease; (iv) employment of only natural and necessary inputs; and (v) prohibition of the use of genetically modified organisms (Hensler, 2013).

2. Current Trends, Actors, Principles, Standards, Regulations, and Certification in Organic Aquaculture

2.1. Current trends in organic aquaculture

According to the IFOAM (International Federation of Organic Agriculture Movements), organic production dramatically reduces external inputs by prohibiting the use of chemosynthetic fertilizers, pesticides, pharmaceuticals, and feed additives, while encouraging natural ecological processes, biodiversity, and the use of locally available resources (IFOAM, 2008). Even though organic aquaculture is still relatively new in concept and a very recent development, it has attracted the attention of both researchers and industry (Pelletier, 2003; Bergleiter et al., 2009; Perdikaris and Paschos, 2010). Historically, organic aquaculture is rooted in the organic agriculture movement. However, the practice of organic aquaculture is ancient, especially in Asia and particularly in China.

The first organic aquaculture initiatives were developed in the mid-1990s as an alternative and innovative culture system (Bergleiter et al., 2009). The organic movement throughout the world is continuously growing with 35 million hectares of agricultural land being presently farmed. In contrast, only 0.43 million hectares of aquacultural land are managed organically (Willer and Kilcher, 2010). Accordingly, the global production of certified organic aquaculture products was estimated to be about 5,000 tonnes in 2000 (Tacon and Brister, 2002). In 2008, there were 225 certified organic aquaculture operations in 26 different countries, with an overall production of 53,000 tonnes (Bergleiter et al., 2009). These facts demonstrate a 950% increase in seven years. According to Bergleiter et al. (2009), production is expected to increase further to 38% by the end of 2009 (Figure 2.1). It is predicted that the production of organic aquaculture will increase 240-fold by 2030, i.e., to 0.6% of total aquaculture production (FAO, 2002).

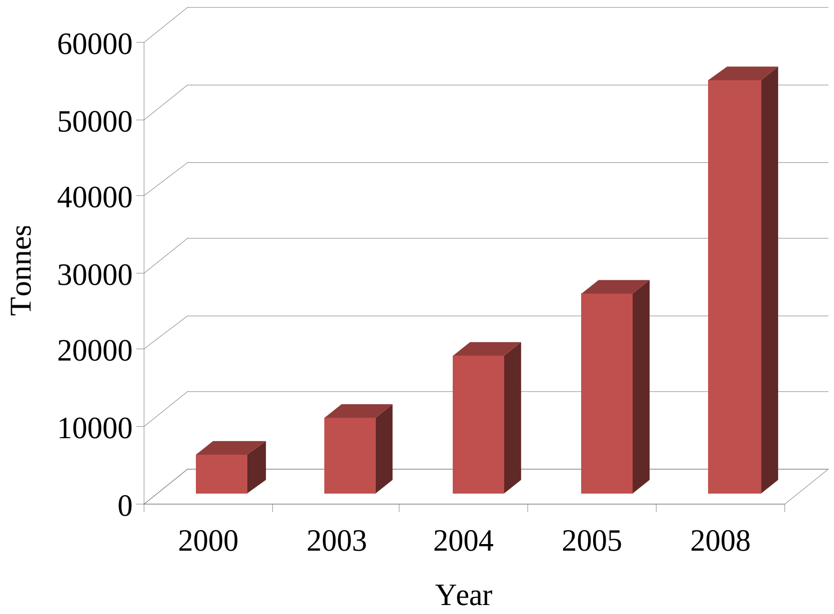

Figure 2.1. Development of organic aquaculture production (Bergleiter et al., 2009).

Even though the growth in organic aquaculture production has been impressive, the current production still represents only one thousandth of the total global aquaculture production (approx. 64 million tonnes in 2011 according to FAO, 2012). The number of certified producers per continent is shown in Table 2.1 as well as the production per continent. The arrows in the last column of the table indicate the trends in production, as reported by the certification body in charge (Bergleiter et al., 2009).

Table 2.1. Certified organic aquaculture producers per continent: number, production, and trends (Bergleiter et al., 2009)

Continent	Number of operations	Production (Tonnes)	Emerging trends
America	14	7,000	↑
Europe	123	24,500	↑↑
Asia	75	19,000	↑↑↑
Africa	1	2,000	↑
Australia/ New Zealand	12	<1,000	↑

In Europe, 87%–93% of the certified organic aquaculture products come from marine and brackish water sources. Almost 50% of all organic certified fish (by weight) are still being produced in Europe, but Asia is catching up with 36% and Latin America already has a stake of 13% (Bergleiter et al., 2009). Globally, organic aquaculture is limited to a few species, mainly shrimp, salmon, trout, and carp (FAO, 2002; GLOBEFISH, 2005). The current trends of species distribution in organic aquaculture shows that the majority of the production is trout (36%), followed by organic shrimp (18%), whereas salmon holds third place at 14% (Bergleiter et al., 2009). The details of species distribution are shown in Figure 2.2.

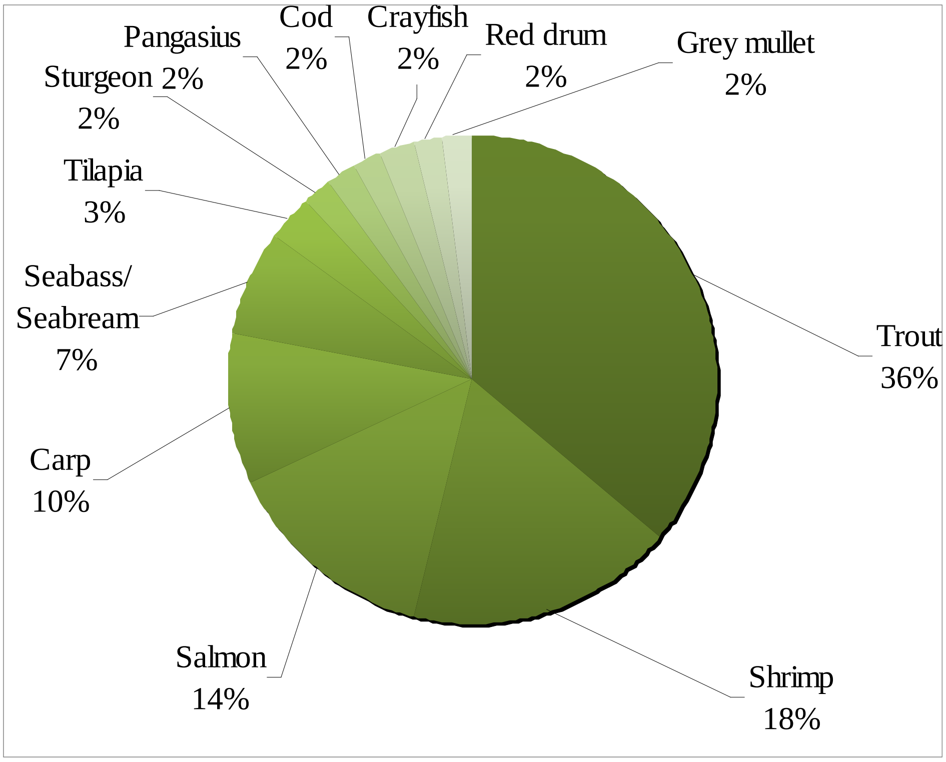

Figure 2.2. Distribution of aquatic species in organic farming (Bergleiter et al., 2009).

When making individual country comparisons, China is the frontrunner with a production of 15,300 tonnes, followed by the United Kingdom (9,900 tonnes) and Ireland (7,500 tonnes). Ecuador is in fourth place with 5,800 tonnes (Bergleiter et al., 2009). In regard to the production quantity, salmon is the leader with 16,000 tonnes production worldwide, followed by organic shrimp (8,800 tonnes) (Bergleiter et al., 2009). Most of the aquaculture companies rear only one species although two or more species can be an option for their aquaculture system. About a fifth (21%) of the operators practice polyculture, primarily rearing carp in combination with tench, grass carp, and pike. Organic aquaculture has attracted attention due to consumers' awareness of overfishing, environmental degradation, health risks, sustainability, and animal welfare issues associated with conventional aquaculture (Lien and Anthony, 2007; Biao, 2008).

2.2. Actors in the organic aquaculture sector

The organic aquaculture sector involves a heterogeneous group of actors. The principal actors, especially in organic shrimp production, are the producer, the consumer, official agencies, and lending institutions. Potential actors are hatchery and nursery authorities, farmers (small-scale and large-scale), input suppliers, middlemen, processors, exporters, and importers. Third-party certifiers, NGOs, and government also play conspicuous roles. The key actors in organic aquaculture are identified in Figure 2.3.

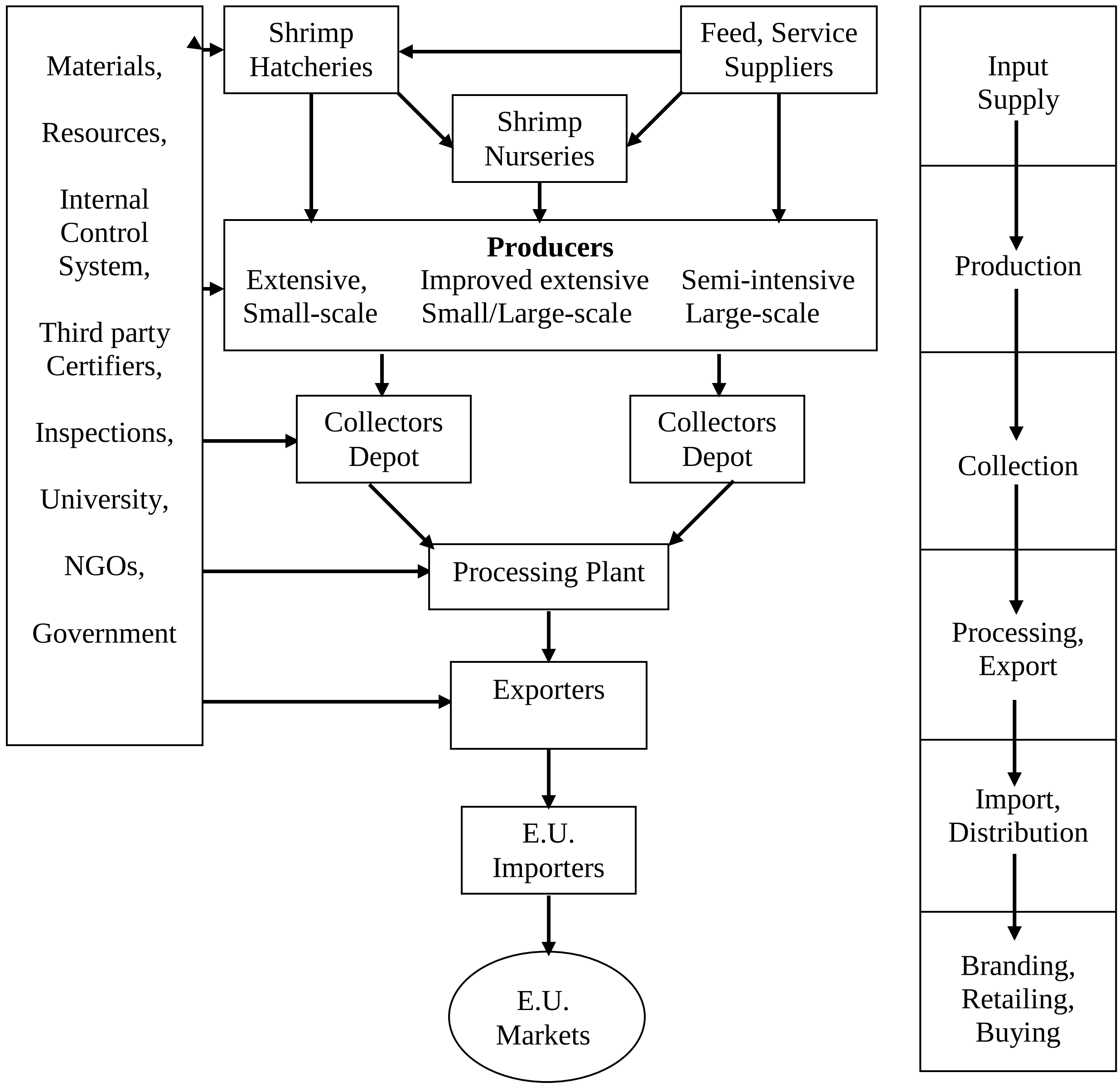

Figure 2.3. Key actors in the organic shrimp aquaculture supply chain in Bangladesh (Nhuong et al., 2011).

Organic shrimp farming has advanced because it integrates the whole production chain, from collection of larvae to export. Before cultivation, hatcheries produce post larvae. They can collect post larvae from wild sources such as estuaries and coastal rivers, although stocking of wild post larvae in organic shrimp ponds is prohibited due to environmental concerns. Before stocking the pond, post larvae stays in the nursery pond for couple of days to become familiar with the local water. Farmers stock post larvae in their farms/ponds and the shrimp grows until it is about four months old. At this age, the shrimp has the urge to travel back to the sea to breed. When the moon is in the correct phase and the tides are high, the shrimp start to travel and swim around the pond to find a way out. But the farmer has put net traps in the pond to trap adult shrimp. Many inputs and much technology used by other industries are involved in shrimp farming. In organic shrimp farming, famers carry their produced shrimp directly to local depots established for organic products. In conventional shrimp farming a middleman delivers the farmers' shrimp to a processing plant.

In the depot, the shrimp are weighed and stored in ice to maintain quality. Then a truck picks up the shrimp from different depots and takes them to the processing plant. When the shrimp reach the processing plant, they are washed and sorted by an automatic machine, the heads are removed by the processing workers (mainly female), they are washed again, gutted and cleaned inside, frozen, packed, and stored in a package that is ready for export. The shrimp from the processing plant are monitored by national fish inspection and quality control services to make sure that they are of good quality, with no traces of pesticides or antibiotics. They approve permission for export. When the shrimp arrives in Europe, it enters the retail or food service chain and is likely sold to a supermarket from where it can be purchased by a restaurant or a private consumer.

NGOs are important actors in promoting organic aquaculture through different sustainable development programs. These programs are oriented to issues such as feasibility study, training, advocacy, credit support, and rural development. As recently as 2005, organic aquaculture was not considered to be an important activity by the Bangladesh government. Accordingly, no policies were implemented to support the organic sector. Importers (WAB Trading International Ltd.) organized in farmers associations or cooperatives collaborated with local partner organizations to produce organic shrimp in Bangladesh in 2005. The internal control system of the organic shrimp project comprises quality management procedures, training, and inspection. Currently, WAB farmers are certified to be organic farmers following European Union (EU) organic regulations. This certification is underwritten by the private German organic farmers association 'Naturland' and monitored by an independent third party certifier, the Institute for Market Ecology (IMO).

2.3. Organic aquaculture principles and guidelines

The main principles of organic aquaculture are listed below (Naturland, 2011).

1. absence of GMOs (genetically modified organisms) in (brood-, seed-) stocks and feed focusing on vegetable feed ingredients (e.g., soy beans) and feed additives derived from biotechnology, as well as on transgenic, triploid, and all-female stock
2. limitation of stocking density; considering ecological capacity of site and species-specific behavior of animals
3. origin of feed and fertilizer from certified organic agriculture, no artificial feed ingredients; basic principles of organic production: networking of organic operations
4. criteria for fishmeal sources; in general, decreased protein and fishmeal content of diets; trimmings of fish processed for human consumption or by-catches; no dedicated fishmeal harvesting operations are permitted
5. no use of inorganic fertilizers; basic principles of organic production: recycling of nutrients instead of intensive input
6. no use of synthetic pesticides and herbicides; basic principle of organic production: maintaining natural diversity on the farm area
7. restriction of energy consumption (e.g., regarding aeration) as a general trend; de-intensification of operations, lowering of input
8. preference of natural medicines; no prophylactic use of antibiotics and chemotherapeutics, no use of such substance in invertebrate aquaculture
9. intensive monitoring of environmental impact, protection of surrounding ecosystems and integration of natural plant communities in farm management; focusing on the effluents of farms and the design of farm ponds
10. processing according to organic principles; basic requirement for final products to be certified as organic

According to Naturland (2011), supplementary regulations for the pond culture of shrimp **(**e.g., *Litopenaeus vannamei*, *Penaeus monodon*, *Macrobrachium rosenbergii*) are described below and these regulations are presented in this thesis as a direct verbal quote from the original Naturland document.

Principle 1: Site selection, protection of mangroves

1.1. Mangrove plant communities have to be protected. Mangroves are considered as extremely important ecosystems that, at the same time, are endangered world-wide by human activities. Therefore, it is not permitted to remove or damage mangrove forest for purposes of construction or expansion of shrimp farms. Any measure carried out by the farm or on the farm's demand likely to influence an adjacent mangrove forest (e.g. construction of pathways and channels to the farm area) shall be announced to and approved by Naturland.

1.2. Farms (here: independent, coherent production units), which in parts occupy a former mangrove area, can be converted to organic aquaculture according to Naturland standards if the former mangrove area does not exceed 50% of total farm area (under specific geographical or historical conditions exceptions can be made for extensive mangrove aquaculture systems). A precondition, however, is that in any case the relevant legal requirements for land use, reforestations, etc., have been observed. The former mangrove area in the property of the farm shall be reforested to at least 50% during a maximum period of 5 years. The harvest of this area is not permitted to be labeled and marketed as an organic product according to Naturland standards until Naturland's certification committee has confirmed the successful completion of reforestation. Furthermore, the yearly progress in reforestation activities as laid down in the conversion plan shall be confirmed by the certification committee.

Principle 2: Protection of ecosystems—farm area and surroundings

2.1. Effluent water quality (ammonia, dissolved oxygen, biological oxygen demand, phosphate, suspended solids) has to be monitored and documented on at least a monthly basis by the farm.

2.2. Adequate measures must be taken to minimize the outflow of nutrients and/or suspended solids, especially during harvesting. Organic sediments shall be removed on a regular basis from the channels and brought to appropriate utilization (e.g., as fertilizer in agricultural units).

2.3. Adjacent agricultural areas shall be influenced negatively neither by saline water filtering from the ponds nor by scattered salt dust. If there are indications of adverse effects (e.g., yellowing of plants on the borders), adequate preventive measures (e.g., construction of drainage channels, plantation of salt-resistant, high-growing grasses, e.g., *Setifer zizanioides*) must be taken.

2.4. In order to stabilize/enhance the ecological system and the natural dynamics on the farm area, at least 50% of the total dyke surface shall be covered by plants. This state shall be reached during a maximum period of three years. Recommended plant species are, e.g., leguminosae trees (e.g., *Algorrobo spp.*), aloe, and others for the tops of the dykes, mangrove species, semiaquatic herbs, and floating grasses for the lower parts of the slopes. Farms situated in areas originally free from vegetation (e.g., dunes, desert) are excluded from this requirement.

2.5. In order to find an ecologically adequate and economically effective management against predatory birds, documentation on foraging predators, estimated harvest losses, and type of preventive measures shall be kept. It is recommended to raise ducks in the ponds that will expel intruding birds from their breeding territories. Native animals (e.g., ant-eaters, iguanas, wild cats, and migrating water birds) shall be protected as indicators for an intact environment.

2.6. Unwanted fish in the ponds shall be regulated only by mechanical means (e.g., seining) or by application of natural, herbal ichtyocides (e.g., barbasco, saponine). The use of synthesized herbicides and pesticides, except those permitted on the farm area, is not allowed.

2.7. Release of toxic or otherwise harmful substances in the ponds, the channels, or the banks shall be prevented. This applies especially to installation and management of pumping stations (e.g., oil spoilage), harvesting technique, as well as the overall hygienic conditions on the farm.

Principle 3: Species and origin of stock

3.1. Species naturally occurring in the region shall be preferred as stock. If other species are kept, ecological harmlessness of this measure must be proved (e.g., by relevant scientific studies). Diversification in the species cultivated is recommended. This can be achieved either by polyculture systems (e.g. shrimps, tilapia, ducks) or by separate production of different shrimp species.

3.2. If available, stock from certified organic origin has to be used. If stock from nonorganic origin is used, the respective timetable has to be complied with. Collecting wild shrimp larvae is prohibited. It is the declared objective to become fully independent from collecting wild post larvae or brood stock, and to use only stocks obtained through reproduction in captivity (‘closed cycle’).

3.3. Feral larvae of fish and crustaceans are allowed for stocking only if there is a passive inflow when the ponds or other aquaculture constructions are refilled. Mussel larvae are also allowed for stocking if they have settled on substrate that has been especially introduced for this purpose.

Principle 4: Hatchery management

4.1 In hatchery management, the use of antibiotics, chemotherapeutics, and comparable substances is prohibited.

4.2. Alimentation of parent stock and larvae as well as culture of feed organisms (algae, *Artemia salina*, rotifers) in the hatcheries is carried out according to the principles of organic agriculture. Administration of untreated seafood (e.g., fish, worms, mussels) as a protein supplement for parent stock is permitted. Measures that enrich the larval environment (e.g., by providing special substrates) and increase the productivity of the rearing tanks/nursery ponds (culture of feed organisms) are recommended.

4.3. Physical manipulations of the animals for obtaining eggs are principally prohibited. If dealing with species that, at present, provably cannot be reproduced without such manipulations (principally Black Tiger shrimp/*Penaeus monodon*), the hatchery must run a program dedicated to achieve natural reproduction. This program consists as a general rule in keeping a part of parent stock (benchmark: 10% of total stock) at low stocking density to provide an opportunity for natural mating. Subsequently, the offspring of this program is systematically propagated and reintroduced in this program’s population.

4.4. With culture of brood stock and larvae as well as feed organisms in the hatchery, technical measures for aeration, artificial lighting, and heating shall be decreased as much as possible.

Principle 5: Pond design, water quality, and stocking density

5.1. Efforts shall be made to support the natural foraging behavior of shrimp, being typical feeders of benthic microorganisms and detritus, by an adequate pond design (e.g., by providing substrates that enlarge the surface to be suitable for growth of benthic algae/diatoms).

5.2. In order to decrease energy consumption as well as nutrient losses by the farm, efforts shall be made toward the lowest possible water exchange rate. Pumping periods shall be limited to high tide, and unnecessarily protruding (in altitude) pipes shall be avoided; both efforts will help to minimize energy consumption. Data regarding energy consumption/area shall be carefully recorded by the farm operator and recorded during the annual inspection.

5.3. A provisional maximum for stocking density shall be set to 15 post larvae/m^2. Shrimp biomass in the ponds shall not exceed 1600 kg/ha. Calculation of the feed conversion ratio serves as an additional indicator for maintaining a permissible stocking density.

Principle 6: Health and hygiene

6.1. Particular stress shall be laid on preventive measures (e.g., controlled origin of larvae, monitoring of water quality, and ecological conditions in the ponds). Application/culture of (nongenetically modified) probiotic microorganisms in the ponds is permitted.

6.2. Health status of animals shall be monitored and documented on a regular basis. Special efforts shall be made to detect correlation between management measures, manifestation of viral diseases, reasons for mortalities, individual growth, and yields/biomass development.

6.3. Treatment of shrimp with antibiotics, chemotherapeutics, and comparable substances in the ponds is not permitted.

6.4. After harvest, the pond bottom shall be given enough time to dry. Waterfowl shall be allowed to forage on the drying bottom for remaining fish and invertebrates. Additional measures (e.g., ploughing, intermediate cultures such as Salicornia) shall be considered after several production cycles for recovery of the pond bottom.

Principle 7: Fertilizing of ponds

Supplementary doses of phosphate (as raw phosphate from natural sources) are permitted. The overall quantity of fertilizers shall be limited in first order by the effluent water quality.

Principle 8: Feeding

8.1. Efforts shall be made to reduce the total doses of external feed to increase the importance of natural feed production (phytoplankton and zooplankton) in the ponds. Therefore, careful documentation shall be kept by the farm operator, allowing calculation of the feed conversion ratio. For moderately eutrophic water bodies (e.g., lower courses of rivers, estuaries), it holds true that a feed conversion ratio of 0.8 should not be exceeded. Additionally, the fishmeal content as well as the total protein content of compound feed shall be reduced as far as possible. Provisional maximum levels shall be set: 20% for fishmeal/-oil content and 30% for total protein (For shrimp companies who were certified after the enforcement of the EU regulation 710/2009 on 1.7.2010, fish meal is allowed in the feed only up to an amount of 10%).

8.2. Feed intake shall be monitored and documented carefully in order to avoid accumulation of organic sediments by an excess of feed. Feed application by feeding trays (comederos) is recommended.

Principle 9: Harvesting and processing

9.1. Feeding and fertilizing shall be ceased for an adequate period before harvesting; a minimum time is three days. Drainage of ponds shall be carried out as carefully/slowly as possible in order to not release uncontrolled quantities of organic sediment into the channels. Alternatively, a barrier in the channel draining the pond shall be used to retain the sludge. The status of pond sediments (type, quantity) shall be analyzed and documented carefully after harvesting in order to optimize management measures accordingly.

9.2. The use of metabisulfite during harvest procedure or for processing is prohibited.

9.3. Shrimp heads and other processing residues/trimmings shall be brought toward an adequate reuse. Direct feeding of untreated processing residues to the same species is not permitted due to hygienic reasons.

2.4. Aquaculture production standards

Aquaculture production standards are an internationally applicable organic standard developed by IFOAM (2012) and these standards are presented in this thesis as a direct verbal quote. Due to structure of the thesis, the number of aquaculture production standards are changed from the original IFOAM document.

2.4.1 Conversion to organic aquaculture

General principle: Conversion in organic aquaculture production reflects the diversity of species and production methods.

Standards shall require that:

2.4.1.1 Operators shall comply with all the relevant general requirements of chapters 3 and 5.

2.4.1.2 The conversion period of the production unit shall be at least one life cycle of the organism or one year, whichever is shorter.

2.4.1.3 Operators shall ensure that conversion to organic aquaculture addresses environmental factors, and past use of the site with respect to waste, sediments, and water quality.

2.4.1.4 Production units must be located at an appropriate distance from contamination sources and conventional aquaculture.

2.4.2. Aquatic ecosystems

General principle: Organic aquaculture management maintains the biodiversity of natural aquatic ecosystems, the health of the aquatic environment, and the quality of surrounding aquatic and terrestrial ecosystems.

Standards shall require that:

2.4.2.1 Aquatic ecosystems shall be managed to comply with relevant requirements of chapter 2.

2.4.2.2 Operators shall take adequate measures to prevent escapes of introduced or cultivated species and document any that are known to occur.

2.4.2.3 Operators shall take verifiable and effective measures to minimize the release of nutrients and waste into the aquatic ecosystem.

2.4.2.4 Fertilizers and pesticides are prohibited unless they appear in Appendices 2 and 3.

2.4.3. Aquatic plants

General principle: Organic aquatic plants are grown and harvested sustainably without adverse impacts on natural areas.

Standards shall require that:

2.4.3.1 Aquatic plant production shall comply with the relevant requirements of chapters 2 and 4.

2.4.3.2 Harvest of aquatic plants shall not disrupt the ecosystem or degrade the collection area or the surrounding aquatic and terrestrial environment.

2.4.4. Breeds and breeding

General principle: Organic aquatic animals begin life on organic units.

Standards shall require that:

2.4.4.1 Aquatic animals shall be raised organically from birth. When organic animals are not available, brought-in conventional animals shall spend not less than two thirds of their life span in the organic system. When organic stock is not available, conventional sources may be used. To promote and establish the use of organic stock, the control body shall set time limits for the selected use of nonorganic sources.

2.4.4.2 Operators shall not utilize artificially polyploided organisms or artificially produced monosex stock.

2.4.4.3 Aquatic animal production systems shall use breeds and breeding techniques suited to the region and the production method.

2.4.5. Aquatic animal nutrition

General principle: Organic aquatic animals receive their nutritional needs from good quality, organic sources.

Standards shall require that:

2.4.5.1 Aquatic animals shall be fed organic feed. Operators may feed, up to 31st December 2014, a limited percentage of nonorganic feed under specific conditions for a limited time in the following cases:

a. organic feed is of inadequate quantity or quality;
b. areas where organic aquaculture is in early stages of development.

In no case may the percentage of nonorganic feed exceed 5% dry matter calculated on an annual basis.

2.4.5.2 The dietary requirements for aquatic animals shall comply with the requirements of 5.6.4 and 5.6.5.

2.4.5.3 Use of water containing human excrement is prohibited.

2.4.6. Aquatic animal health and welfare

General principles: Organic management practices promote and maintain the health and well-being of animals through balanced organic nutrition, stress-free living conditions appropriate to the species, and breed selection for resistance to diseases, parasites and infections.

Standards shall require that:
2.4.6.1 Operators shall comply with relevant requirements of section 5.7.
2.4.6.2 Prophylactic use of veterinary drugs is prohibited.
2.4.6.3 Operators must use natural methods and medicines as the first choice when treatment is necessary. Use of chemical allopathic veterinary drugs and antibiotics is prohibited for invertebrates.
2.4.6.4 Synthetic hormones and growth promoters are prohibited for use to artificially stimulate growth or reproduction.
2.4.6.5 Stocking densities do not compromise animal welfare.
2.4.6.6 Operators shall routinely monitor water quality, stocking densities, health, and behavior of each cohort (school) and manage the operation to maintain water quality, health, and natural behavior.

2.4.7. Aquatic animal transport and slaughter

General principle: Organic aquatic animals are subjected to minimum stress during transport and slaughter.

Standards shall require that:
2.4.7.1 Operators shall comply with relevant requirements of section 5.8.
2.4.7.2 The operator shall handle live organisms in ways that are compatible with their physiological requirements.
2.4.7.3 Operators shall implement defined measures to ensure that organic aquatic animals are provided with conditions during transportation and slaughter that meet animal specific needs and minimize the adverse effects of:
a. diminishing water quality;
b. time spent in transport;
c. stocking density;
d. toxic substances;
e. escape.
2.4.7.4 Aquatic vertebrates shall be stunned before killing. Operators shall ensure that equipment used to stun animals is sufficient to remove sensate ability and/or kill the organism and is maintained and monitored.
2.4.7.5 Animals shall be handled, transported, and slaughtered in a way that minimizes stress and suffering, and respects species-specific needs.

2.5. Organic aquaculture regulations and certification

An organic standard is a relatively new concept. The development of the standard is an ongoing process requiring consideration of the consumer and concern for conservation; it will be healthy for the rapid development of the organic farm industry (Biao, 2008). An organic standard will continuously contribute to technical possibilities (e.g., substituting fish meal with vegetable products in feedstuff, natural antioxidants replacing the regular chemical ones) and provide new insights (e.g., better understanding of microbiological processes in fish ponds) (Bergleiter et al., 2009). Organic standards are not “written in stone” but need to be considered as instruments of a dynamic process (Bergleiter et al., 2009). Standard settings can be modified for successful implementation of organic production considering factors such as species and region, and technical, geographical, infrastructural, and social conditions (Bergleiter et al., 2009). The history of organic aquaculture and its certification standards are discussed in detail in (Bergleiter et al., 2009). The earliest standard was established in 1995 in Austria for common carp (*Cyprinus carpio*) (Table 2.2).

Table 2.2. Organic aquaculture certification programs and standards (Bergleiter et al., 2009)

Certification program				Country	Year of implementation	Certified species
	Europe	Private standards	Bio-Austria	Austria	1995 2001	carp trout
			Biokreis	Germany	2000	carp, tench, trout
			Naturland e.V.	Germany	1996	carp, char, sea bass, sea bream, mussel, shrimp, trout, tilapia, pangasius, milkfish
			Bioland	Germany	1995	carp tench
			Biopark	Germany	2006	carp, tench, trout
			Demeter	Germany	2003	Carp, tench
			Gäa	Germany	1998	Carp, tench
			Associazione Italiana per I′Agricoltura Biologica (AIAB)	Italy	2004	carp, catfish, eel, salmon, sea bass, sea bream, trout
			Quality, Certification and Inspection (QC&I)	Italy	2003	trout
			Biokontroll Hungária	Hungary	2002	carp, tench, and other cyprinids
			Bio Suisse	Switzerland	2000	carp, char, tench, trout, perch
			CAAE	Spain	2001	trout and sturgeon
			Debio	Norway	2001	char, cod, perch, pike-perch, salmon, trout
			Irish Organic Farmers and Growers Association (IOFGA)	Ireland	2006	salmon
			Irish Quality Organic Salmon Standards (IQS)	Ireland	2007	salmon
			KRAV	Sweden	2000	char, mussel, perch, pike-perch, salmon,

						trout
			Organic Food Federation (OFF)	United Kingdom	2002	cod, hake, haddock, pollock, saithe, mussel, oyster, salmon, trout
			Soil Association	United Kingdom	1999	carp, char, clam, mussel, oyster, salmon, scallop, shrimp, trout
			Marine Stewardship Council	United Kingdom		Organic aquaculture standards
			SGS	Netherlands		Organic aquaculture standards
			Vottunarstofan Tún ehf.	Island	2001	arctic char, salmon, sea bass
		National Standards	Oesterreichischer Lebensmittel Codex (Codex Alimentarius Austriacus)	Austria	1997 1998	carp trout
			Økologisk	Denmark	2004	salmonids, eel
			Agriculture Biologique	France	2000	carp, char, salmon, sea bass, sea bream, maigre, turbot, cod, trout, shrimp
			Junta de Andalucia	Spain (Andalusia)	2007	sea bass, sea bream
	Asia	Private standards	Israel Bio-Organic Agriculture Association (IBOAA)	Israel	2001	Mediterranean fish species, aquatic plants
			Organic Agriculture Certification Thailand (ACT)	Thailand	2005	shrimp
			Organic Good Development and Certification Centre of China (OFDC)	China	1999	No specification
		National standards	China (GB/T19630)	China	2005	No specification
			Organic Thailand	Thailand	2006	shrimp
	Oceania	Private standards	Australian Certified Organic (ACO)	Australia	2001	fish, crustacean, mollusks, and related aquatic species; wild sea vegetables, algae

			National Association for Sustainable Agriculture, Australia (NASAA)	Australia	1997	fish, crustacean, aquatic plants
			AsureQuality	New Zealand	2004	No specification
			BioGro	New Zealand	2001	fish, shellfish, crustacean
	America	Private standards	IBD	Brazil	2000	No specification
			Letis Aquaculture Standards	Argentina	2007	clam, mussel, oyster, seaweed, trout
			Canadian Organic Aquaculture Standard	Canada		salmon, trout and shellfish
		National standards	Appellations Agroalimentaires du Quebec (CAAQ)	Canada	2004	carp, char, salmon, sea bass, sea bream, croaker, turbot, trout
	IFOAM		International Federation of Organic Aquaculture Movement (IFOAM)		2005	Basic standards
	EU		Organic Aquaculture Legislation		2009	

The standards for organic aquaculture production were privately developed to achieve an alternative food supply chain by Naturland, KRAV, NASAA, and OFDC between 1996 and 2000 (Bergleiter et al., 2009) (Table 2.2). Private organic certification bodies are required to ensure concordance with internationally established regulatory frameworks for the organic food industry such as FAO, Codex Alimentarius “organically produced foods,” EU council regulation/EEC no 2092/91, USDA/National organic program, and national regulations for organic agriculture (Bergleiter et al., 2009). The first national general standards for organic aquaculture were established by France and the United Kingdom in 2000. The first global organic aquaculture criteria were established by the International Federation of Organic Agriculture Movements (IFOAM) in 2000. However, the European Union (EU) is the pioneer in legislation for organic farming and a legislative framework for organic aquaculture was introduced in 2009 (EU, 2009). In the United States of America, the state of California in 2005 banned the labelling of organic aquaculture products pending the establishment of state regulations for such products. Numerous conferences and workshops enabled practitioners, traders, certifiers, and other stakeholders to continually advance the approach (Prein et al., 2012).

Currently, there are at least 35 certification standards in the world that regulate the performance of organic aquaculture production. Of these, 28 are private law-based regulations set up by organic farmers’ associations or certification bodies. Most of these certifiers already had standards for organic agriculture in place and amplified their scope of activity to include the aquaculture standards. In addition to the private standards, six countries have public regulations in place. The first regulation of organic aquaculture on a national level was implemented in Austria in 1997. The so-called “Codex alimentarius austriacus” is a collection of standards and regulations directing the quality and the labelling of food. The codex is part of the food law. At first, the codex applied only to carp, but in 2008 specifications for trout came into force (Bergleiter et al., 2009).

3. Rationale of the Study

3.1. Research problem

Many researchers and scholars have raised questions about the restoration of aquatic ecosystems and sustainable management of coastal zone resources and have explored the influence of aquatic ecosystems on the livelihoods of fishermen. Numerous reports on water resources and community-based resource management (CBRM) and comanagement for the sustainable governance of coastal fisheries in different parts of the world have emerged over the last 15 years (Pomeroy, 1995; Datta and Subramanian, 1997; Sillitoe, 1998; Usher, 2000; McCormack, 2001; Mirza et al., 2001; Mirza, 2002). A growing number of researchers are calling on government regulatory agencies to integrate traditional knowledge with “scientific” knowledge in resource areas, notably agriculture (DeWalt, 1994; Bellon, 1995; Sillitoe, 1998) and fisheries (Johannes, 1998).

In Bangladesh, global warming drastically affects water resources. Agriculture, fisheries, and thus human livelihoods are vulnerable to the extreme unpredictability of climatic conditions and the threats of a greater variability in monsoon patterns. These climatic conditions encroach on and destroy ecological resources, increase pollution, and decrease water quality. Inappropriate development leads to catastrophic flooding and coastal erosion (or accretion in other areas) accompanied by the depletion of other resources. In terms of livelihood development, the most striking feature of the coastal zone of Bangladesh is the multiple vulnerabilities that dominate the lives of many people in the area.

The contribution of aquaculture to poverty alleviation is not widely appreciated. Aquaculture is commonly, and erroneously, equated narrowly with the intensive farming of finfish and shrimp. Global aquaculture production has experienced continuous growth over the past few decades, from less than 1 million tonnes in 1950 to over 60 million tonnes in 2010 (excluding aquatic plants and nonfood products) (FAO, 2012). From 1980 to 2010, world food fish production from aquaculture has increased by almost 12 times, at an average annual rate of 8.8 percent (FAO, 2012). The growing importance of the aquaculture sector implies an ever increasing responsibility and accountability to produce safe and healthy products in sustainable ways in terms of economic competence with respect to growth, efficiency, profits, and stability; environmental integrity, i.e., ecosystem resilience, pollution control, conservation of biodiversity and natural resources (land, water, forest, etc.); and social imperatives such as inclusion, participation, and empowerment, wealth distribution and equity, and good governance (Rahman et al., 2006b; Bergleiter et al., 2009).

Historically, people depended mainly on natural waters for supplies of fish. But as a result of declining wild fish catches due to the increase in fishing engendered by a growing population and encroaching environmental degradation, people began to culture fish in enclosed waters in Bangladesh. At the same time, land and water degradation increasingly pose threats to food security and the livelihoods of rural people who often live on degradation-prone lands (Pokrant and Bhuiyan, 2001). Marine capture fishery has collapsed due to high fishing intensity and an increase in population. As a result, huge numbers of coastal communities are forced to switch from their traditional employment of fish capture in open waters to fish culture in enclosed water bodies. Traditionally, farmers dependent on rain water to culture finfish in enclosed water bodies used tidal waters for shrimp culture in nearby coastal enclosures known as *"gher"* where no feed, fertilizer, or other inputs were applied. An increasing demand for fish/shrimp from both national and international markets is motivating farmers to switch from traditional culture systems to improved extensive and semi-intensive systems. As a result, huge ecological changes have occurred in Bangladesh.

Shrimp is the highest valued largest single seafood commodity, accounting for about 15 percent of the total value of internationally traded fishery products in 2010 (FAO, 2012). The shrimp industry has carried forth economic benefits such as foreign exchange earnings, employment and income generation, and livelihood opportunities for many people in developing countries, especially for people in Bangladesh. The production, processing, and trading of shrimp are capital intensive; however, shrimp provides quick economic returns to exporters and supports the employment and livelihoods of the many people involved in shrimp production and processing. Apart from the primary production sector, the shrimp industry provides numerous jobs in ancillary activities such as processing, packaging, marketing and distribution, manufacturing of fish-processing equipment, net and gear making, ice production and supply, boat construction and maintenance, research, and administration. The positive impacts of shrimp farming include the growth of average wage rates in rural areas, growth in individual and household purchasing power, an increase in the number of earning members in households, development of rural infrastructure, improved health, increased access to facilities such as tube-wells, sanitary latrines, better housing, declines in land sales, rises in land prices, greater household food security, and greater earning opportunity for women (Pokrant and Reeves, 2003; Mallick et al., 2004).

The enormous growth of shrimp production from 1,600 tonnes in 1950 to close to 4.5 million tonnes in 2006 has been achieved at a value of just under US$18 billion (FAO, 2009). This achievement has been causing a concurrent reduction in mangrove areas in some countries of between 50 to 80%, leading to considerable loss of biodiversity and coastal ecosystem function (Valiela et al., 2001; Alongi, 2002; Manson et al., 2005). The shrimp industry has many stakeholders with many backward and forward links and multiple economic, social, and ecological dimensions. However, quick economic gain can be associated with ecological impacts and social disturbance in the forms of rapid social change and breakdown of traditional livelihoods, sometimes resulting in poverty and social inequity in the shrimp growing regions. The major negative social consequences of shrimp farming are a growth in income inequality, disruption of local networks of social security, violence against the landless and women, decline in access to sharecropping opportunities, privatization of public lands, and the exacerbation of existing unequal gender and class relations (Siddique and Rahman, 1996; Datta, 2001). Environmental problems sometimes associated with shrimp farming are mainly related to rapid development of the industry which leads to habitat destruction, poor water quality, excessive use of chemicals, and disease outbreaks in shrimp farms. The relatively high earnings in the industry have in some cases led to corruption, out migration, intimidation, rapid social changes, and violence (Hambrey, 2006).

Diseases in cultured shrimp became a great threat during the mid-1990s. Due to the higher incidence of disease, the promise of high returns on investment has gradually been tempered by riskier returns in global markets and increasing levels of social and ecological uncertainty and vulnerability (Bush et al., 2010). Broader environmental conditions such as temperature, dissolved oxygen, salinity, and soil condition can influence vulnerability to diseases both as stress factors for shrimp by reducing defense mechanisms, and as determinants of virulence and transmission of pathogens (Lightner and Redman, 1998). The FAO estimated a shrimp loss of US$ 3 billion in 1998 due to disease outbreaks in Bangladesh. The billions of dollars a year that are lost to diseases world-wide threaten every cycle to plunge farmers into debt. Diseases have forced entire economies to rethink their approach to shrimp farming and begin a new with regulations and more sustainable practices in the 21st century. There are five known causes of shrimp disease: (i) environmental, (ii) parasital, (iii) fungal, (iv) bacterial, and (v) viral (McClennen, 2006). Among these, viral diseases are the most destructive. Major viral diseases of penaeid shrimp are listed in Table 3.1 with the species affected.

Table 3.1. Viral diseases and the species that are generally affected (Lightner and Redman, 1998)

Sl. No.	Viral Diseases	Species Affected
1.	Monodon baculovirus (MBV)	*Penaeus monodon* *Penaeus merguiensis* *Penaeus semisulcatus* *Penaeus karathurus* *Penaeus vannamei* *Penaeus esculentus* *Penaeus penicillatus* *Penaeus plebejus* *Metapenaeus chinensis*
2.	Infectious hypodermal and haematopoietic necrosis virus (IHHNV)	*Penaeus stylirostris* *Penaeus vannamei* *Penaeus monodon and others*
3.	White spot syndrome virus (WSSV)	*Penaeus monodon* *Penaeus chinensis* *Penaeus indicus* *Penaeus merguiensis* *Penaeus setiferus* *Penaeus stylirostris* *Penaeus vannamei*
4.	Taura syndrome virus (TSV)	*Penaeus vannamei* *Penaeus stylirostris* *Penaeus seteferus*
5.	Yellow head disease (YHD)	*Penaeus monodon* *Penaeus vannamei* *Penaeus stylirostris* *Penaeus seteferus* *Penaeus aztecus* *Penaeus duorarum*

Shrimp farming in Bangladesh has improved extensively and environmental problems are not as acute as they are in other shrimp producing countries where intensive and semi-intensive shrimp farming is more common. However, unplanned and rapid expansion of shrimp farming has caused several environmental problems that include increases in soil and water salinity in canals and ponds; growing scarcity of drinking water; loss of agricultural land and grazing land and consequent reductions in livestock; destruction of mangroves; overexploitation of wild post larvae of shrimp, fish, and other aquatic organisms resulting in reduced aquatic resources and biodiversity; loss of trees and plants and adverse effects on cropping intensity; cropping patterns and crop diversity (Bhattacharya et al., 1999). The intrusion and retention of salt water for longer periods in shrimp farms has increased soil salinity in the farms and adjacent areas, reducing land fertility, rice production, and plant and tree growth. Conversion of agricultural and fallow land to shrimp farming has reduced rice and milk production. Collection of shrimp fry for shrimp farms, brood shrimp for fry production in hatcheries, commercial exploitation by trawlers, and subsistence/artisanal fishing by set bag nets have placed tremendous stress on aquatic resources, particularly for commercially important species of shrimp. Habitats of animals, birds, and fish have been lost due to the loss and degradation of mangroves to shrimp farming.

3.2. Research objectives

The objectives of this study are to assess the potential of organic shrimp farming and the risks of conventional shrimp farming for livelihood systems in Bangladesh and to assess the available local and global knowledge pertaining to sustainable shrimp production using a sustainable livelihood framework. These objectives will involve the following efforts:

1. By focusing on rural development and poverty reduction, I will investigate whether organic shrimp farming can be a viable alternative for farmers in Bangladesh, resulting in an improvement of their livelihood situation.
2. Considering the hindrances to and challenges of sustainable shrimp production, I will highlight the advanced knowledge obtained with respect to the environmental and socioeconomic impacts of aquaculture systems.
3. I will evaluate the potential of organic aquaculture with respect to environmental damage and socioeconomic changes and compare it with conventional and integrated aquaculture systems.
4. I will pursue a better understanding of organic shrimp aquaculture techniques and evaluate the economic importance of organic shrimp aquaculture production.
5. I will identify the uncertainties in and vulnerability of sustainable shrimp production and explore potential resources to cope with these conditions.

3.3. Research hypothesis

It is hypothesised that:

1) Organic aquaculture can be used as an alternative solution to restore the ecological process that is being degraded due to conventional aquaculture systems and will allow an enhanced sustainable socioeconomic development of coastal communities.
2) Organic aquaculture can provide higher shrimp production than conventional aquaculture because it preserves a higher diversity of species.
3) Organic aquaculture creates good physical well-being, ensures food security, reduces farmer vulnerability, and makes household livelihoods sustainable.
4) Poorer farmers supplement their diets with organic aquaculture produce; large scale farmers use organic aquaculture for business purposes.

3.4. Research questions

The main question to be addressed is how to achieve sustainable socioeconomic development through organic shrimp aquaculture, especially in coastal communities, while alleviating poverty and preserving the unique environment and biodiversity of the coastal belt. The research questions that will be answered by this study include:

(1) What is the impact of organic shrimp farming on the farm household?
(2) What does the adoption of organic farming mean to a farm household? What are the potential resources of household members?
(3) How does organic farming fit into the livelihood strategy of a farm household?
(4) How does organic aquaculture create physical well-being, ensure food security, and reduce the vulnerability of the farm household?

3.5. Justification of the study

Bangladesh lies between the Himalayan mountains and the Bay of Bengal in the delta of the River Ganges and Brahmaputra. Bangladesh is a densely populated, low-lying deltaic country of 147,570 km^2 with a population of 130 million people. It has been prone to flooding and coastal cyclones for centuries and there is evidence from hundreds of years ago of efforts to build flooding and cyclone protection (Datta, 2001). Bangladesh is fortunate in having an extensive water resource in the form of ponds, natural depressions (*haors* and *beels*), lakes, canals, rivers, and estuaries covering an area of 4.56 million ha (DoF, 2009a). Fish and fisheries have been an indispensable part of the life and livelihood of the people of the country since time immemorial; they are elements of the cultural heritage. Fisheries in Bangladesh have immense prospects and scope for development toward the sustainable utilization of fisheries resources to ensure food security. The establishment of aquatic sanctuaries in Bangladesh will provide effective tools for conserving fish stock, protecting biodiversity, and increasing fish production.

Bangladesh is one of the world's leading inland fish producers with a production of 1,646,819 tonnes during 2003–2004, a marine catch of 455,601 tonnes, and a production from aquaculture of 914,752 tonnes during 2003–2004. Bangladesh's total fish production for that year totaled above 2.1 million tonnes (DoF, 2009a). FAO (2006) ranked Bangladesh as the sixth largest aquaculture producing country with an estimated production of 856,956 tonnes in 2003. Aquaculture accounted for about 43.5 percent of the total fish production during 2003–2004, with inland open water fisheries contributing 34.8 percent (DoF, 2009a). The present per capita annual fish consumption in Bangladesh stands at about 14 kg/year against a recommended minimum requirement of 18 kg/year; hence there is still need to improve fish consumption in the country (FAO, 2006). Fisheries in Bangladesh are diverse; there are about 795 native species of fish and shrimp in the fresh and marine waters of Bangladesh and 12 exotic species have been introduced. In addition, there are 10 species of pearl bearing bivalves, 12 species of edible tortoise and turtle, 15 species of crab, and 3 species of lobster (DoF, 2009b).

Bangladesh possesses vast marine water resources. Despite the abundance of marine waters, only about 18% of country’s total fish production is contributed by the marine sector (DoF, 2012). The present democratic government sets the protection, conservation, and biodiversity of marine and coastal resources as the utmost priority. As a result, Saint Martin Island and the Sundarbans, the world famous mangrove forest, have been declared as sanctuaries to develop and protect the fisheries resources as well as the biodiversity in that area. The government has also proclaimed a marine reserve in the Bay of Bengal to protect and preserve the breeding grounds of marine flora and fauna. The area of the marine reserve is 698 sq. km surrounded by two fishing grounds in the middle ground and the south patches (DoF, 2012).

Some half a million people are engaged in marine artisanal fisheries. Most coastal fishermen operate in the coastal zone and own neither land nor assets. Most of them pursue only fishing activities for their livelihood. With the rapid increase in the fisherfolk population, fishing in coastal areas is characterized by low catches and fishing rights conflicts. Fishermen are now opting to fish away from the coast. The livelihoods of such fishermen are vulnerable in terms of food insecurity because the coastal region is highly susceptible to tropical storms. Fishermen use their traditional knowledge to survive the elements as well as to predict the location of fish schools to increase the catch with less effort. Some scientists have observed that the fishing effort is increasing day by day, and as a result the fisheries stock is declining drastically.

Due to environmental degradation, a huge number of fishermen are switching from their customary occupation to aquaculture. Aquaculture comprises diverse systems of farming plants and animals in inland and coastal areas, many of which have relevance for the poor. Fisheries continue to play an important role, and in many areas remain adequate to satisfy subsistence and may even offer a valuable source of cash income for farmers. Organic aquaculture becomes an attractive and important component of rural livelihoods in situations where increasing population pressures, environmental degradation, or loss of access limits catches from wild fisheries. Organic aquaculture has experienced a remarkable growth over the last decade. However, certification of organic aquaculture is recognized as a vital consideration in improving organic aquaculture standards in Europe and internationally. The benefits of organic aquaculture in rural development relate to health and nutrition, employment, income, reduction of vulnerability, and farm sustainability. The conversion to organic shrimp farming is relatively new and under development. The development of organic shrimp farming in Bangladesh is mainly driven by the farmers with the involvement of international importing organizations.

For sustainable household livelihoods, organic aquaculture techniques can be introduced with a sustainable livelihoods framework by applying the diffusion of innovations theory. The diffusion of innovations theory can provide better adaptation and mitigation techniques to reduce farmer vulnerability and enhance the successful livelihoods strategy of shrimp farmers. Organic aquaculture knowledge is currently not well documented and is unfortunately being discarded in favor of more progressive modern science. This study will explore the potential of organic aquaculture systems in relation to the livelihoods realized and will assess the challenges and risks of organic aquaculture by highlighting the diffusion of innovations theory.

Organic aquaculture is an integrated system that is an “organism” whose individual parts—the environment, the aquatic animals, off-farm energy and material inputs, and the farmers—mesh together into an entire production system (Brister and Kapuscinski, 2001). Organic aquaculture production encourages reliance on photosynthetic waste reuse and recirculation and on-farm energy sources by restricting or prohibiting harmful substances and practices to produce net protein gains without degradation of natural ecosystems. It is community-based, and has social and environmental benefits in addition to economic benefits. “Organic” in the context of food production connotes standards and certification – a verifiable claim for the production process and production practices – as well as more elusive characteristics such as consumer expectations for food quality and safety and general environmental, social, and economic benefits for farmers and for society (Boehmer et al., 2005).

4. Theory, Concept, Framework, and Methodology

4.1. Diffusion theory

In 1983 a diffusion model that describes the process of change was developed in the United States by the rural sociologist Everett M. Rogers (Rogers, 2003). Roger’s model was the main theoretical model for agricultural extension and the development of agricultural advisory services for the 20th century (Vanclay and Lawrence, 1994). The diffusion of innovations theory predicts how, why, and at what rate new ideas and technology will spread through cultures. According to Rogers (2003), innovations diffuse over time through communication among the members of a social system. Accordingly, new ideas are spread by individuals sharing information with one another to reach a mutual understanding of a new concept

In 1962, Rogers suggested that there are four main elements that influence the spread of a new idea: the innovation, communication channels, time, and the social system (Rogers, 2003). An innovation is an idea, practice, or object perceived as new by an individual or other unit of adoption (Rogers, 2003). A technology is a design for instrumental action that reduces the uncertainty in the cause-effect relationships involved in achieving a desired outcome. Most technologies have two components: hardware – the tool that embodies the technology as a material or physical object – and software – the knowledge base of the tool. The characteristics of an innovation, as perceived by the members of a social system, determine its rate of adoption. Five attributes of innovations are: (i) relative advantage, (ii) compatibility, (iii) complexity, (iv) trialability, and (v) observability. As, organic farming is an information based innovation, the availability of information about the innovation is an important precondition for its wider diffusion. A communication channel is the means by which messages get from one individual to another. Mass media channels are effective in creating the knowledge of innovations, whereas interpersonal channels are effective in forming and changing attitudes toward a new idea, and thus in influencing the decision to adopt or reject a new idea. Most individuals evaluate an innovation not on the basis of scientific research by experts but through the subjective evaluations of near peers who have adopted the innovation. These near peers thus serve as role models, whose innovation behaviour tends to be imitated by others in their field.

According to the adoption model, innovators and early adopters can be characterized as being different from later adopters. Innovators are venturesome, interested in developing cosmopolitan social relationships, and tend to communicate with a clique of other innovators, often not considering geographical distance (Rogers, 2003). Innovators must be able to cope with a high degree of uncertainty and have an ability to be understood by other members of the social system. Early adopters are more intensively involved in their local community than innovators. Early adopters usually have a degree of opinion leadership and have potential contact with information sources. The role of early adopters in the diffusion process is to help trigger the innovation to an acceptable critical mass (Rogers, 2003). The later adopters can be divided into two categories: the early majority adopts new ideas just before everyone else does, whereas the late majority remains rather sceptical.

Time is an important factor in diffusion theory. It takes time for an innovation to diffuse throughout a culture and to be adopted by the members of the culture. The individual passes from first knowledge of an innovation, to forming an attitude toward the innovation, to a decision to adopt or reject the innovation, to implementation of the new idea, and to confirmation of this decision. Thus the innovation decision process must go through five steps: knowledge, persuasion, decision, implementation, and confirmation. Early adopters differ from late adopters in that it takes them a longer time period to go through the five steps, and much time is required for an innovation to spread among all potential adopters (Rogers, 2003).

Although the model can be criticized for not accounting for economic, structural, and institutional environments of farming, the diffusion of innovations model remains important in agricultural extension and marketing theory. Therefore, it is of interest to see whether the diffusion process can be applied in organic farming. According to Padel (2001), conversion to organic farming is a typical example of the diffusion of an innovation. A number of environmental benefits attributed to organic farming were confirmed by reports in the literature regarding soils, the farm ecosystem, ground and surface water protection, and farm inputs and outputs (Stolze et al., 2000). According to Rogers (2003), the diffusion of innovations model accommodates socioeconomic characteristics such as age, education, income level, farm size, personality, and communication behaviour as well as innovativeness. Several studies of conversion to organic farming have also looked at aspects of the socioeconomic status of organic farmers, such as farm size, farming background, social relationships, and motivation to convert to organic farming (Padel, 2001). Other studies of the conversion to organic farming have looked at socioeconomic characteristics (Tovey, 1997; Duram, 1999; Rigby et al., 2001; Koesling et al., 2008; Kallas et al., 2010).

In considering technological components (hardware and software), organic farming would be mainly a software based innovation. That is, the technology is simple whereas the knowledge component is complex, involving both traditional information and experience and new management skills. New adaptors need to learn how to plan diverse rotation, techniques to manage biological resources to achieve regulation of pests and diseases, and the use of mechanical or biological control methods for weeds, pests, and diseases (Padel, 2001). The rate of diffusion of organic farming is very slow but in many ways organic farming is not a typical innovation. As the organic sector is still small, the diffusion of organic farming is at the so-called "innovation" stage. Hence, organic shrimp farming can be considered a new innovation because the process of conversion has been started recently. This conversion process is going through a complex system change and farmers will be designated as innovators or early adopters.

4.2. The concept of sustainable development

The term "sustainable development" was first used in the early 1980s in the *World Conservation Strategy* (International Union for Conservation of Nature and Natural Resources, 1980) but became popular after the publication in 1987 of *Our Common Future* by the World Commission on Environment and Development (WCED), or the Brundtland Commission. The commission popularized the idea of sustainable development with a report that development called for meeting the needs of the present generation without compromising the needs of future generations (WCED, 1987). From this definition, the emphasis on "needs" is closely related to problems of poverty, especially in the Third World. The definition of sustainable development provided by the Food and Agriculture Organization (FAO, 1988) was:

> Sustainable development is the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs to present and future generations.

Such sustainable development is environmentally nondegrading, technically appropriate, economically viable, and socially acceptable; it includes different sectors such as agriculture, forestry, and fisheries which conserve land, water, plant, and animal genetic resources (Barg, 1992). A further definition was provided by (Goodland and Daly, 1996): "Sustainable development is development without growth of matter and energy beyond regenerative and absorptive capacities." An even more succinct definition derived from the International Union for the Conservation of Nature (IUCN) on 2006 says "sustainable development improves people's quality of life within the context of the Earth's carrying capacity (IUCN, 2006)." By this time, international debates had highlighted the impact of growth and socioeconomic change on the physical environment. It was emphasized that fulfilling human needs and aspirations is the most important goal for all development efforts throughout the world (Martinussen, 1999). In general, sustainable systems are those that are considered to be "… productive, socially relevant, profitable, and environmentally compatible while making environmentally sound use of resources, not diverting or replacing resources that may be used in a more productive way, and not degrading the environment and jeopardizing the livelihood of future generations …" (AIT, 1994). Shrimp aquaculture has the potential to meet the needs of the present demand of resources, it will not exceed the capacity of the resources used, and it can be renewed continuously for future generations without any environmental hazard.

According to the World Commission on Environment and Development (WCED, 1987), through the Brundtland report,

> Sustainability is the process of sustainable development and it is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Since the last decade, sustainability has been a popular concept in global aquaculture development. The sustainability concept of environment friendly agriculture/aquaculture has been widely accepted as a powerful mechanism around the world to foresee the future. Sustainability in the context of shrimp aquaculture in Bangladesh has been given priority concern in this thesis. Sustainability was further divided into social sustainability, economic sustainability, and environmental sustainability, and customized by Goodland and Daly (1996) (Table 4.1).

Table 4.1. Different categories of sustainability (Goodland and Daly, 1996).

Social sustainability (SS)	Economic sustainability (EcS)	Environmental sustainability (ES)
SS will be achieved only by systematic community participation and strong civil society. Social cohesion, cultural identity, diversity, sodality, comity, sense of community, tolerance, humility, compassion, patience, forbearance, fellowship, fraternity, institutions, love, pluralism, commonly accepted standards of honesty, laws, discipline, etc., constitute the part of social capital that is least subject to rigorous measurement, but probably most important for SS. This "moral capital," as some have called it, requires maintenance and replenishment by shared values and equal rights, and by community, religious, and cultural interactions. Without this care it will depreciate just as surely as will physical capital. Human capital – investments in the education, health, and nutrition of individuals – is not accepted as part of economic development (WDR, 1990, 1991, 1992, 1995), but the creation of social capital, as needed for SS, is not yet adequately recognized.	The widely accepted definition of economic sustainability is "maintenance of capital," or keeping capital intact, and has been used by accountants since the Middle Ages to enable merchant traders to know how much of their sales receipts they and their families could consume. Thus the modern definition of income (Hicks, 1946, in Goodland and Daly, 1996) is already sustainable. Of the four forms of capital (human-made, natural, social, and human), economists have scarcely at all been concerned with natural capital (e.g., intact forests, healthy air) because until relatively recently it had not been scarce. Economics also prefers to value things in monetary terms, so it is having major problems valuing natural capital – intangible, intergenerational, and especially common-access resources, such as air, etc. In addition, environmental costs used to be "externalized" but are now starting to be internalized through sound environmental policies and valuation techniques. Because people and irreversible impacts are at stake, economics has to use anticipation and the precautionary principle routinely, and should err on the side of caution in the face of uncertainty and risk.	Although ES is needed by humans and originated because of social concerns, ES itself seeks to improve human welfare and SS by protecting the sources of raw materials used for human needs and ensuring that the sinks for human wastes are not exceeded, in order to prevent harm to humans. Humanity must learn to live within the limitations of the biological and physical environment, both as a provider of inputs "sources" and as a "sink" for wastes (Serageldin, 1993, in Goodland and Daly, 1996). This translates into holding waste emissions within the assimilative capacity of the environment without impairing it. It also means keeping harvest rates of renewables to within generation rates. Quasi ES can be approached for nonrenewables by holding depletion rates equal to the rate at which renewable substitutes can be created (EI Serafy, 1991, in Goodland and Daly, 1996). ES means maintaining natural capital, similar to the definition of EcS.

Definitions of sustainability are often internally inconsistent, but they share one common theme; sustainable systems are invariably defined by the need for simultaneous consideration of economic, environmental, and sociological objectives (Caffey et al., 2000). Sustainability can mean different things to different people, though most would agree that it involves the three elements futurity, equity, and the environment (Pretty, 2008). This notion was echoed in a stakeholder survey conducted by Caffey et al. (2000) in an attempt to develop a consensus assessment of sustainable aquaculture in the southeastern United States. Therefore, sustainable aquaculture development is in some way interlinked with better management and institutional considerations by implementing regulations that are based on economically viable, socially equitable, environmentally acceptable principles. Sustainability can be acquired only when environmental conditions are appropriate and maintained; this includes ecological, socioanthropological, and economic aspects of environment (Frankic and Hershner, 2003). Sustainability in the shrimp aquaculture industry depends on two primary factors: site selection and pond management. The density of a farm within an area may be more important than whether the farm operation is semi-intensive or intensive, provided, of course, that appropriate pond management is practiced (Dierberg and Kiattisimkul, 1996; Boyd, 1999). Shrimp aquaculture has provided an economic benefit to shrimp farm owners, but the increased incidence of negative consequences to surrounding local communities and environments has generated a huge research effort aimed at improving the long-term sustainability of shrimp aquaculture. Therefore, an alternative innovative culture system must be identified as a pathway to making aquaculture production sustainable. That pathway can be organic aquaculture, as it is environmentally sound and easily managed by using locally available resources. Sustainability means that progress in poverty reduction is lasting rather than fleeting. To achieve this goal it is necessary to accumulate a broad capital base that provides improved livelihoods, especially for poor people.

4.3. Sustainable livelihood framework

The concept of a "sustainable livelihoods approach" is becoming a new focus for development research and aid programming in a number of organizations (Ashley and Carney, 1999). The concept of sustainable livelihood is widely used in contemporary studies which not only speak about poverty elimination and rural development but also cover aspects such as social development, land reform, community-based natural resource management (particularly forest management), biodiversity studies, and development planning. The sustainable livelihood approach promoted by the British Department for International Development (DFID) is the most widely accepted today (Ashley and Carney, 1999). The core principles of the approach are: Development activity should be (a) people centred, (b) responsive and participatory, (c) multileveled, (d) conducted in partnership, (e) sustainable, (f) dynamic, and (g) committed to poverty eradication (Carney, 2002). Sustainable livelihoods approaches have evolved over three decades because of changing perspectives of poverty, a plethora of inquiries into how poor people construct their lives, and due to an increasing emphasis on the importance of structural and institutional issues (Scoones, 1998; Ashley and Carney, 1999). The sustainable livelihoods framework is a useful tool for livelihoods analysis (Ellison et al., 2000).

In considering the main aspects of people's livelihoods, the sustainable livelihood framework goes far beyond the constricted economic ideas of employment and income, and attempts to examine multidimensional issues and complexities that center on the ways people live their lives (Ellison et al., 2000). The framework is an integrated package of policy, technology, and investment strategies together with appropriate decision making tools, elements that are used together to promote sustainable livelihoods by building on local adaptive strategies (De Haan and Lipton, 1998; Rakodi, 1999). Originally implemented with a top-down approach, the sustainable livelihood framework now uses a bottom-up approach by considering the participation of stakeholders at all levels in the development process (Allison and Ellis, 2001). According to Bebbington (1999), a sustainable livelihood framework should address the diverse assets that rural people draw on in building livelihoods, the access to these assets, and the abilities of people to transform those assets into income, dignity, power, and sustainability. This framework stresses the relationships between intrahousehold, regional, micro- and macroeconomics, and incorporates the relationships that households have with institutions and organizations (Ellison et al., 2000; Carney, 2002).

The well-known DFID (1999) sustainable livelihoods approach will be used as a framework for this study. The livelihoods approach achieves livelihoods outcomes by employing actual livelihood assets and strategies. Livelihood interventions are very hard to execute in remote or agriculturally underdeveloped areas due to political instability and chronic conflict; these are the places where humanitarian aid is most essential for saving human life and incorporating both relief and development modes of operation (Longley and Maxwell, 2003). For a sustainable livelihood approach to succeed, a government must follow an appropriate political discourse for creating an enabling environment for the poor and to guide its institutions toward the materialization of sustainable livelihoods for the citizens (Chambers and Conway, 1992). Policies and regulations need to be directed in a way that ensures the poorest communities are not discriminated against, and are socially prioritized when it comes to appropriating assets. As is fundamental to any intervention process, the sustainable livelihoods approach is holistic and demands the exercise of cross-scale negotiation with a variety of stakeholders (Scoones, 1998). The next section describes qualitative and quantitative methods of data collection, analysis, and interpretation of this sustainable livelihood approach study.

4.4. Methodology

In this socioecological research, both qualitative and quantitative data collection methods were used in an interactive way. For decades, quantitative and qualitative purists (also called constructivists and interpretivists) have formed distinct schools of thought. Drawing on the strengths and minimizing the weaknesses of both approaches, a new “mixed method” approach evolved about 10 years ago (Creswell, 2003; Johnson and Onwuegbuzie, 2004). Qualitative research is more concerned with the what, how, why, where, and when of subjects under query whereas the quantitative approach tends to be about size, duration, number of items being investigated (Bhattacherjee, 2012). When studying the real life-worlds of people, qualitative researchers try to focus on the naturally emerging languages and meanings that individuals assign to experience (Offermann and Nieberg, 2001). In contrast, quantitative methods usually try to generalize, testing and validating already constructed theories about how things happen. An advantage of quantitative methods is that the data are numerical and thus can be processed using statistical software (Offermann and Nieberg, 2001). Development practitioners have been proceeding in an entirely different direction, utilizing approaches collectively known as “participatory rural appraisal” (PRA), the origins and strands of which have been aptly and popularly described by Chambers (1994a, 1994b, 1994c). PRA methodology is described in detail in chapter 5. The study was carried out in four phases.

Phase 1 – Review of the literature and concept development

The research began in October, 2008, with a draft proposal prepared from Bangladesh. Pertinent literature was retrieved from the databases ScienceDirect, Google Scholar, Scopus, using the key words: aquaculture, shrimp, organic farming, development, livelihood, and sustainability. Documents relevant to the study were reviewed systematically to develop the final research proposal and plan the research activities. The purpose of a literature review was three-fold: (1) to survey the current state of knowledge in the area of inquiry, (2) to identify key authors, articles, theories, and findings in that area, and (3) to identify gaps in knowledge in the research area (Bhattacherjee, 2012). The preliminary literature reviews were helpful in finding a possible research partner for the field study. The field research was implemented in collaboration with WAB Trading International Asia Ltd., an international private company based in Germany. A review of the literature has been presented in a paper that describes the research and has been submitted for publication.

Phase 2 – Site selection and survey strategy

A total of 44 villages were selected from 11 unions' (are the smallest rural administrative and local government units in Bangladesh) locations initially from two subdistricts (Kaligonj and Shymnagar) of the Satkhira district where the third phase (data collection) of the study was carried out. Before beginning the study, secondary data were obtained from WAB Trading International Ltd. to obtain basic information about the study villages and to inform the selection of a survey design and a sampling procedure. WAB Trading International Ltd. took over the operation of the organic shrimp project in the Satkhira district in 2007 when the Swiss Import Promotion Programme (SIPPO) shifted activity from Asia toward Europe.

Phase 3 – Data collection

The main data collection techniques used were semistructured questionnaire interviews, participatory rural appraisal (PRA), and direct observation. PRA tools such as rapport building, focus group discussion, transect walks, and the seasonal calendar were also employed to collect information on the livelihoods of organic shrimp farmers as well as the problems in their lives that were associated with organic shrimp farming. Community meetings with key informants and other villagers were organized to brief them about the objectives of the research. Regular experience-sharing meetings were conducted with the WAB International Ltd. manager and staff members. The researcher incorporated feedback from key informants and WAB International staff. The researcher facilitated communication and research process with supervisor in Vienna.

Phase 4 – Data processing, results, and write up

Qualitative data were recorded using a field diary and digital recorders. Quantitative data were recorded using a semistructured interview schedule. In this phase, the researcher incorporated suggestions from the reviewers engaged by the journals into a final version and resubmitted three articles for publication. Finally, this thesis was written based on the findings of the four published papers.

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PART – 2

Results

5. Research Papers

Paper – 1

Impacts of shrimp faring in Bangladesh: Challenges and alternatives

Brojo Gopal Paul and Christian Reinhard Vogl

Division of Organic Farming, Department of Sustainable Agricultural Systems,
University of Natural Resources and Life Sciences (BOKU), Vienna, Austria

I selected the topic, searched and analyzed literature and prepared a first draft of the paper. I revised the draft paper with inputs from Christian Vogl. The paper was published in Ocean & Coastal Management Journal in 2011, 54: 201−211.


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Review

Impacts of shrimp farming in Bangladesh: Challenges and alternatives

Brojo Gopal Paul*, Christian Reinhard Vogl

Division of Organic Farming, Department of Sustainable Agricultural Systems, BOKU-University of Natural Resources and Life Sciences, Gregor Mendel Strasse 33, A-1180 Vienna, Austria

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ABSTRACT

Shrimp farming is growing in Bangladesh due to suitable agro-climatic conditions, adequate water resources, cheap labour force, international donor agencies and the involvement of multinational corporations. Although it provides immediate economic benefits, contributes to poverty reduction and food security, as well as generates employment from seed collectors to exporters, it has also been facing a host of challenges. They hinder the sustainable development of this otherwise thriving sector. This paper aims to expound the hindrances and challenges for sustainable shrimp farming in Bangladesh by means of reviewing the available scientific literature. It finds that socioeconomic impacts such as traditional livelihood displacement, social unrests and market fluctuations are hindering the sustainable development of shrimp farming in Bangladesh. Similarly, environmental impacts such as mangrove degradation, salt water intrusion, sedimentation, pollution and disease outbreaks are found to be obstacles for the development of sustainable shrimp farming. Inappropriate management practices and inadequate plans regarding water quality, seed supply, irrigation facilities and fishery resources, added to institutional weaknesses, jeopardize the future growth of shrimp farming. Therefore, this paper shall provide substantial input to set the directions that research for alternatives can take and that can contribute to the sustainability of shrimp farming.

1. Introduction

Shrimp farming is growing in almost all regions of the globe and it has a long history also in Bangladesh. Between 2002 and 2008, global shrimp production has increased by 34 percent (FAO, 2008) as a result of industrial transformation and intensification of production patterns (Lebel et al., 2002) as well as the global decline in fish catch from marine sources (Bailey, 1988; Naylor et al., 2000; Erondu and Anyanwu, 2005). It has become an important part of the economic sector in many tropical and subtropical countries. Aquaculture currently accounts for nearly half of the world's food fish (FAO, 2006; Hishamunda et al., 2009). Annual global aquaculture production has almost tripled since 1990 (Sapkota et al., 2008). In Bangladesh, the export of frozen shrimp was 15,023 tonnes in 1988, which tripled to about 49,907 tonnes two decades later, i.e. in 2008 (DoF, 2009a). The contribution of frozen seafood towards the GDP amounted to about 4 percent in the financial year 2008–09 (BBS, 2009). Frozen seafood is Bangladesh's second largest export commodity after ready-made garments (EPB, 2009). However, environmental and socioeconomic impacts have increasingly become a matter of concern for both government and public. Objections are often associated with ecological consequences (mangrove destruction, salt water intrusion, disease outbreak and pollution), social conflicts, and negative impact on the economy. Several authors have already expressed doubts about the sustainability of shrimp aquaculture (Dewalt et al., 1996; Dierberg and Kiattisimkul, 1996; Primavera, 1997; Deb, 1998; Flaherty et al., 1999; Hein, 2002; Paez-Osuna et al., 2003; Hall, 2004; Chowdhury et al., 2006; Azad et al., 2009).

The negative impacts of shrimp farming have arisen from poor planning and management practices, as well as a weak application of the existing regulations. As a response to criticism, donors and shrimp experts have been trying to develop good aquaculture practices (GAP) and better management practices (BMP); these aim at reducing ecological losses and social disruption, which would provide good quality and safe food products (FAO/NACA/UNFP/WB/WWF, 2006). The management practices of GAP have addressed the issues of site selection, farm management, fish health management, feeds and feeding, record keeping, as well as the application of drugs and chemicals to ensure uncontaminated, safe food (Yamprayoon and Sukhumparnich, 2010). The BMP have additionally raised the issues of farm sustainability and environmental

* Corresponding author. Tel.: +43 (0)1 47654 3777; fax: +43 (0)1 47654 3792.
E-mail addresses: brojo.paul@boku.ac.at (B.G. Paul), christian.vogl@boku.ac.at (C.R. Vogl).

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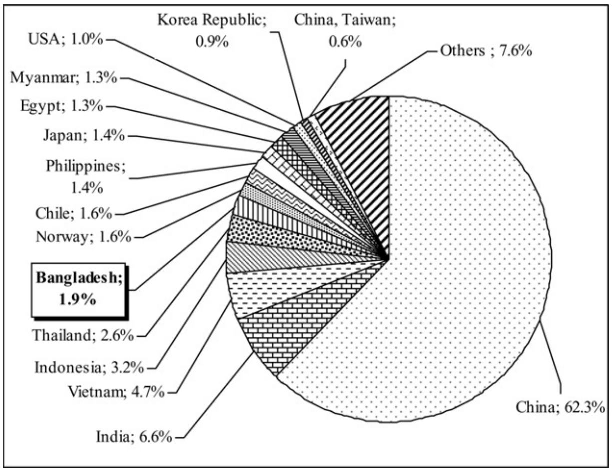

Fig. 1. Percentage distribution of aquaculture production by the top fifteen countries of the world (FAO, 2010).

degradation, and they are solving mostly technical problems (Bene, 2005). Both management guidelines can provide an important stimulus for government, public and private sectors to take over responsibility. Still, GAP and BMPs continue to be criticised for not considering social, political and health issues in many countries (Bene, 2005; Rahman et al., 2006). Shrimp farming expansion in Bangladesh is often unregulated, uncontrolled and uncoordinated (Deb, 1998; Metcalfe, 2003; Samarakoon, 2004; Alam et al., 2005). The shrimp sector is facing problems essentially due to the increasing occurrence of diseases and the lack of government stimulus: quality feed, available seed, good quality water and soil, and improved management practices are needed in order to establish sustainable farming and well-managed farms.

As a reaction to the negative socioeconomic and ecological impact of conventional farming methods, organic shrimp aquaculture has been introduced to the southwest region of Bangladesh as an alternative culture. In 2005, the Organic Shrimp Project (OSP) was initiated in Bangladesh by the Swiss Import Promotion Program (SIPPO). Recently, the OSP has been implemented by the Germany-based importing organization WAB-Trading International together with Gemini Sea Food Ltd. The organic farms of the OSP are certified by Naturland, a German private organic farmers association. The compliance of the farmers with this Naturland scheme gets inspected by the Institute of Market Ecology. The concept of organic shrimp aquaculture is relatively new to Bangladesh. WAB cooperates with 160 farmers' groups (consisting of 15–40 farmers each) and 3379 individual farmers. Worldwide, the growth rate of organic shrimp aquaculture is unknown but estimates for organic aquaculture ranged from 20% to 30% annually (Ruangpan, 2007). This is due to high market prices, growing consumer awareness regarding safe food, because it protects environment and biodiversity, and also for the further social and economic benefits it offers to farmers and society (Boehmer et al., 2005; Biao, 2008).

This paper reviews the global trends in aquaculture development as well as the role and culture patterns of shrimp farming in Bangladesh. The main aim of the review is to provide a firm foundation for advancing knowledge on the environmental and socioeconomic impacts of shrimp farming. It also investigates the links between shrimp production and economic growth, as well as the impact of institutional weaknesses. Finally, this review will lead to an empirical viability study of organic shrimp production in Bangladesh.

2. Trends in global aquaculture and its status in Bangladesh

The aquaculture sector is being fostered all around the globe because it is assumed to substantially contribute to food security, nutritional supply, poverty reduction and economic development (Bondad-Reantaso and Subasinghe, 2008). Between 1999 and 2008, annual global production of aquaculture increased from 31 to 53 million tonnes and earned 45 to 98 billion US dollars (FAO, 2010). Aquaculture in the developing countries contributes about 90% of global production in weight and 80% in value (Beveridge et al., 1997; Hishamunda et al., 2009). Recent statistics for global aquaculture show that eleven of the top fifteen producer countries are in Asia, accounting for 86.9% of the total global production (Fig. 1) (FAO, 2010). China is the leading producer in the world, accounting for almost 62.3% of the total production. The position of Bangladesh is sixth, contributing approximately 1.9% to the total aquaculture production (Fig. 1).

Capture fisheries account for 64% of the total fishery production in worldwide, while the remaining 36% of the food fish supply comes from the aquaculture sector (FAO, 2007). Globally, annual

Table 1
Relative importance of aquaculture production by the top fifteen countries of the World, 1999–2008.

Country	Total fishery production (tonnes)		Total aquaculture production (tonnes)		Share of aquaculture in total food fish production (%)	
	1999	2008	1999	2008	1999	2008
China	35,162,719	47,527,107	20,141,602	32,735,944	57.3	68.9
India	5,606,963	7583,567	2,134,814	3478,690	38.1	45.9
Vietnam	1,784,768	4549,200	398,468	2,461,700	22.3	54.1
Indonesia	4,736,188	6647,219	749,269	1,690,121	15.8	25.4
Thailand	3,646,070	3831,208	693,762	1,374,024	19.0	35.9
Bangladesh	**1,552,417**	**2,563,296**	**593,202**	**1,005,542**	**38.2**	**39.2**
Norway	3,103,466	3274,572	475,932	843,730	15.3	25.8
Chile	5,325,835	4397,956	274,216	843,142	5.1	19.2
Philippines	2,223,364	3302,334	352,567	741,142	15.9	22.4
Japan	5,944,302	4981,071	759,262	732,374	12.8	14.7
Egypt	648,941	1,067,630	226,276	693,815	34.9	65.0
Myanmar	1,011,124	3168,526	91,114	674,776	9.0	21.3
USA	5,228,325	4849,967	478,679	500,114	9.2	10.3
Korea Republic	2,422,561	2417,664	304,036	473,794	12.6	19.6
China, Taiwan	1,347,447	1340,372	247,732	323,982	18.4	24.2
Total (15)	79,744,490	101,501,689	27,920,931	48,572,890	21.6	32.8

Sources: (FAO, 2010).
Bangladesh highlighted to show the importance of aquaculture production compared to the top fifteen countries.

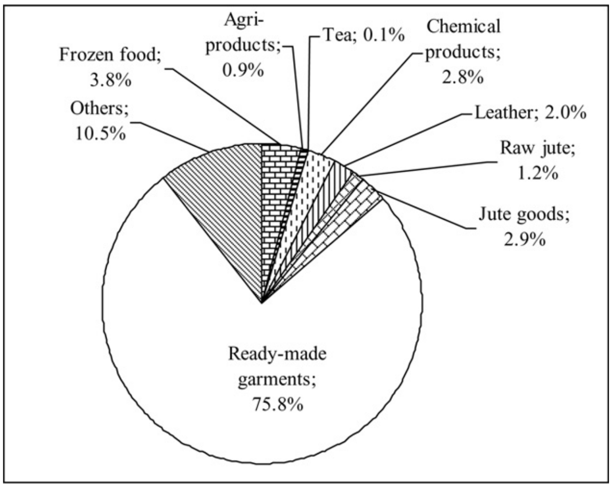

Fig. 2. Relative position of frozen seafood in Bangladesh from principal exported commodities (EPB, 2009).

capture fishery production decreased from 93 to 89 million tonnes between 2000 and 2008 (FAO, 2010). However, the top fifteen countries' total fishery production increased significantly, from 80 million tonnes in 1999 to 102 million tonnes in 2008 due to an increase in aquaculture production (Table 1). In the same period, the annual aquaculture production of the fifteen leading countries has increased from 28 to 49 million tonnes (Table 1). These countries together contribute almost 92% to the world's aquaculture production, but there are significant differences in their relative shares (Table 1). Bangladesh's production, in the same period, has grown at an annual average rate of 0.593 million tonnes to 1.005 million tonnes. The total share of aquaculture has increased from 21.6% in 1999 to 32.8% in 2008 in the top fifteen countries, but when individual countries are taken into account, the growth may be lower, as in the case of Bangladesh, where it was only 1% (Table 1). This proportionally low increment may be attributed to a commensurate increase in capture fisheries, as well as disease outbreaks and inadequate management practices.

3. Role and pattern of shrimp aquaculture in Bangladesh

The export-oriented production of frozen seafood plays a significant role in the national economy of Bangladesh and accounts for 3.8% of the country's export earnings (Fig. 2) (EPB, 2009). Frozen seafood earned US$ 550.53 million of foreign exchange from export in the financial year 2007–08, to which shrimp contributes with approximately 81% (BSFF, 2008). Thereof, shrimp aquaculture accounts for 42.2% of total production. The remainder comes from marine and coastal sources by means of capture fishery (Table 2). Shrimp farming activities alone both directly and indirectly employ more than 0.6 million people in the country (Islam et al., 2005).

Shrimp aquaculture has expanded from the south-eastern to the south-western parts of the coastal areas of Bangladesh. Initially, the pond area under shrimp aquaculture comprised 20,000 ha (ha) in 1980, growing rapidly to approximately 217,877 ha in 2007/08 (Metcalfe, 2003; DoF, 2009a). This expansion of shrimp aquaculture in the country is ascribed to its suitable climatic conditions and the availability of resources such as feed, seed, water and a cheap labour force (Islam, 2003). The swift increase after the 1980s is mainly due to the high profits obtained, high demand for shrimps on the international markets, employment generation, and earning of foreign currency (Deb, 1998). The private sector initiatives include the involvement of multinational corporations, which attracted both national governmental and international development agencies to expand shrimp aquaculture in the country (Deb, 1998). This same notion has been articulated by scholars of several Asian countries (Bailey, 1988; Bailey and Skladany, 1991; Stonich and Bailey, 2000).

In the 1970s, shrimp aquaculture in Bangladesh was started in *ghers,* which are traditional earthen ponds or fields situated by riversides and impounded by dykes (Islam et al., 2005; Ahmed et al., 2008b). Generally, a *gher* is used to grow rice between the months of August and December/January, and shrimp culture is practiced during the months of February to July/August (Deb, 1998; Ahmed, 2003; Islam et al., 2005). Tidal water exchange is important in the *gher* system for trapping wild seeds and natural food as well as for maintaining water quality (Primavera, 1991; Islam et al., 2005; Ahmed et al., 2008a).

However, this system has evolved over time and today, Bangladeshi shrimp aquaculture is classified into four categories: traditional, extensive, semi-intensive and intensive (Table 3) (Deb, 1998; Islam et al., 2005); similar classification systems have been reported for Southeast Asia, however, the categories can vary from country to country (Primavera, 1993, 1998; Dierberg and Kiattisimkul, 1996; Rönnbäck, 2002). The Bangladeshi classification is fully based on the intensity of the culture pattern such as stocking density, inputs (feed, fertilizer) and water quality management (Table 2). The stocking rate is low and any kind of sophisticated management is almost absent in traditional culture practices (Islam et al., 2005). Therefore, smaller size *ghers* and improved management practices are encouraged to obtain sustainable production and profits (Wahab, 2003). Intensive culture achieves 50 times more production than traditional culture if water management and supplementary feed are adequately employed together with a high stocking density (Primavera, 1993). In Bangladesh, 70% of the shrimp farms use traditional and/or

Table 2
Annual shrimp production (tonnes) and percentage contribution of shrimp aquaculture in Bangladesh (1998–99 to 2007–08). Source: DoF (2009a,b).

	Year-wise shrimp production (tonnes)							Percentage of cultured shrimp
	Inland Fisheries			Marine Fisheries				
Financial year	Capture	Culture	Total	Trawl	Artisanal	Total	Grand total	
1998–99	49,296	63,164	112,460	3765	27,977	31,742	144,202	43.8
1999–00	43,167	64,647	107,814	2915	28,480	31,395	139,209	46.4
2000–01	44,343	64,970	109,313	3172	27,865	31,037	140,350	46.3
2001–02	54,965	65,579	120,544	3168	28,808	31,976	152,520	43.0
2002–03	60,876	66,703	127,579	2486	29,445	31,931	159,510	41.8
2003–04	63,103	75,167	138,270	3075	33,413	36,488	174,758	43.0
2004–05	68,768	82,661	151,429	3311	40,950	44,261	195,690	42.2
2005–06	77,381	85,510	162,891	3444	44,675	48,119	211,010	40.5
2006–07	82,422	86,840	169,262	2175	49,694	51,869	221,131	39.3
2007–08	75,678	94,211	169,889	2620	50,586	53,206	223,095	42.2

Table 3
Four different types of shrimp aquaculture practices. Source: Primavera (1993, 1998), Dierberg and Kiattisimkul (1996), Deb (1998), Rönnbäck (2002), Islam et al. (2005).

Criteria	Intensity of farming systems			
	Traditional	Extensive	Semi-intensive	Intensive
1) Pond (*gher*) size (ha)	5–10 or >	5–10 or >	1–10	< 1
2) Stocking	Natural	Natural + artificial	Artificial	Artificial
3) Stocking density (seed/m^2)	1–1.5	2–10	20–40	40–60
4) Seed source	Wild	Wild	Wild + hatchery	hatchery
5) Survival rate (%)	50–60	60–80	70–80	70–90
6) Feed used	Natural	Natural, little low cost feed	Natural and pelleted feed	Formulated complete feed
7) Water exchange	Tidal	Tidal, minimal pumping	Tidal, pumping	Pumping, reservoir, filter
8) Aeration	No	Little or no	Yes	Yes
9) Yield (t/ha/yr)	0.1–0.5	0.6–1.5	2–6	7–15
10) Production cost (US $/kg)	No data	1–3	2–6	4–8
11) No. of crops/year	1–2	1–2	2–3	2–3
12) Diversity of species	Polyculture	Polyculture	Monoculture	Monoculture
13) Lime used (kg/ha/yr)	Little or no	< 100	250–400	500+
14) Fertilizers used (kg/ha/yr)	Little or no	Cowdung-500, little or no urea/TSP	Cowdung-2000+, Urea-300+, TSP-100+	Cowdung-4000+, Urea-500+ TSP-200+
15) Chemicals used	No	No or little	Used	Widely used
16) Employment (Persons/ha)	No data	< 7	1–3	1
17) Disease problems	Rare	Rare	Moderate to frequent	Frequent
18) Operational costs	Little or no	Low	Moderate to high	Extremely high
19) Development costs	Little or no	Low	Moderate to high	Extremely high
20) Environmental impact	Little or no	Relatively little	Moderate to high	Extremely high
21) Social implications	Little or no	Relatively little	Moderate to high	Extremely high
22) Economic proliferation	Subsistence	Subsistence	Commercial	Entrepreneurial
23) Sustainability concerns	High	Moderate to high	Moderate to low	Relatively low

extensive, 25% semi-intensive, and 5% intensive culture techniques (Hussain, 1994).

4. Environmental impact

The rapid growth of shrimp farming has led to both short and long-term negative environmental impacts, involving ecological imbalance, environmental pollution and disease outbreaks. Thus, shrimp farming is facing management-related difficulties which lead to greater concerns about water quality, feed and seed supply.

4.1. Destruction of the mangrove ecosystem

The transformation of the naturally multifunctional mangrove ecosystem into privately-owned, single-purpose shrimp aquaculture systems is destroying the ecology of the coastal zone (Folke and Kautsky, 1992; Primavera, 1997). Roots and stems of intact mangrove forests provide free multiple services such as shelter, habitat for fry and brood stock, feeding ground, buffers against storm surges and shoreline erosion (Primavera, 1991, 1997; Dierberg and Kiattisimkul, 1996; Ahmed, 2003; Iftekhar, 2006; Giri et al., 2008). A lot of literature points to the fact that the biodiversity in both fauna and flora has degraded due to the unabated destruction of the diverse mangrove ecosystem (Iftekhar, 2006; Hoq, 2007; Iftekhar and Takama, 2008). Mangrove destruction in the world is caused by two main factors: aquaculture and agricultural expansion, as well as industrial and settlement development (Primavera, 1997; Giri et al., 2008). Destruction of mangroves due to shrimp aquaculture has been reported by several scholars in different parts of the world (Primavera, 1991, 1997; Dierberg and Kiattisimkul, 1996; Hein, 2002). Around the world, between 30% and 70% of the mangrove area has been lost due to shrimp farming (Barbier and Cox, 2004). Mangrove clearing gets further escalated by the low price of shrimp, minimum wage, distance from market, price of feed, population growth and the density of shrimp farms (Barbier and Cox, 2004).

In the Bengali Sundarbans, most of the mangrove destruction occurred before the rise of shrimp farming and is associated with agricultural expansion (Richards and Flint, 1990). However, in Bangladesh, mangrove wetlands are still being converted to ponds/*gher* for shrimp aquaculture (Deb, 1998; Chowdhury et al., 2006). The exact rate of mangrove destruction due to the construction of ponds in the south-western parts of Bangladesh is not yet known. However, the rates as well as the causes for the reduction of mangrove forests vary, both spatially and temporally (Giri et al., 2008). Nevertheless, in the south-eastern parts of Bangladesh an area of 18,200 ha of mangrove (Chakaria Sundarbans) has almost completely been destroyed to make place for shrimp aquaculture (Akhtaruzzaman, 2000). The government-led development projects for shrimp aquaculture, patronized by the Asian Development Bank (ADB) and the World Bank, might have caused massive destruction of the forests (Deb, 1998). However, shrimp aquaculture is not the only reason for mangrove degradation; other land uses such as rice production and salt production have also played a substantial role in the destruction of mangrove forests in Bangladesh (Deb, 1998). The remaining mangrove forests are under pressure by continuous cutting, encroachment, storms and climate change (Iftekhar and Saenger, 2008).

4.2. Land degradation

Shrimp aquaculture in Bangladesh is competing with farmers' cultivable plain land, state-owned mangrove swamp, and coastal land. Worldwide, most shrimp ponds in coastal areas have been converted from rice-producing fields and the remainder by manipulating coastal salt flats, marshes and mangroves (Bailey, 1988; Paez-Osuna, 2001). However, large areas of natural mangrove and other land uses such as low-lying floodplains, marshes, etc. have been used for the construction of *gher* in southwest Bangladesh (Chowdhury et al., 2006; Ahmed et al., 2008b). This construction of ponds/*gher* and associated dykes and polders for shrimp cultivation as well as access roads has changed the current land use pattern (Islam, 2003). Unplanned construction of canals and dykes causes flooding and waterlogging for several months every year in some coastal areas of Bangladesh (Islam, 2009). The conversion of natural wetland ecosystems may reduce fish migration routes and avert natural water flows. Newly constructed ponds may accumulate salt water for shrimp aquaculture and the salt water slowly alters the chemical properties of the pond water and soil. This alteration renders the land unsuitable for crop production in the future (Chowdhury et al., 2006). The land may previously have been used for rice production during the wet season, but shrimp aquaculture affects the rice ecosystem and does not allow this any longer. In other cases, rice land converted to shrimp ponds is of poor quality for agriculture because it is salt affected; thus, conversion in some cases can be a quite sensible land use if there is no potential for the ponds to leach salts into surrounding fields (Flaherty and Karnjanakesorn, 1995; Dierberg and Kiattisimkul, 1996; Flaherty et al., 1999). Still, the transformation of rice fields into shrimp ponds has significantly reduced the rice yield in Bangladesh (Ali, 2006), which may create food insecurity in rural areas. Like elsewhere in the country, rice fields are often used as pastures as well as for cultivating other crops and vegetables in the dry season. The decline in grazing land has substantially reduced livestock resources (Ali, 2006). The degradation of land has altered the coastal land use pattern, which increases the threat of an unsustainable use of natural resources.

4.3. Loss of capture fishery stock

Shrimp aquaculture farms in Bangladesh stock wild-caught juveniles rather than hatchery-reared post-larvae. Owners of shrimp farms encourage the local people to collect wild spawn from estuaries and coasts. However, trawl fishermen collect mother shrimps as brood stock from the deep sea. This collection of brood stock and spawn plays a major role in the loss of capture fisheries as the by catch increases (Primavera, 2006). The rate of depletion from rivers and estuaries in Bangladesh has been 10% during the past 10 years (DoF, 2009a). In Mexico, the stock of capture fisheries has gone down at the rate of 28–30% between 1980 and 1990 due to overexploitation (Paez-Osuna et al., 2003). Capture fisheries are used to supply trash fish to make fish meal. When the shrimp industry uses pelagic fish as trash fish to make fish meal, and ultimately to produce pellet feed, it diminishes the wild fishery resources (Naylor et al., 2000). In intensive farming, pellet feed is applied as a supplement for rapid growth. Compared to poultry and livestock feeds, high quantities of fish meal are required to produce pellet feed for the shrimp aquaculture industry; the production of 1 kg of carnivorous fish requires up to 5 kg of wild fish (Naylor et al., 2000). The high proportion of fish meal in the shrimp aquaculture industry has induced a loss of wild capture fish stock (Primavera, 2006). In most cases, fishermen collect very small fish for making fish meal, which directly reduces the chance of getting table fish. Shrimp farms and the growing number of people dependent on fishing have had a significant role in the decline of fish stocks. Catches of wild shrimp in both open sea and coastal ecosystems have declined because of the overexploitation and contamination of the coastal zone (Paez-Osuna et al., 2003).

4.4. Seed supply

Natural sources for shrimp collection are threatened by environmental pollution and overexploitation, causing a severe scarcity of wild seed supply (Islam et al., 2004; Hoq, 2007). Shrimp seeds are harvested exclusively by women and children in estuaries and coasts, using a variety of fine-mesh hand-handle push nets. Men do not usually harvest seed, except by boat.

The rate of mortality in post-larvae (PL) is high, and biodiversity is reduced for every single PL collected (Dewalt et al., 1996; Primavera, 1998; Naylor et al., 2000; Hoq et al., 2001). In Bangladesh, 12 to 551 PL of other shrimps, 5 to 152 PL of finfish, and 26 to 1636 PL of other macro-zooplankton are wasted during the collection of a single *P. monodon* PL (Hoq et al., 2001). Collection of shrimp seeds from natural sources for aquaculture operations directly influences wild fisheries (Naylor et al., 2000; Primavera, 2006). More than fifty hatcheries have been built in Bangladesh in the last seven years to meet the demand for shrimp farms (DoF, 2009b). While precise data do not exist, an estimated 60–75% of the post-larvae used by shrimp farms get produced in these hatcheries (Islam et al., 2004). This has reduced the dependency on wild sources and avoided risks of disease, as hatcheries provide pathogen-free shrimp seeds that grow better and survive better than wild post-larvae (Islam et al., 2004). Still the big concern is better quality: what mechanism should hatchery operators apply to reduce the mortality of shrimp and free them of pathogens, so to ensure their rapid growth?

4.5. Sedimentation

Water runoff during the rainy season carries sediments from upstream through river tributaries to coastal areas (Dewalt et al., 1996). When water from estuaries or river channels is stored in shrimp *ghers* or ponds, the sediments quickly settle on the bottom as water velocity slows down (Dewalt et al., 1996). In intensive shrimp farming, however, sediments originate also from the pond bottom and surrounding walls as well as from the sludge that accumulates on the pond bottom during each production cycle (Briggs and Funge-Smith, 1994). Furthermore, the pond management activities worsen the sedimentation problem, as a daily exchange of water is required (Barraclough and Finger-Stich, 1996; Funge-Smith and Briggs, 1998). Management practices, including high stocking density, feed application, aerator use, liming and fertilizers, etc., also contribute to suspension and sediment accumulation (Funge-Smith and Briggs, 1998). Intensive farming accumulates high amounts of sediment, such as 185–199 tonne dry wt./ha or 139–150 m^3/ha (Briggs and Funge-Smith, 1994). Extensive culture systems in Bangladesh produce less than 1 tonne/ha/year, which does not pollute the surrounding water and rather acts as a sink for nutrients and solids (Wahab et al., 2003).

The sediment is often discharged into waterways leading into the sea, or is sometimes used to build new dykes or maintain existing dykes (Barraclough and Finger-Stich, 1996; Dierberg and Kiattisimkul, 1996; Paez-Osuna, 2001). Maintenance of dykes deteriorates the quality of water during the next production cycle and discards sludge into the open sea, creating a waste disposal problem (Dierberg and Kiattisimkul, 1996). The pond bottom accumulates excessive organic materials such as nutrients (nitrogen, phosphorus and ammonia) and hydrogen sulphide, which creates foul odours, hypernutrification and eutrophication (Barraclough and Finger-Stich, 1996; Funge-Smith and Briggs, 1998). The action of suspended solids or colloids produces turbidity, which reduces sunlight penetration into the water column, which, in turn, ruins primary productivity and the trophic structure of the ecosystem (Dewalt et al., 1996). Turbidity is reported at 23% for extensive farms and at 39% for semi-intensive farms in Bangladesh (Wahab et al., 2003). Furthermore, the sediment loads have a detrimental impact on other water users as well as the local fauna and flora (Barraclough and Finger-Stich, 1996; Dewalt et al., 1996).

4.6. Pollution

Intensive shrimp farming requires a daily change of water, approximately 5–10% of the total pond volume per day during earlier, and 30–40% during later stages of growth period (Flaherty and Karnjanakesorn, 1995). In extensive shrimp farming, water gets changed for four or six days at full and new moon in every fortnight at a rate of 0–10% of the total pond volume (Wahab et al., 2003).

Sluice gates are constructed to maintain water flow and to control salinity levels via water exchange. They are also used as effluents to remove waste, dissolved metabolites and particulate matters, which are formed by the collective action of various chemicals, fertilizers, excreta, unused feed, unwanted organisms, detritus, etc. (Flaherty and Karnjanakesorn, 1995; Flaherty et al., 2000; Hall, 2004). Such directly discharged effluents can easily pollute the surrounding water and soil quality (Deb, 1998; Neiland et al., 2001). Effluents from shrimp ponds are typically enriched in suspended solids; nutrients such as ammonia, nitrate, nitrite; Chlorophyll *a* and biochemical oxygen demand (BOD) (Barraclough and Finger-Stich, 1996; Paez-Osuna, 2001). The discharging effluents can reduce the dissolved oxygen, create hypernutrification and eutrification, increase sedimentation load, and cause changes in the benthic communities (Flaherty and Karnjanakesorn, 1995; Dewalt et al., 1996; Stonich et al., 1997; Flaherty et al., 2000).

The major sources of marine pollution in the Bay of Bengal are industrial, municipal and agrochemical waste and oil spill (Islam, 2003). The negative impact of pollutants on human beings, fish and other organisms has already been reported (Matin, 1995; Gräslund and Bengtsson, 2001). Agrochemicals and pesticides contaminate the water environment through agricultural runoff (Paez-Osuna et al., 2003). About 9000 tonnes of different pesticides and more than 2 million tonnes of fertilizers are used annually in Bangladesh (Matin, 1995). The unplanned use of agrochemicals and the discharge of industrial and municipal waste without treatment through river channels to the sea cause a decline in capture fisheries (Islam, 2003; Hall, 2004). In the same way, polluted water from the sea contaminates the aquaculture ponds. Sources of quality water are becoming scarce because effluents are impaired by the combined effects of shrimp pond, industrial, municipal and agricultural waste. Similarly, the water quality in shrimp ponds declines when weather and tidal conditions affect it through a combination of factors such as cloudy days, low winds and neap tides (Paez-Osuna, 2001).

4.7. Saltwater intrusion

Shrimp aquaculture has raised serious concern about the impact of saltwater intrusion into the surrounding agricultural lands (Flaherty and Vandergeest, 1998; Flaherty et al., 2000). The impact of saltwater intrusion into different coastal areas is reported by the following authors (Primavera, 1991, 1997; Flaherty et al., 1999). Ponds are being constructed for shrimp aquaculture behind mangrove forests where freshwater wetlands and rice-growing areas still exist (Flaherty and Karnjanakesorn, 1995; Dierberg and Kiattisimkul, 1996). Inundation of land by saline water for long periods leads to its percolation into the surrounding soils, resulting in an altered soil chemistry (Islam, 2003). Prolonged inundation inhibits the fixation of free nitrogen and halts mineralization, thus impairing soil fertility within a few years (Islam, 2003). Nevertheless, shrimp farms need additional fresh and salt water supplies throughout the growing phase of the cultures, as water is lost by seepage and evaporation (Flaherty et al., 1999; Paez-Osuna, 2001). The demand for salt water is fulfilled by digging narrow canals from near the shore or river channel for each shrimp-growing season, which disperse salt water along the coast of Bangladesh. Fresh water demand is fulfilled by setting up deep tubewells, which directly affects groundwater aquifers (Islam, 2003; Chowdhury et al., 2006). In the south-western parts of Bangladesh, salt water intrusion has not only changed the productivity of *ghers* and the land use pattern, but also affected freshwater supplies for irrigation (Deb, 1998). The withdrawal of groundwater through pumping has lowered the groundwater table and consequently fresh groundwater is contaminated by salt water (Barraclough and Finger-Stich, 1996; Flaherty et al., 2000).

4.8. Danger of imported fry and genetic alteration

The scarcity of wild shrimp seeds has inspired traders to import them from different countries. This importing of shrimp seeds without quarantine has spread several viral and fungal diseases throughout Bangladesh (Deb, 1998). Additionally, various infectious diseases have been widely disseminated through the introduction of fishes to the natural environment, as shrimp cultivators draw on the tidal water. Several research articles about gene pool alteration through mismanagement, accident or storm surges from farm to natural environment, discuss corresponding precautionary measures (Deb, 1998; Neiland et al., 2001). Gene pool interactions between wild animals and farm livestock may negatively affect the surrounding ecosystem through interbreeding (Naylor et al., 2005). The native biodiversity of both wild and farm stocks are confronting environmental hazards due to the introduction of invasive species and modified genotypes (Naylor et al., 2000; Diana, 2009).

4.9. Diseases

Intensive farming makes the shrimps highly susceptible to diseases (Primavera, 1991). Bangladesh has experienced disease outbreak in both semi-intensive and extensive farms in 1996 (Alam et al., 2007). When physico-chemical factors such as pH, temperature, dissolved oxygen, etc. fluctuate frequently, shrimps become susceptible to stress, leading to diseases (Paez-Osuna et al., 2003) such as red colour, soft shell, tail rot and black gill (Primavera, 1991; Alam et al., 2007). Disease outbreak has been recognized as the biggest obstacle to the development of shrimp aquaculture in Bangladesh. High stocking density and excessive use of feed lowers water quality, which contributes to stress and diseases among shrimp in intensive farming systems (Flaherty and Vandergeest, 1998; Paez-Osuna et al., 2003). It is dangerous when redundant feed and waste are discharged directly into the environment, which renders it extremely susceptible to carrying diseases. The intake of polluted water from neighbouring farms often spreads water-borne diseases from farm to farm (Paez-Osuna, 2001). Poor water quality, associated with unplanned and uncontrolled farming, has increased the incidence of diseases and reduced production (Deb, 1998). Viral diseases such as the White Spot Syndrome Virus (WSSV) and Yellowhead virus have infected shrimps in a catastrophic manner, causing huge economic losses across Asia (Primavera, 2006). In 1996, Bangladesh lost 44.4% of its total shrimp production due to an outbreak of disease caused by WSSV (Mazid and Banu, 2002).

4.10. Use of biological and chemical products in shrimp aquaculture

Shrimp aquaculture in Bangladesh relies heavily on the input of artificially formulated feed and the application of agrochemicals, antibiotics and disinfectants. The impact of these chemicals and biological products on shrimp farming as well as other aquaculture industries is well recognized by several authors (Alderman and Hastings, 1998; Gräslund and Bengtsson, 2001; Holmström et al., 2003; Cabello, 2006; Uddin and Kader, 2006; Sapkota et al., 2008). These products are often used in shrimp ponds to treat water and sediment as well as to prevent disease outbreaks. Some chemicals are used even in hatcheries to disinfect equipment. Information on the names and quantities of chemicals is not available for want of documentation. The quantities of these products usually vary, depending on the type of management system followed (Gräslund and Bengtsson, 2001; Uddin and Kader, 2006). The most common products used in shrimp aquaculture are fertilizers for the enhancement of natural feed and liming material for water and soil control. Disinfectants, antibiotics, algaecides, herbicides and probiotics are also used to increase production (Boyd and Massaut, 1999). When diseases spread out extensively, shrimp farmers tend to make heavy use of antibiotics as a prophylactic measure. The use of certain antibiotics in aquaculture may cause the development of antibiotic-resistance among pathogens, which compromises both human and the cultivated animals' health (Holmström et al., 2003). Chloramphenicol, Erythromycin, Oxytetracycline, Furazolidone and Prefuran, which are effective against Gram-positive and Gram-negative bacteria, are the synthetic agents commonly used as antibiotics in hatcheries (Uddin and Kader, 2006). However, these antibiotics are used in different concentrations and spectrums in most Asian countries (Baticados et al., 1990; Primavera et al., 1993). Nitrofuran is suspected to be infected with carcinogens and, therefore, prohibited for use on food animals in the European Union (GESAMP, 1997). Chloramphenicol may cause severe adverse effects, such as aplastic anaemia, in the human body and increase drug resistance (GESAMP, 1997). Some chemicals used in shrimp farming, such as organotin compounds, copper compounds and toxic residues, are likely to have a negative impact on the environment (Gräslund and Bengtsson, 2001). The commonly used disinfectant chlorine is applied to kill bacteria and viruses. Further pesticides are applied in shrimp ponds to kill unwanted organisms such as fish, crustaceans, snails, fungi and algae (Gräslund and Bengtsson, 2001).

5. Social impact

In addition to the environmental and economic impacts, the social impact of shrimp aquaculture has been widely discussed by several scholars (Primavera, 1991; Barraclough and Finger-Stich, 1996; Primavera, 1997; Stonich and Bailey, 2000; Neiland et al., 2001; Alam et al., 2005; Primavera, 2006; Costa-Pierce, 2008). In Bangladesh, most of the coastal land is operated by national and multinational investors (Deb, 1998; Ito, 2002). These investors are highly influential persons or institutions such as political leaders, army officers, bureaucrats, bankers, businessmen, journalists and NGOs (Deb, 1998). In India, powerful landlords and elected state representatives violate laws and acquire large areas for shrimp aquaculture (Primavera, 1997). These investors offer money to small landowners to lease out or sell their rice fields to them for shrimp aquaculture (Ito, 2002). If landowners refuse, then investors sometimes forcibly submerge their fields in salt water (Ito, 2002). In such cases, the small landowners have no choice but to either migrate out of the area or accept the investors' humiliating proposals (Deb, 1998). There are protests against illegal or forced occupation of land, but in fact, they often lead to violence and killing. In Bangladesh, about 85% of the investors are from outside the local area (Gain, 1995). However, in West Bengal (India), small-scale farmers and traditional (paddy-cum-prawn) cultivators have recently been actively participating in shrimp aquaculture (Philcox et al., 2010). Conflicts have arisen between investors and local farmers over land grabbing and denial of access to natural resources (Shiva, 1995; Dewalt et al., 1996; Stonich and Bailey, 2000; Neiland et al., 2001). In the Indian Sundarbans, a comparatively low level of conflict has arisen, which is probably due to the farmers being locals, low-intensity cultivation practice, and the small area of land under operation (Knowler et al., 2009). This situation might change if investors got access to pursue large scale commercial cultivation.

When investors get access to an area for shrimp aquaculture either by purchasing land or by forcibly taking it, land prices skyrocket (Barraclough and Finger-Stich, 1996; Ito, 2002). In Bangladesh, land prices have risen eighteen fold between 1994 and 2000 (Ito, 2002). In India and Thailand, too, land prices have multiplied following the initiation of shrimp farming in coastal areas, and, as a result, local farmers could no longer afford to purchase land (Barraclough and Finger-Stich, 1996). Thus, local farmers are losing access to common property resources such as mangroves, marshes, etc. Mangrove areas are directly important for coastal fishermen, mainly for aquatic food items such fish, crustaceans, molluscs, but also for other economic activities (Primavera, 1997). It is assumed that the catch per unit effort (CPUE) for widely caught fish has declined substantially because of reduced fishing stock and, therefore, fishermen's livelihoods have been rendered vulnerable (Dewalt et al., 1996). Traditional fishermen from the open sea and coastal lagoons are facing unemployment risk due to the damaging of the coastal ecosystem and the resulting decrease in fishery yields (Paez-Osuna et al., 2003). Loss of fisheries has forced fishermen to switch to other employment avenues such as cutting mangroves for firewood and other economic activities inside mangrove forests in order to survive (Dewalt et al., 1996). These changes in employment pattern have greatly contributed to the destruction of mangrove forests.

Destruction of mangroves causes loss of wildlife, increases flood risk and leads to damages on property through typhoons and tsunamis every year (Primavera, 1997; Iftekhar and Takama, 2008). In the recent past, the cyclones SIDR and AILA have destroyed huge numbers of shrimp farms in the south-western parts of Bangladesh, jeopardizing farmers' futures.

The earnings from *gher* construction through conversion of rice fields are temporary (Ito, 2002). As soon as the construction of a *gher* is completed, this employment opportunity as a labourer is gone. Rice farming is more labour-intensive than shrimp farming (Barraclough and Finger-Stich, 1996). In India, rice cultivation on 40 ha of land requires 50 labourers, but shrimp farming in the same area needs only five workers (Shiva, 1995). Also, the conversion of rice fields into shrimp ponds has reduced the opportunities for other traditional dry season activities, such as grazing cattle and homestead gardening (Alam et al., 2005).

The expansion of shrimp ponds causes massive waterlogging in the south-western parts of Bangladesh (Ito, 2002). The main cause is unplanned *gher* construction, which has extended from coastal agricultural land to residential areas. In consequence, a large number of people are forced to flee their homes and take shelter in unoccupied school or government buildings. Long-term water logging by saline water reduces soil fertility for agricultural production, diminishes opportunities for freshwater irrigation and creates scarcity of fresh drinking water in the community (Primavera, 1997; Flaherty et al., 2000; Islam, 2003; Ito, 2004; Ali, 2006). Fresh water is used in shrimp ponds both to minimize salinity and in hatchery operations. The contribution of shrimp aquaculture to poor people's nutrition can be neglected because most of the farmers cannot afford to eat the high-value shrimp. Poor farmers are forced to sell their high-value shrimp and buy low-value fish from the local markets for domestic consumption. Even the low-value fish is scarce in the local markets because it is used as a raw material for fish feed that in turn is to be administered in shrimp aquaculture. Accordingly, when fish supplies decline and prices go up in the local market, poor consumers are forced to shift to inferior food and fish tends to disappear from dinner plates (Kent, 1997). Therefore, international and national environmental organizations, human rights groups and academics are raising their voices against the social and environmental problems caused by shrimp aquaculture (Stonich and Bailey, 2000).

6. Economic impact

Shrimp aquaculture has expanded in many countries without considering the total economic value (TEV) of intact mangrove forests (Balmford et al., 2002; Gunawardena and Rowan, 2005). The cost-benefit analysis of a 42-ha farm in Sri Lanka shows that the internal benefits of shrimp farming are higher than the internal costs in the ratio of 1.5:1 (Gunawardena and Rowan, 2005). When the wider environmental impact is comprehensively evaluated, however, the external benefits are much lower than the external costs in a ratio which ranges from 1:6 to 1:11 (Gunawardena and Rowan, 2005). The economic benefits of shrimp aquaculture may perhaps be manifold, but considering its environmental costs, shrimp aquaculture needs to be treated as economically more harmful than good (Khor, 1995). The economic performance of shrimp farming is also affected by fluctuations in the local and international markets. The market price of cultured shrimp fluctuates, especially in the beginning and at the end of the production cycles. The prices for inputs increase meteorically, but the price of shrimp declines during the harvest season, which also has directly impeded the growth of shrimp cultivation. Therefore, shrimp farmers are facing various challenges because of the hike in the prices of inputs during the culture period, and unanticipated market fluctuations during the harvesting season (Neiland et al., 2001).

In Bangladesh, the shrimp price decreases when importing countries put restrictions on the import volume because there is no local market for shrimps. Furthermore, shrimp farmers incur losses when importing countries impose import bans due to harmful components in the processed shrimp. Farmers that are on the edge of surviving with the income from their farms face difficulties when the prices for inputs (seed, feed, fuel) increase tremendously, which may even force them out of business (Shang et al., 1998). Due to the scarcity of shrimp seed from natural sources, also the price of the shrimp seed rises, and small operators face problems in maintaining their costs. Shrimp seeds are still not sufficiently available from hatchery sources and, in addition, their prices are controlled by hatchery operators. The market for the pellet feed used in shrimp farming is highly competitive, with many private companies from Bangladesh and outside in the fray. Nevertheless, the price of pellet feed for shrimp farming has gone up and remains high, which has had severe impacts on production costs and returns. Shrimp farming is hindered by this steep hike in the price of feed, which can undermine the long-term viability of shrimp aquaculture. The price of fuel also influences the costs for inputs, and the inflation in Bangladesh has further increased the farmers' production costs. The scale of operation depends on the farmers' financial capacity, which in turn influences the intensity of the culture system.

The financial risk is always associated with the intensity of the culture pattern and is influenced by planning, design, management capacity and market fluctuations. However, the financial risk varies substantially, depending on farm size, management capacity and knowledge, and the operators' financial conditions. Recently, the economics of shrimp aquaculture in Bangladesh have changed: a twin-driven commodity chain has developed, in which buyers govern the supply network, while third party certifiers and environmental NGOs define the regulatory aspects of the industry (Islam, 2008). This governance of the chain offers opportunities for sustainable aquaculture and has the potential to identify the key market players and roles in the supply chain (Islam, 2008).

7. Institutional impact

Sustainable shrimp farming is possible, but it takes numerous technological improvements, adequate knowledge transfer through institutional changes, and sufficient monitoring of compliance with environmental and social requirements (Dierberg and Kiattisimkul, 1996; Primavera, 1997; Stonich and Bailey, 2000; Hein, 2002; Alam et al., 2005). Improved governance is an essential precondition to reduce social discrimination and safeguard the natural ecosystem (Samarakoon, 2004; Costa-Pierce, 2008). The shrimp sector of Bangladesh is characterized by a multitude of institutions, including 17 ministries and divisions, and 28 departments and agencies (Maniruzzaman, 2006). In addition, there are several institutions and organizations that play a role in the shrimp sector, such as NGOs, donor agencies, cooperatives of shrimp farming groups and the local union *parishad* (council) (Pokrant and Bhuiyan, 2001). Seventeen major policies, laws, acts, rules and ordinances have been enacted in Bangladesh to develop the shrimp sector (DoF, 2006; Maniruzzaman, 2006; DoF, 2010) (Table 4). The Department of Fisheries is the main implementing agency in the fisheries and aquaculture sector under the administrative control of the Ministry of Fisheries and Livestock. The other policies relevant to the shrimp sector include the FAO Code of Conduct for Responsible Fisheries, the National Water Policy, National Agricultural Policy, National Rural Development Policy, National Land Use Policy, National Environmental Policy and Coastal Zone Policy (DoF, 2006). These legal issues promote the conservation of natural resources and protect the rights of the local people and those of various stakeholders of the shrimp sector (Ahmed et al., 2002). The Government of Bangladesh has amended several acts such as an act permitting farmers to take up saline water into new

Table 4
Relevant fishery policies, laws, rules, acts and ordinances in Bangladesh. Source: Maniruzzaman (2006), DoF (2006, 2010).

Title of policy/law/rule/act/ordinance	Aspects covered
The Protection and Conservation of Fish Act, 1950	Conservation of fisheries resources as a whole
Embankment and Drainage Act, 1952	Protecting crops, not allowing cuts in embankments (to produce shrimp)
Bangladesh Water and Power Development Board Ordinance, 1972	Develop water management infrastructure for shrimp farming
Territorial Water and Maritime Zone Act, 1974	Conservation of marine fisheries
Marine fisheries ordinance, 1983	Conservation of marine fisheries
Fish and fish product (Inspection and quality control) ordinance, 1983	Quality control of fish and shrimp, mainly targeting export
Fisheries Rules, 1985	Framing rules for enforcement of various provisions of Fish Act 1950
Manual for Land Management, 1990	Allocate unused state (*Khas*) land to the landless on a permanent or temporary basis
Shrimp Estate (*mohal*) Management Ordinance, 1992	Allocate suitable state (*khas*) land for shrimp culture
Shrimp farm taxation law, 1992	Imposing higher tax on shrimp land to cover cost of polder infrastructure
Bangladesh environment conservation act, 1995	Conservation of natural resources and ensure eco-friendly development
Bangladesh environment conservation rules, 1997	Conservation of natural resources and ensure eco-friendly development
Fish and fish product (quality control) rules, 1997	Quality control of fish and shrimp, mainly targeting export
National Fisheries Policy, 1998	Conservation, management, exploitation, marketing, quality control and institutional development
Fish and Animal Food Act, 2010	Safe fish and animal feed production, processing, quality control, import, export, marketing and transportation
Hatchery Act, 2010	Sustainable hatchery development to ensure quality fish and shrimp seed

farms with the approval of the Bangladesh Water Development Board. Collection of shrimp fry from natural sources has been banned and import of shrimp seeds has been stopped (Alam et al., 2005). The use of chemicals and drugs has been regulated, and farmers are encouraged to apply sustainable pond management techniques (Alam et al., 2005). As for the existing provisions, each shrimp farm has to register and get a licence from the Department of Fisheries, but still a substantial number of farms have not been registered (Alam et al., 2005). The implementation of these policies and regulations by the institutions concerned as well as institutional assertiveness is weak, so huge gaps exist in enforcement (Hein, 2002; Alam et al., 2005). Furthermore, it is essential that a policy on waste treatment be formulated and pollution abatement from near shore tidal zones be emphasized. Strict enforcement of the FAO code of conduct, and the amendment of rules and regulations, including a multisectoral approach, interdepartmental cooperation and resource diversification, is indispensable for sustainable shrimp aquaculture (Paez-Osuna, 2001; Alam et al., 2005). A clear legal and institutional position about land use change by shrimp aquaculture is still missing in the national policy of Bangladesh (Alam et al., 2005; Chowdhury et al., 2006).

8. Conclusion/discussion

In Bangladesh, shrimp aquaculture has not progressed as much as in China or Thailand, owing to inadequate planning and inappropriate regulations. The economic benefits of shrimp aquaculture are well recognized. However, when its environmental and social problems are considered, shrimp farming has not improved the farmers' living standard. Although it has created temporary employment opportunities, the cost of destruction is much higher than these benefits. The major environmental impacts include the conversion of mangroves and agricultural lands into shrimp ponds/*ghers*, loss of capture fisheries and biodiversity, pollution and disease outbreak. Salinizations of groundwater and consequent problems with potable water and agriculture have been recognized as the main environmental and social impacts. Displacement and marginalization of fishermen, water logging and loss of livestock resources are other social problems that have affected the local communities. Resources such as feed, seed and water supply affect the sustainability of shrimp aquaculture.

Nevertheless, the existing type of aquaculture has enabled farmers to meet their immediate needs at the cost of environmental degradation; however, it is not a sustainable type of aquaculture. A sustainability concept for an eco-friendly and socially acceptable farming and management system must be developed around the world to ensure the future. The increasing negative environmental and social impacts have generated huge research efforts aimed at improving shrimp aquaculture's long-term sustainability.

According to the World Commission on Environment and Development through the Brundtland report, 'sustainability is the process of sustainable development and it is development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED, 1987). Shrimp aquaculture does have the potential to be carried out in such a way as to meet the needs of the present and at the same time not exceed the capacity of the resources. Pertinent management practices need to be renewed and adjusted continuously for future generations, so as not to pose an environmental hazard.

The definition provided by the FAO reads that 'sustainable development is the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs to present and future generations' (FAO, 1988). Such sustainable development is environmentally non-degrading, technically appropriate, economically viable, socially acceptable and includes different sectors such as agriculture, forestry and fisheries, conserving land, water, plant and animal genetic resources (Barg, 1992).

In a further definition provided by Goodland and Daly, 'sustainable development is development without growth in throughout of matter and energy beyond regenerative and absorptive capacities' (Goodland and Daly, 1996). The sustainable development of aquaculture requires adequate consideration of environmental, social and economic factors (Goodland and Daly, 1996; Caffey et al., 2000). Therefore, sustainable aquaculture development is interlinked with better management and institutional considerations, implementing regulations which have to be based on the principles of economic viability, social equity, and environmental acceptability. Although GAPs and BMPs are widely used at international and national levels as standardized methods, both are in many ways ignoring the environmental and socioeconomic factors in Bangladesh. Sustainability can only be acquired when environmental conditions are appropriate, and maintained, which expressly includes the ecological, socio-anthropological, and economic aspects of the environment (Frankic and Hershner, 2003).

The adoption of an ecosystem approach to aquaculture depends on governance and social issues, which requires combined action of science, policy and management (Costa-Pierce, 2008). The sustainability of shrimp farming relies on many factors, e.g., comprehensive policies and regulations, good ecology, excellent breed, appropriate technology and adequate support from the government (Biao and Kaijin, 2007) as well as mutual respect between farmers and exporters. Therefore, alternative and innovative culture systems must be identified as they form pathways to make aquaculture production sustainable; this can be attained by organic shrimp aquaculture. According to the definition given by the IFOAM, organic agriculture is a holistic approach which includes all agricultural systems (the farming of animals and plants) that promote the environmentally, socially and economically sound production of food and fibers. These production systems sustain the health of soils, ecosystems and people. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved (IFOAM, 2008). Organic production dramatically reduces external inputs by prohibiting the use of chemosynthetic fertilizers, pesticides, pharmaceuticals and feed additives, while encouraging natural ecological processes, biodiversity and using locally available resources (IFOAM, 2008). Therefore, this review study has inspired the author to undertake research for a future development of organic shrimp production, to assess its potentials, and to understand its impacts.

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Paper – 2

Key performance characteristics of organic shrimp aquaculture in southwest Bangladesh

Brojo Gopal Paul and Christian Reinhard Vogl

Division of Organic Farming, Department of Sustainable Agricultural Systems, University of Natural Resources and Life Sciences (BOKU), Vienna, Austria

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Article

Key Performance Characteristics of Organic Shrimp Aquaculture in Southwest Bangladesh

Brojo Gopal Paul * and Christian Reinhard Vogl

Division of Organic Farming, Department of Sustainable Agricultural Systems, BOKU-University of Natural Resources and Applied Life Sciences, Gregor Mendel Strasse 33, Vienna A-1180, Austria; E-Mail: christian.vogl@boku.ac.at

* Author to whom correspondence should be addressed; E-Mail: brojo.paul@boku.ac.at; Tel: +43-1-47654-3777; Fax: +43-1-47654-3792.

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Abstract: In Bangladesh, black tiger shrimp (*Penaeus monodon*; Fabricius, 1798) aquaculture has come to be one of the most important sectors in both the rural and national economies. Likewise, organic shrimp aquaculture has emerged as an alternative farming enterprise for farmers especially in the southwestern districts of Bangladesh. The present study aims to show key performance characteristics of organic shrimp farmers and farming in a prototypical shrimp farming area in Bangladesh. Data was collected in 2009 from organic shrimp farmers in the Kaligonj and Shyamnagar sub-districts through questionnaire interviews, transect walks and focus group discussions. The mean productivity of organic shrimp farming in the area is 320 kg ha^{-1} yr^{-1} (ranging from 120 to 711 kg $ha^{-1}year^{-1}$). Organic farmers are more likely to have a higher monthly income and less aquaculture experience. Moreover, suitable landholdings and classified labor distribution have been found to play an important role in the development of organic shrimp aquaculture. The most common assets of organic shrimp aquaculture are high yield, low production cost, available post larvae and high market prices. Small business farmers are likely to earn more income benefits from organic shrimp aquaculture than their larger-scale counterparts. Finally, the paper suggests that more research is needed to stimulate the success of organic shrimp aquaculture.

Keywords: organic shrimp; organic aquaculture; production; land; labor; Bangladesh

1. Introduction

Worldwide, aquaculture is dominating all other animal food-producing sectors in terms of growth. The sector has been growing at an average annual rate of 8.9% since 1970, compared with 1.4% for capture fisheries and 2.8% for terrestrial meat production systems [1]. Aquaculture has lagged behind the agriculture sectors in terms of both quantity and diversity of certified organic produce [1,2]. Organic agriculture is rapidly developing worldwide with 35 million hectares of agricultural land presently farmed, whereas in aquaculture only 0.43 million hectares of land are managed organically [3].

Consumer demand for organic produce is growing faster than supply [4]. The growth in global demand for organic foods is estimated at 20% per annum [5]. The growth rate of organic aquaculture products, however, is unknown, but estimates range from 20% to 30% annually [6]. In 2008, there were 225 certified organic aquaculture operations in 26 different countries, with an overall production amounting to 53,000 tons [7]. The production of organic aquaculture is predicted to increase 240-fold by 2030, *i.e.*, to an equivalent of 0.6% of the total estimated aquaculture production [1]. Organic aquaculture has attracted attention due to consumers' awareness about overfishing, environmental degradation, health risks, sustainability and animal welfare [8–10].

Organic aquaculture is a new concept, and remains under development; basic standards were drafted in 1998 by the International Federation of Organic Agriculture Movements [1,5,11,12]. However, the practice of organic aquaculture is ancient, especially in Asia and particularly in China. The EU is the pioneer in legislation for organic farming and a legislative framework for organic aquaculture was introduced in 2009 [13]. There are 20–25 private and non-private certifying bodies currently involved in the organic aquaculture sector. These certifying bodies manage a diverse set of aquaculture standards, which often vary considerably from country to country, certifier to certifier, and species-to-species [1]. Entrepreneurs such as retailers and supermarket chains have now introduced organic aquaculture products as a response to this increased consumer demand [14]. In Europe, 87%–93% of the certified organic aquaculture products come from marine and brackish water sources. Globally, organic aquaculture is limited to a few species, mainly shrimp, salmon, trout and carp [1,14]. Research on organic diets and nutrition is steadily progressed. Accessible information on organic diets and nutrition is not extensive for scientific reference. Sourcing suitable feed and the costs are major challenges for the organic aquaculture operation. Substitution of fish meal and fish oil is an important limiting factor impeding organic feed development. Organic aquaculture operations manage to reduce the dependency on capture fisheries and to reduce the feed costs [7,15].

In Bangladesh, shrimp, locally known as *Bagda*, has been attracting considerable attention over the last three decades due to its export potential for international markets. In the financial year 2007–2008, Bangladesh exported 49,907 tons of shrimp and prawn (*Macrobrachium rosenbergii*; De Man, 1879), valued at US$ 409 million, while the sector contributes about 4.04% to the total export earnings and 3.74% to the GDP [16]. The shrimp industry employs approximately 1.2 million people in Bangladesh for production, processing and marketing activities. Likewise, the well-being of 4.8 million household members depends on this sector [17]. Despite the export potential and the employment generated, shrimp aquaculture has incurred considerable environmental cost. Shrimp aquaculture has therefore been criticized by environmental and social scientists around the world especially in terms of unplanned expansion [18–20]. In southwestern Bangladesh, agricultural land and low-lying floodplains have been turned into *gher* (Bangladeshi local term for modified rice fields or ponds located beside canals or rivers that are used to cultivate shrimp and fin fish) systems for shrimp cultivation since the early 1970s [21]. These conversions have had adverse effects on the wetland ecosystems, and in addition to this ecological drawback, the intrusion of saline water into paddy lands has created social conflicts [19,22]. The remaining mangrove forests are under pressure due to the unplanned expansion of shrimp *ghers*, and continuous cutting, encroachment, storms and climate change [19,23]. Viral diseases such as the White Spot Syndrome Virus (WSSB) have caused huge economic losses in shrimp production of Bangladesh [24,25]. In addition to these problems, the sector has been facing many other issues, such as low yields, lack of adequate technology, price fluctuations in international markets, bans imposed by the European Union and lack of government stimulus [19,21,22,24,26]. However, the major importing countries' demand for quality and safe shrimp products has increased tremendously. It is these countries that set up strict standards and regulations to ensure quality and safety. As a consequence, organic shrimp aquaculture has been introduced to southwest Bangladesh as an alternative culture.

In 2005, an Organic Shrimp Project (OSP) was initiated in Bangladesh by the Swiss Import Promotion Program (SIPPO). This program is authorized by the Swiss government to promote small and medium enterprises from developing and transition countries through consulting, training, marketing support, and facilitating access to trade fairs. According to the memorandum of understanding between Bangladesh Frozen Food Exporters Association (BFFEA) and SIPPO, signed on 6 December 2004, SIPPO is involved in training farmers and processors for producing organic shrimp in Bangladesh. SIPPO facilitates the necessary contracts for imports into Switzerland and the European Union, and promotes organic products in Bangladesh. This project was implemented in collaboration with the national NGO *Shushilan*. SIPPO closed their activities in 2007, because the program's focus shifted from South Asia to Eastern Europe, Africa and Latin America. The service-providing organization, Euro Centra (a member of Wünsche business group), took over the responsibilities for the OSP in the same year, but discontinued activities in 2007. As successor, the Germany-based importing organization, WAB-Trading International, continued the OSP operations, with Gemini Sea Food Ltd. as the processor. Now, the organic farms of the OSP are certified by Naturland, a German private organic farmers association that runs an aquaculture scheme. The farmers' compliance with the private Naturland scheme is inspected by the Institute of Market Ecology (IMO), an international certification body inspecting and certifying various schemes related to eco-friendly products, accredited by the Swiss Accreditation Service according to EN 45011/ISO 65 [27]; Naturland being an organic farmers' and processors' association pioneering the development of several private standards for organic farming, including for aquaculture, to be inspected and certified by third party certifiers like e.g., IMO. Naturland is the pioneer in organic shrimp; the pilot project was initiated in Ecuador in 1999, and from there, OSPs have spread to Vietnam, Indonesia, Thailand, Peru and Bangladesh [1].

Various criteria need to be followed by Naturland certified organic operations. For example, approximately 50–70% of the total dyke surrounding the *gher* must be covered by natural vegetation. Culture techniques must be extensive and a very low stocking density (<15 post larvae/m^2) is required. The farmers are allowed to release only native shrimp post larvae from nominated nurseries. The nurseries have to collect hatchlings from hatcheries located in Cox's Bazar, which is in southeastern Bangladesh. There are about 57 private and two government powered shrimp hatcheries in Bangladesh [28]. The collected hatchlings are required to be antibiotic-free and the quality of the hatchlings must be monitored by an external consultant. Other native shrimp species come from the wild via water exchange, although this is controlled strictly using fine sieves in the pipe inlets. The shrimp nourish themselves on natural food produced from processed cow dung or compost. No additional feeding and chemical fertilizers are to be used by the farmers. The shrimp are grown following traditional systems, which use the tides to control the water quality and to harvest the *ghers*. In this method, farmers stock post larvae 8 to 10 times during a full production cycle. Every *gher* must have small ditches inside the *gher* to acclimatize the post larvae before they are released to the main *gher*.

Thus, the organic shrimp production system has come to be comparatively elaborate, and functioning certification and marketing bodies have been established. Nevertheless, in Bangladesh, neither organic aquaculture nor organic shrimp farming have so far been addressed by scientific research. The purpose of this paper is to understand why organic shrimp aquaculture is expanding in Bangladesh and who is getting more benefit. The hypotheses of this paper that characterization of farmers performance can inspire the adoption of organic shrimp farming. The aim of this paper is to show how shrimp farmers perform organic practices and to identify key performance characteristics considering land and labor distribution in a study site prototypical for aquaculture in Bangladesh.

2. Methods

The study was conducted in the Satkhira district, a salinity-affected coastal area of the Bay of Bengal, situated in southwestern Bangladesh (Figure 1). The SW regions of Bangladesh (Khulna, Bagerhat and Satkhira districts) are operating eighty percent of the country's shrimp farms [29,30]. Satkhira has been identified as the most promising area for brackish water shrimp culture due to year-round moderate to high water salinity [31]. Mostly, shrimp is cultivated in this area between February and November when the water of the surrounding rivers becomes saline. The dry season is from November to February; with its high water salinity and scarcity make it hardly suitable for shrimp cultivation. During summer monsoon, from July to October, some farmers grow rain-fed transplanted rice as the overall salinity becomes low [32]. Satkhira district is divided into seven sub-districts. Among them, only Kaliganj and Shyamnagar sub-districts have been considered in this study, because there are a large number of shrimp farms are operating in the area due to the available saline water and the closeness to the river channels. Both sub-districts are located close to the world's largest continuous mangrove forest. Here, an OSP is implemented by WAB trading international. The OSP has about 200 staff members whose education levels vary from secondary to doctoral degrees. Most of the staff members are local farmers. The OSP works according to an "internal control system" (ICS). The ICS includes internal quality management procedures, internal training, and internal inspections done by the staff as a means to prepare for the external, independent, third-party inspection by IMO. The internal trainers cannot be an inspector and vice versa.

Data was collected between October and December in 2009 during the late harvesting season. This study applied both quantitative and qualitative data collection methods which are used by the following authors, e.g., Ahmed *et al*. [33]. Research was done in collaboration (to help identifying the respondents) with WAB Trading International. WAB cooperates with 160 organic farmers' groups (15–40 per group) and 3,379 individual organic farmers. From these 160 groups, 12 per sub district were selected through a stratified random sample (stratum = sub-region). In every group, farmers were again selected through stratified purposive random sampling based on the strata *gher* size (small, medium and large) (Table 1). A total of 144 organic shrimp farmers, 24 in each stratum from each sub-district, were sampled.

Figure 1. The study areas Kaliganj and Shyamnagar in SW Bangladesh (Sathkira district) (Source: Banglapedia—the National Encyclopedia of Bangladesh, 2003) [34].

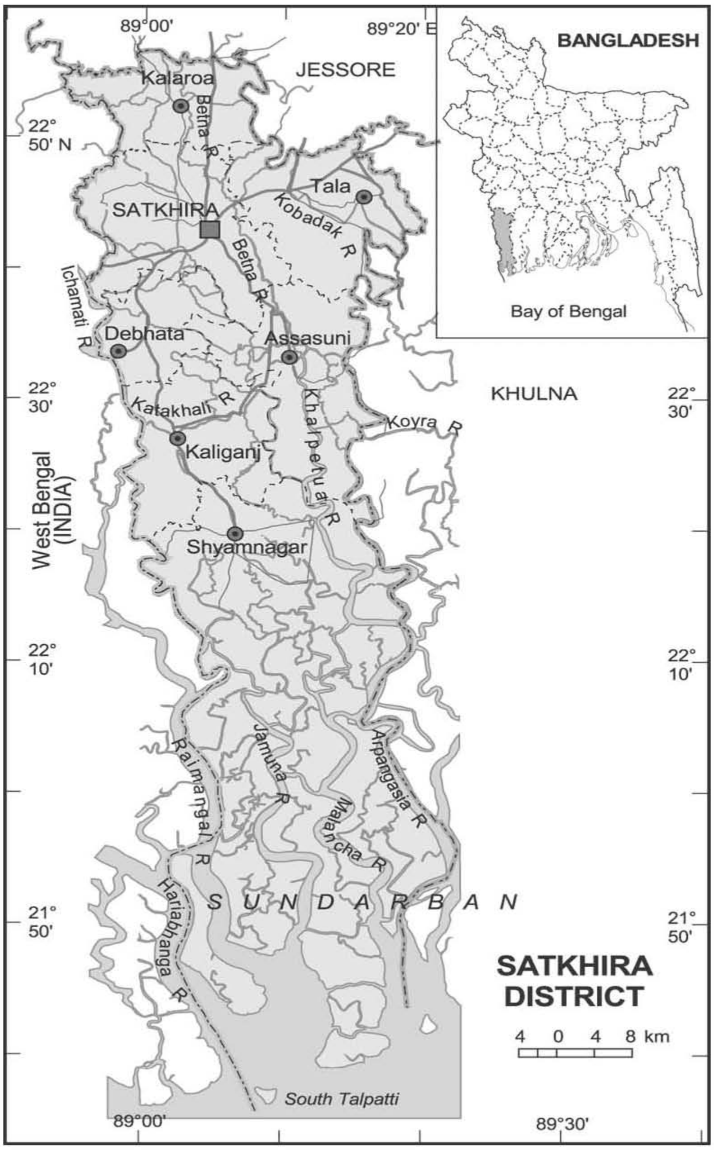

Table 1. Categories (farm size) and sample size of shrimp farms and their distribution in the study areas Kaliganj and Shyamnagar (Bangladesh).

Farms category	*Gher* size	Sample size (farms)	
		Kaliganj	Shyamnagar
Small farms	≤0.67 ha (≤5 bighas *)	24	24
Medium farms	0.68 to 2.00 ha (5.1 to 15 bighas)	24	24
Large farms	≥2.01 ha (≥15.1 bighas)	24	24

* The *bigha* is a unit of measurement for an area of a land in Bangladesh (1 ha = 7.48 bighas);
*: the meaning of bighas.

Primary data was collected during a face-to-face field survey using a pre-tested questionnaire. Pre-tests were done on 14–16 October with 6 non-sampled shrimp farmers. The questionnaire contained both pre-coded and open-ended questions. The questionnaire was developed in English and then translated into Bengali by the first author to ensure efficient communication with farmers during interviews. Each respondent was given a brief introduction about the nature and purpose of the study before the interview commenced. Then the questions were asked in sequence, with replies being recorded directly onto the questionnaire. For each interview, the time required was about 40 minutes.

As a means of triangulating the data derived from questionnaires, several topics relevant to the study such as farmer's views and experiences in shrimp culture activities, where presented and discussed in focus groups [35,36]. A total of 8 focus group discussions were conducted in both sub-districts. Each focus group session comprised 8–12 individuals and the duration of each discussion was approximately an hour. Focus group discussions were conducted only with organic shrimp farmers. The discussions were recorded with a digital voice recorder, and organized with the help of WAB staffs (identification of convenient venues and time). The focus group discussions were held inside collection centers of WAB and in farmer's residences. During the discussion, the first author of this paper acted as moderator of the sessions. WAB staff was not present during the focus groups.

In addition, 10 transect walks [37] were performed systematically with shrimp farmers by walking across the *gher* sites at the beginning of the study to build rapport. Transect walks allow researchers to speak and observe with farmers directly at the sites relevant to the research [38]. Thus, they provided informal information on resource use patterns and helped to understand the farming practices and daily livelihood activities. The experiences from the transect walks were also useful for validating farmers' answers from the questionnaires.

Questionnaire interview data were coded and entered into a database system using MS-Access (Microsoft 2003). The statistical package for social science (SPSS 15.0 for Windows) was used to produce descriptive statistics. Comparisons among farmer's categories were made by ANOVA F-test and Spearman correlation. The ANOVA was followed by a Tukey Post-hoc comparison of means. Differences are reported as significant at a level of $p \leq 0.05$. In some cases, data was normalized using the log transformation.

All results presented in this paper in the results section about "farmers" refer to organic shrimp farmers.

3. Results

3.1. Socio-Economic Characteristics of Shrimp Farmers

The studied farmers are on average 41.9 years old, ranging from 19 to 82 years (Table 2). The mean household size of the farmers' families is 5.6 persons, ranging from 2 to 16. This is slightly higher than the national average of 4.9 from census data of 2001 [39]. Among the farmers, 15% are illiterate, while 85% have a formal education. Larger farmers stayed significantly longer at school than smaller farmers. On average, farmers have 14.4 years' experience working with shrimp. Smaller farmers have significantly less experience (in years) than medium and large size farmers. The monthly income of organic farmers is US$ 477.9 on average (Table 2), and is significantly higher for larger farmers than for small and medium size farmers.

All farmers have more than one livelihood activity. Of the total farmers, 83% consider shrimp farming as their main activity and primary source of income, followed by 8% of the farmers seeing business, and 4% seeing agriculture as their main activity. Altogether, 17 % of the farmers have earned money from shrimp farming as their secondary activity and source of income. Livelihood activities such as business (26%), shrimp purchasing and selling (19%), agriculture (13%), and agricultural day labor (11%) occur as secondary sources of income for the farmers. Several of these occupations offer neither full-time employment nor food security. Thus farmers rely on multiple sources of income.

Table 2. Socio-economic variables (Arithmetic mean, standard deviation in parenthesis) of surveyed respondents (n = 144).

Variables	Small farms	Medium farms	Large farms	All farms	Standard error	F-statistics	Significance level
Age in years	40.1 a (13.1)	42.5 a (12.9)	43.3 a (9.1)	41.9 (11.8)	0.989	0.944	ns
Household size in number of persons	5.0 a (2.1)	6.1 a (2.5)	5.6 a (2.6)	5.6 (2.4)	0.205	2.377	ns
Years of school attendance	6.1 a (4.5)	6.8 ab (4.1)	8.4 c (3.9)	7.1 (4.3)	0.359	3.827	*
Experience with shrimp farming in years	9.6 a (4.0)	15.7 bc (4.5)	17.9 c (5.9)	14.4 (6.0)	0.501	36.190	***
Monthly income in US$[#]	161.4 a (76.7)	287.3 ab (204.3)	984.9 c (884.5)	477.9 (636.3)	53.030	34.137	***

Statistical tests based on transformed data. Values of mean given untransformed. Significance level: * = $p \leq 0.05$; ** = $p \leq 0.01$; *** = $p \leq 0.001$; ns = not significant; a, b, c: Different letters indicate significant differences at $p \leq 0.05$. # US$ 1 = Taka 70 in December 2009 (Taka = Bangladesh currency).

3.2. Land and Labor Distribution

Of the farmers' total land holdings, 70% are used for organic shrimp production, followed by 19% used for agriculture activities. Eight percent of the land is used for homestead purposes where farmers construct their houses. Recently, homestead land has often been used by the farmers for producing rice and vegetables because of a lack of agricultural land. Three percent of the land is used as ponds for producing fish. On average, each organic shrimp farmer owns 1.24 ha of land (Table 3).

Table 3. Distribution of total owned land, arithmetic mean, standard deviation (SD) and percentage in terms of land use pattern of the respondents (n = 144).

Land use pattern	Total own land (ha)	Mean	SD	Total own land (%)
Shrimp farming	140.80	0.98	1.47	70
Agricultural land	37.44	0.26	1.07	19
Homestead land	15.73	0.11	0.11	8
Ponds	5.79	0.04	0.07	3
Total	199.76	1.24	1.87	100

The land used as *gher* consists of owned, leased-in, and leased-out land. The total *gher* area of all interviewed farmers is 333.86 ha; however, non-sampled farmers related to WAB are keeping more than 4,000 ha of land under organic shrimp farming. Large business farmers take up 77% of the total land area for *gher* operation, while only 6% of the area belongs to small business farmers. The average size of *gher* under organic shrimp production is 2.32 ha (as opposed to conventional shrimp farming with 2.28 ha) [22]. The mean *gher* size for shrimp production of larger farms is 5.37 ha, followed by medium (1.17 ha) and small (0.43 ha) farms.

Of the total farmers, 78.5% own land for the use of *gher*. About 21.5% do not own any land for shrimp farming, but they are operating *gher* for shrimp production as lease-in or participate in a jointly managed *gher*.

Of all farmers, 82.6% do not lease out their land, meaning that they operate their *gher* themselves. Nevertheless, 71.5% of organic farmers take lease-in land from their neighbors to pursue shrimp farming. In comparison to small and medium size farms, larger farms perform shrimp farming on larger size plots of owned land and they also lease in larger size plots (Table 4). Leasing periods vary from one to five years. Leasing values depend on location and vary from US$428 to $748 $ha^{-1}year^{-1}$.

Table 4. Distribution of mean land size (ha) according to tenancy pattern of *gher* by farmer's category (n = 144).

Land tenancy pattern	Small farms	Medium farms	Large farms	All farms	Standard error	F-statistics	Significance level
Owned land (ha)	0.29 a (0.28)	0.64 ab (0.51)	2.01 c (2.13)	0.98 (1.47)	1.226	24.203	***
Leased-in land (ha)	0.18 a (0.22)	0.56 ab (0.46)	3.65 c (4.84)	1.46 (3.19)	0.266	22.004	***
Lease-out land (ha)	0.04 a (0.14)	0.05 a (0.13)	0.29 a (0.95)	0.13 (0.56)	0.047	3.077	ns

Values of mean given untransformed. Standard deviation in parenthesis; Significance level: *** = $p \leq 0.001$; ns = not significant; a, b, c: Different letters indicate significant differences at $p \leq 0.05$.

Shrimp farming uses a combination of family and wage labor. Shrimp farms require labor for various activities such as *gher* preparation (drying, clearing and leveling of land, trench excavation and levee construction, liming, manuring, letting in saline water), carrying and releasing post larvae, weeding, guarding farms and harvesting, transporting and marketing shrimp and fish. All such work is seasonal or semi-permanent. On average, 1.38 persons per family are involved for *gher* preparation such as drying *gher*, liming, manuring, entering saline water, *etc*. *Gher* preparation is seasonal work and the farmers employ daily-paid workers as casual workers or on a work contract basis. Most farmers hire wage labor to construct *gher*; on an average, 4.51 persons per production cycle hire during *gher* preparation work. Wage labor for *gher* preparation is mostly used for heavy work such as clearing and leveling of land, trench excavation and levee construction. Mostly, family labor is directly involved in taking care of the *gher*. *Gher* care by hired laborers is performed by an average 0.69 persons per respondent. The pertinent correlation value (r) confirms the association between the amount of labor used for different purposes and farm size. The larger the *gher* area, the lower is the possibility of involving only family members. The larger the area used for *gher* operation, the larger is the likelihood of hiring wage laborers for *gher* preparation and maintenance (Table 5).

Table 5. Relationship between labor use pattern and farm size (n = 144).

Labor use pattern with purposes	Persons involved in mean	r value
Family labor involved for *gher* preparation	1.38 (0.036)	−0.551 ***
Wage labor involved for *gher* preparation	4.51 (0.089)	0.437 ***
Wage labor involve for taking care of gher	0.69 (0.013)	0.726 ***

Significance level: *** = $p \leq 0.001$. Standard deviation in parenthesis.

3.3. Perspectives for Organic Farming

Organic shrimp production is monitored by WAB, and all organic farmers have an identification number supplied by WAB. No farmer can sell shrimp to WAB-established collection centers without showing this identification number. All farmers reported that the prices of organic shrimp are comparatively higher than conventional shrimp. The average prices of shrimp from conventional aquaculture in local markets varied from US$5 to US$7/kg, while WAB-nominated processor Gemini offered one dollar more than the local markets for organic shrimp. The prices of organic shrimp are paid in national currency (taka). Almost all farmers get training on organic shrimp farming activities from WAB and each farmer has received training at least three times for 2–3 hours each.

Organic shrimp aquaculture depends on the availability of post larvae. Two types of post larvae are available in Bangladesh: natural post larvae and hatchery post larvae. Only one designated hatchery is allowed to supply hatchlings to local nurseries using air transportation. This does not stress hatchlings as much during the long journey from southeastern to southwestern Bangladesh. The estimation of the annual production of shrimp post larvae from hatcheries in Bangladesh is more than 5 billion [27]. In considering 144 organic shrimp farmers, they required approximately 1.6 million post larvae to stock in their *gher*, which is only 0.03% of the total annual production. Currently, organic shrimp farmers are stocking the rate of 1−2 post larvae/m^2, which is much lower than the recommended density by Naturland. Seventy-nine percent of farmers reported that natural post larvae are hardly available (often not found due to scarcity), and 14% claimed moderate availability (often found, but not in high enough quantities). On the other hand, 94% of the farmers stated that hatchery post larvae are sufficiently available for shrimp cultivation.

The mean yield of organic shrimp is 319.61 kg/ha/year (Table 6). The shrimp yield of small business farmers is higher than that of medium and large businesses. Seventy-six percent of farmers do not stock prawn in *gher* due to high salinity, and the remaining farmer's stock prawn during rainy season only. Medium business farmers produced higher prawn yields compared to small and large businesses. Most fish and others (different shrimp species) found in *gher* enter during water exchange, although few farmers stock them. Large business farmers harvest higher yields of fish and other kinds of shrimp species compared to medium and small businesses. Farmers of all categories benefited from shrimp farming, be it from shrimp yield or from the combination with fish and others.

Aquaculture activities (including shrimp, prawn, fish and other kinds of shrimp species) generated more than 75% of the total annual income, and shrimp alone generated about 63.3%. In comparison to other aquaculture items, shrimp contributes significantly to the income, because this species is exported and the farmers earn foreign currency. Income from shrimp as compared with the share of fish and others is significantly higher for large businesses than for medium and small ones. Farmers earn 10.2% of their income from fish and other kinds of shrimp, the major share belonging to large business farmers. Income from agriculture is 3.8% of the total income. Of the total incomes, 12.1% of earnings come from other sources and 7.7% come from business sectors (shop keeping and petty trading) (Table 7). Other sources of income such as foreign remittances, pension, laborers' wages, *faria* (local agents buy shrimp from farmers and sell them to depots or processor), rickshaw or van puller wages jointly contribute to the second largest portion of the income.

Table 6. Yield (arithmetic mean, standard deviation in parenthesis) of different species (n = 144).

Variables (Yield)	Small farms	Medium farms	Large farms	All farms	Standard error	F-statistics	Significance level
Shrimp (kg/ha/year)	431.47 a (133.38)	261.97 bc (93.52)	265.40 c (104.48)	319.61 (136.42)	11.368	36.091	***
Prawn * (kg/ha/year)	23.25 a (13.37)	34.72 ab (16.23)	18.49 c (15.32)	25.49 (16.21)	2.739	3.665	*
Fish & others (kg/ha/year)	115.29 a (55.02)	152.74 ab (85.84)	271.32 c (133.53)	179.78 (9.77)	9.765	33.847	***

Values of mean given untransformed; Significance level: * = $p \leq 0.05$; *** = $p \leq 0.001$; a, b, c: Different letters indicate significant differences at $p \leq 0.05$. * Prawn (*Macrobrachium rosenbergii*).

Table 7. Percentage distribution of total annual income from different sources distinguish by farmers category (n = 144).

Source of income	Small farms	Medium farms	Large farms	All farms	Significance level
Shrimp	51.3	48.8	69.5	63.3	***
Prawn	0.8	1.7	1.0	1.1	**
Fish and others	2.7	5.9	12.7	10.2	***
Agriculture	2.6	9.7	2.3	3.8	ns
Livestock	1.2	0.8	0.3	0.5	ns
Business	7.9	10.4	6.9	7.7	***
Job	1.8	5.4	0.0	1.3	*
Other	31.5	17.3	7.3	12.1	ns
Total	100.0	100.0	100.0	100.0	

Significance level: * = $p \leq 0.05$; ** = $p \leq 0.01$; *** = $p \leq 0.001$; ns = not significant.

Shrimp are harvested twice every month from April to November. The timing of the harvest in its seasonality is linked to the lunar cycle. Shrimp are trapped with a local tool called *Atol* (trap made from bamboo). Shrimp harvesting is done starting at the full and new moon, respectively, and continues for five to seven days. Trapped shrimp are collected every morning and kept in aluminum or plastic containers.

Eighty percent of the organic farmers revealed that the yield of organic shrimp has increased as compared to their previous experience with conventional shrimp farming. According to FGD participants, the yield has increased, because organic farmers' *ghers* are not affected by shrimp diseases (e.g., white spot and yellow head, *etc*.). Overall mortality of post larvae in each restocking are decreased due to maintaining low stocking density. The increases of yields are not quantified by the farmers, although they recognize the increase of yields comparing their earnings from past years.

Ninety-one percent of the organic farmers stated that production cost has decreased tremendously, since they do not use fertilizers, additives, supplementary feeds or vitamins any longer. Organic farmers depend on processed cow dung, compost and the exchange of natural water to maintain water quality. Ninety percent of farmers exchange water from natural sources and 10% do not exchange water because they do not have the necessary facilities. The sources of saline water are river and canal. The distance to a saline water source varied from 10 meters to 3 kilometers. The tidal flows of saline water are regulated by the sluice gates. Most farmers receive post larvae from nurseries on credit, because they usually negotiate payment to take place after harvest started. Farmers can only restock post larvae having paid the earlier delivery.

4. Discussion

Farmers of organic shrimp in Bangladesh tend to be younger, hold an academic degree, and have less aquaculture experience and a high monthly income. This profile is quite different from conventional shrimp aquaculture study in Bangladesh [40]. Many studies from different countries have reported organic agriculture farmers with high levels of academic education, to be younger, have less farming experience and urban backgrounds [4,41,42]. Similar notions are echoed in consumer studies in that households with high levels of education and income are more likely to purchase organic foods [14,43,44]. Education and experience can play important roles in transforming information to enhance knowledge and skills, and in inspiring to choose appropriate technology [20]. Lower levels of education, less experience and lower income availability can affect farmers' capacities to adopt new technologies like organic shrimp aquaculture. Most shrimp producers are locally settled and have little or no information about organic aquaculture. Lack of information and the necessary skills can be a major barrier to the adoption of organic agriculture [1].

The motivations for organic shrimp aquaculture production in Bangladesh are linked with suitable landholdings, labor forces, higher yields and higher market prices. The average farm sizes of organic and conventional shrimp farms are quite similar in the southwest region of Bangladesh. This has happened because the same types of farmers have converted from conventional to organic. In contrast, the average size of organic farms is smaller than that of conventional farms in Western countries [4,45,46]. More recently, however, organic crop farmers in Norway tend to have larger farms than their conventional counterparts [42].

The distribution of landholdings is skewed towards large *gher* owners for organic shrimp aquaculture. Similar results are found with conventional shrimp farmers in Bangladesh [47]. Most farmers rely on combining owned and lease-in land for organic shrimp aquaculture. Conventional and integrated farmers also depend on owned and lease-in land for cultivating shrimp in Bangladesh [40,47]. Currently, organic farmers are not interested in leasing-out their land. Perhaps they recognize that organic farming is environmentally friendly and less prone to production failures. Small business farmers have leased-out their land because it is difficult for them to provide the needed investment for *gher* preparation and stocking shrimp post larvae. In some cases, small business farmers migrated to other locations to earn hard cash in order to manage their daily livelihoods. In addition, small business farmers' land is situated often inside large *gher*. In these cases, small business farmers might increase their *gher* size and see their only opportunity in selling or leasing out their land to large neighboring property owners. All organic farmers are native inhabitants. There is no outside farmer performing organic practices these days. Earlier on, however, during the initial stages, when shrimp farming expansion took place in a conventional manner, outside farmers would control shrimp aquaculture [47].

Organic farming is basically labor-intensive because it is not utilizing heavily mechanized growing techniques [48]. Distribution of labor force plays an important role in the Bangladeshi shrimp sector [47,49]. In Bangladesh, organic shrimp farming relies on labor work and there is no special training required for the laborers to handle shrimp. According to the FGD participants, organic farming required more laborers than conventional farming. The OSP is establishing and implementing labor rights and equal payment for both men and women. Organic agriculture farms provide health benefits to laborers as synthetic chemicals are not allowed in this farming system [48]. Family labor is fully involved in shrimp farming especially for taking care of *gher*. With large business farmers, family members do not participate in *gher* preparation. Perhaps their income is enough and they do not wish to partake in the hard work as laborers. The social structure in Bangladesh is such that a family with a good financial position would not perform hard labor. Therefore, most of the large business farmers depend on hired wage labor to taking care of the *gher* because they are involved in other income-generating activities. Hiring wage labor by all categories of organic farmers creates employment for the poor in every production cycle. The financial capacity of small business farmers to hire wage laborers has increased due to organic farming. The number of permanent labor contracts as given by large business farmers has increased also (e.g., organic farming disallows child labor; for stocking natural post larvae). In contrast, during rice cultivation, only large landlords were the major employers of the poor to manage rice fields [47].

The survey recorded a mean yield of organic shrimp of 320 kg/ha/year, ranging from 120 to 711 kg/ha/year. The certified organic shrimp yield is 227 kg/ha in Indonesia and Vietnam (recorded on 2 farms) and 2,000 kg/ha in China (1 farm) [9]. The highest production of certified shrimp is found in Thailand, 3 tons per hectare from Sureerath farm [6]. The high variation in yield of organic shrimp might be due to different production pattern intensities and a lack of technological knowledge. The Chinese and Thai certified organic shrimp farms probably came from zero water exchange systems, which are supposed to be not feasible in Bangladesh. Considering Bangladesh climatic conditions, it might not be possible to achieve as great a yield as China and Thailand. Intensification in organic shrimp farming is completely reverse to the ideas around organic certification restrictions. Farmers can diversify their culture techniques by considering multi-trophic layers of food and to improve husbandry conditions, which could offer better results in the future. The yield of organic shrimp is comparatively higher than that of conventional shrimp in Bangladesh. Various authors have reported different yields for conventional shrimp such as 260 kg/ha/year [50]; 146 kg/ha/year [24]; 80–200 kg/ha/year [51] in Bangladesh and 91–250 kg/ha/year in India [52]. Organic aquaculture practice has increased the shrimp yield, which directly influences the producers in Bangladesh to shift from conventional to organic.

The yield of organic shrimp is comparatively higher for small rather than for large business farmers and similar results are reported for conventional shrimp aquaculture [51]. This has happened due to small areas, low stocking density, easy management and low mortality. The owners of small *gher* take more care intensively; they perform water exchange for four to six days at the full and new moon every fortnight, and do weeding frequently. They used adequately processed cow dung and compost more frequently than large *gher* owners. Large business farmers get less production in shrimp, probably due to higher production of fish, the presence of other shrimp species and of a high number of predatory fish, which feed on substantial amounts of shrimp. Large business farmers are unable to exchange water quarterly because of farm size. Large business farmers can separate inlets and outlets by developing modern drainage systems to maintain adequate water exchange. Large business farmers can form cluster units within *gher* to attain higher production. Small business farmers strive to use fine sieves in their pipes when they exchange the water. This carefulness directly protects their shrimp harvest from predatory fish and undesirable shrimp species that might enter the *gher* with the natural water.

Globally, the demand of organic products is increasing robustly and sales have increased to over five billion US$ [53]. Organic shrimp farming is attractive for developing countries due to high prices and protection of environment and biodiversity [9]. Nevertheless, organic shrimp has no local market in Bangladesh. Farmers depend on exports and marketing of organic shrimp is a big concern for farmers. The major market for certified organic shrimp is limited to western countries like North America, Europe, Australia and Japan [9] and the choice of exporters is quite limited. Farmers get comparatively higher prices when WAB-nominated processors purchase shrimp directly from farmers in different collection centers. This has a direct influence on the increase of income for organic shrimp farmers. The price of organic shrimp depends on demand, but is also influenced by size, seasonality. A premium price is important to sustain the organic production [54]. An increasing number of consumers are willing to pay premium prices, which enables the farmers to reduce the economic and environmental pressure on production costs [55].

Organic farming is generating employment and promotes local resources as well as locally adapted production methods [48,56]. In Bangladesh, organic shrimp aquaculture has generated substantial employment for educated people, as well as ensuring several diversified working opportunities. According to FGD participants, women are employed in the *gher* of organic farmers, especially for removing weeds and clearing embankments. Various new types of working opportunities have been generated by the shrimp industry, such as production of bamboo-made screens, traps and baskets, net making, sluice gate building, cock-sheet box supplying, post larvae trading, van pulling, *etc*. Various industries such as hatcheries, nurseries, ice plants and processing plants have been established, centering on shrimp cultivation [57].

Organic farming allows antibiotic-free hatchery post larvae to cultivate in *gher* system. Hatchery post larvae are reared locally to ensure their better adaptation to site-specific conditions, and then they are distributed to farmers according to demand. Organic farming does not allow the use of natural post larvae, because of its negative impact on the local biodiversity [58]. The rate of mortality in shrimp post larvae is higher when shrimp seeds are harvested from estuaries and coasts using a variety of fine-mesh hand-held push nets [59,60]. Natural aquatic biodiversity is reduced due to shrimp post larvae collection because harvesters waste 12–551 post larvae of other shrimps, 5–152 post larvae of finfish, and 26–1,636 post larvae of other macro-zooplankton during the collection of a single shrimp post larvae in Bangladesh [58]. Usually women and children exclusively harvest shrimp post larvae from estuaries and coasts in Bangladesh. The Bangladesh government has already banned the collection of natural post larvae from canals or river channels [29].

Conventional aquaculture is often criticized for environmental degradation such as habitat destruction, waste disposal, exotic species and pathogen invasions, huge requirements of fishmeal, and fish oil to produce aquatic feed [61–63]. The method of organic shrimp aquaculture has lowered production costs, as fertilizers, supplementary feeds, feed additives and hormones, antibiotics, *etc*. are not allowed. This method is also environmentally friendly and decreasing production cost, in another sense it is contributing to reducing CO_2 emissions by not using fertilizers and feeds. Organic shrimp farming uses 30−40% less energy than conventional practices do [6].

Despite its advantages, global organic aquaculture production is lagging behind due to the absence of universally accepted standards, accreditation criteria and third-party certification [1,9,64]. Naturland was the first to develop the organic aquaculture standards that are applied in Bangladesh and are closely monitored by the WAB ICS team. In Bangladesh, farmers are not involved in the standard development process and they comply with Naturland standards. The standard developed by Naturland always promoted the use of local resources in organic farming and in this way; local knowledge has not been marginalized. OSP paid the cost of organic certification in favor of farmers. However, it may not be possible to export organic shrimp from Bangladesh to different countries applying similar standards, until multiple inspection and certification bodies work together creating one standard for all.

5. Conclusions

According to the investigated organic shrimp farmers, the prospects for organic shrimp farming in Bangladesh are positive. Nevertheless, the future of organic aquaculture depends not only on the farmers, but also on government stimuli, publicity, technological improvements, diversified marketing opportunities, premium prices, country-specific standards and consumer demand. Organic shrimp farming in Bangladesh has recorded high yields, but still it is low-yielding compared to other shrimp producing countries. The promotion of best management practices and/or good aquaculture practices can be good options for OSP to improve the yield in Bangladesh. Organic shrimp aquaculture will benefit from the adoption of an ecosystem approach [65], which will depend on governance and social issues. An ecosystem approach requires the combined action of scientific bodies, policy makers and sustainable management [65]. Empowerment of the farmers and enforcement of regulations within OSP can play a significant role in enhancing the sustainable development of the organic aquaculture sector. Theerefore, more research efforts are required to improve the yield and success of organic shrimp farming.

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Paper – 3

Organic shrimp aquaculture for sustainable household livelihoods in Bangladesh

Brojo Gopal Paul and Christian Reinhard Vogl

Division of Organic Farming, Department of Sustainable Agricultural Systems,
University of Natural Resources and Life Sciences (BOKU), Vienna, Austria

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Organic shrimp aquaculture for sustainable household livelihoods in Bangladesh

Brojo Gopal Paul*, Christian Reinhard Vogl

Division of Organic Farming, Department of Sustainable Agricultural Systems, BOKU-University of Natural Resources and Life Sciences, Gregor Mendel Strasse 33, A-1180 Vienna, Austria

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ABSTRACT

Black tiger shrimp (*Penaeus monodon*) cultivation in *gher* (modified rice fields or ponds located beside canals or rivers) is widespread in southwestern Bangladesh. Shrimp farming plays an important role in the economy of the country, as it earns foreign exchange and provides employment opportunities. Organic shrimp aquaculture has emerged as an alternative farming enterprise for farmers, especially in the southwestern districts of Bangladesh. In this study, an asset-based conceptual framework known as the sustainable livelihoods approach (SLA) is applied to evaluate the impact of organic shrimp farming on livelihood. Data were collected in 2009 in the Kaligonj and Shyamnagar subdistricts through questionnaire interviews, transect walks, and focus group discussions with 144 organic shrimp farmers. Shrimp farming experience and size of *gher* have been found to influence the income from organic shrimp aquaculture. In this region, all farmers are highly vulnerable to natural phenomena like cyclones, floods, diseases, as well as contamination of saline water from untreated water sources, and market and price fluctuations that directly hinder the economic growth. The study concludes that more options for shaping livelihoods can be achieved if the farmers' capacity in coping with uncertain phenomena is increased. The adoption of organic shrimp farming has increased farmers' assets and has mitigated their vulnerability in ways that make livelihoods sustainable.

1. Introduction

Shrimp derived from open capture fisheries and aquaculture is an important seafood commodity. Global shrimp production increased from approximately 4.3 to 6.5 million tonnes between the years 2002 and 2008 (FAO, 2010a). In the same time, the global production of aquaculture shrimp doubled from 1.5 to 3.4 million tonnes. Aquaculture is mainly found in the Asia-Pacific region, which contributes about 89% of world production in terms of quantity (FAO, 2010b). Bangladesh, eighth in the world in terms of shrimp aquaculture, contributes approximately 2% of the total global production (FAO, 2010a). The annual production of shrimp from aquaculture in Bangladesh increased from 63 to 94 thousand tonnes between the years 1999 and 2008; aquaculture accounts for 42.2% of the total shrimp production in the country (DoF, 2009a). Sales to international markets contribute about 4.04% to the total export earnings and 3.74% to the GDP of Bangladesh (DoF, 2009b). Approximately 1.2 million people in Bangladesh are employed in shrimp production, processing, and marketing activities and the well being of 4.8 million household members relies on this sector (USAID, 2006).

Shrimp aquaculture engenders considerable environmental costs in terms of destruction of natural habitats and displacement of traditional livelihoods. Environmental and social scientists around the world criticize the often unplanned, unsustainable expansion and industrial development of shrimp farms (Primavera, 1997, 2006; Lebel et al., 2002, 2010; Bene, 2005; Paul and Vogl, 2011). Shrimp experts propose that good aquaculture practices (GAP), best management practices (BMP), and ecohydrology-based shrimp farming (ESF) will enhance the sustainable development of shrimp/prawn farming (FAO/NACA/UNFP/WB/WWF, 2006; Wahab et al., 2012; Sohel and Ullah, 2012). The sustainable development of aquaculture requires adequate consideration of environmental, social, and economic factors, e.g., comprehensive policies and regulations, good ecology, excellent breeding, appropriate technology, and governance (Goodland and Daly, 1996; Caffey et al., 2000; Biao and Kaijin, 2007; Costa-Pierce, 2008). As a reaction to the negative publicity, the first organic aquaculture initiatives were developed in the mid-1990s as an alternative and innovative culture system (Bergleiter et al., 2009). The organic movement throughout the world is continuously growing with 35 million

* Corresponding author. Tel.: +43 0 1 47654 3777; fax: +43 0 1 47654 3792.
E-mail addresses: brojogopal@gmail.com, brojo.paul@boku.ac.at (B.G. Paul), christian.vogl@boku.ac.at (C.R. Vogl).

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hectares of agricultural land being presently farmed. In contrast, only 0.43 million hectares of aquacultural land are managed organically (Willer and Kilcher, 2010). Organic aquaculture has attracted attention due to consumers' awareness of overfishing, environmental degradation, health risks, sustainability, and animal welfare issues associated with conventional aquaculture (Lien and Anthony, 2007; Biao, 2008). It is predicted that the production of organic aquaculture will increase 240-fold by 2030, i.e., to 0.6% of total aquaculture production (FAO, 2002). In the year 2005, an organic shrimp project (OSP) was initiated in Bangladesh by the Swiss Import Promotion Program (SIPPO). Currently, the Germany-based importing organization WAB Trading International has taken over the OSP which was certified by Naturland, a German private organic farmers' association that runs an aquaculture scheme. The OSP comprises approximately 4000 ha of the 167,877 ha of coastal land involved in shrimp farming in Bangladesh (DoF, 2009b) and is managed by 3379 individual farmers who have converted from conventional to organic shrimp aquaculture.

According to the IFOAM, organic production dramatically reduces external inputs by prohibiting the use of chemosynthetic fertilizers, pesticides, pharmaceuticals, and feed additives, while encouraging natural ecological processes, biodiversity, and the use of locally available resources (IFOAM, 2008). Recent studies argue that organic farming can reduce poverty and promote sustainable livelihoods in developing countries (Parrot and Marsden, 2002; Giovannucci, 2005). Nevertheless, conversion to organic farming entails a complex change of system (Padel, 2001). Whether organic farming can produce sufficient yields to meet the demand of the world's growing population is also in question (Trewavas, 2001; Goklany, 2002). While economic and ecological aspects of organic farming systems have been extensively studied in western countries (Stolze et al., 2000; Offermann and Nieberg, 2001; Mäder et al., 2002; Lotter, 2003), little research has focused on organic farming practices in developing countries. Likewise, livelihood analyses of organic shrimp aquaculture have so far not been addressed.

We hypothesize that the adoption of organic shrimp farming can reduce economic vulnerability compared to nonorganic shrimp farming and achieve expected livelihood goals better than nonorganic shrimp farming. First, the study seeks to understand how the organic shrimp farmers' assets influence their livelihoods. Second, the article provides an overview of the factors that challenge the conversion to and subsequent operation of an organic shrimp farm—factors that might challenge the diffusion of organic shrimp farming. Third, the article discusses the impact of organic shrimp farming adoption on the livelihood of the farmers and the sustainability of their businesses. Finally, we suggest conditions that can help organic shrimp farmers to meet sustainable livelihood goals.

2. Conceptual framework: a sustainable livelihood approach

Capabilities, assets (both material and social), activities, and access to resources (mediated by institutions and social relations) together determine the living gained by the individual or household (Chambers and Conway, 1992; Carney, 1998; Scoones, 1998; Ellis, 2000). A livelihood is considered to be sustainable when it can cope with and recover from shocks and stresses, and maintain and enhance its capabilities and assets both now and in the future, while not undermining the natural resource base (Chambers and Conway, 1992). The sustainable livelihoods approach (SLA) has become popular in development thinking as a way of conceptualising rural development, poverty reduction, and environmental management (Scoones, 1998; Ashley and Carney, 1999; Udayakumara and Shrestha, 2011). The SLA is an asset-based conceptual framework that has been widely tested and adapted during research and policy analyses (DFID, 1999; Shankland, 2000). The SLA has been applied in developing countries in small-scale aquaculture and aquatic resources management (Allison and Ellis, 2001; Neiland and Bene, 2004; Ahmed, 2009). In 1997, the Department for International Development (DFID) adopted an SLA framework to address the underlying causes of poverty and to assess the importance to poor people of certain structural and institutional issues (Ashley and Carney, 1999; DFID, 1999). The five key indicators for assessing the outcomes of a sustainable livelihood are (i) creation of working days; (ii) poverty reduction; (iii) well-being and capabilities; (iv) livelihood adaptation, vulnerability, and resilience; and (v) natural resource-based sustainability (Scoones, 1998). The SLA has been used by a number of organizations for designing projects and programmes, for assessing existing activities, and for research (Ashley and Carney, 1999).

The sustainable livelihoods framework (Fig. 1) encompasses the forces and factors that affect livelihoods; it addresses various influences (constraints and opportunities) on livelihoods and ensures that important factors are not neglected (Ashley and Carney, 1999). The framework recognises that households may be vulnerable to trends, shocks, seasonality, and other factors beyond their control that affect livelihood sustainability. Households maintain their livelihoods according to the availability of assets which may be owned, controlled, claimed, or in some other means accessed by the household.

The framework identifies five main capital asset categories: human, natural, social, financial, and physical. Access to these forms of capital is enabled or hindered by transforming structures and processes (policies, institutions, organizations). The determination of appropriate livelihood strategies and the achievement of livelihood outcomes depend on access to these assets. A livelihood is sustainable if people are able to maintain or improve their standard of living related to well-being and income or other human

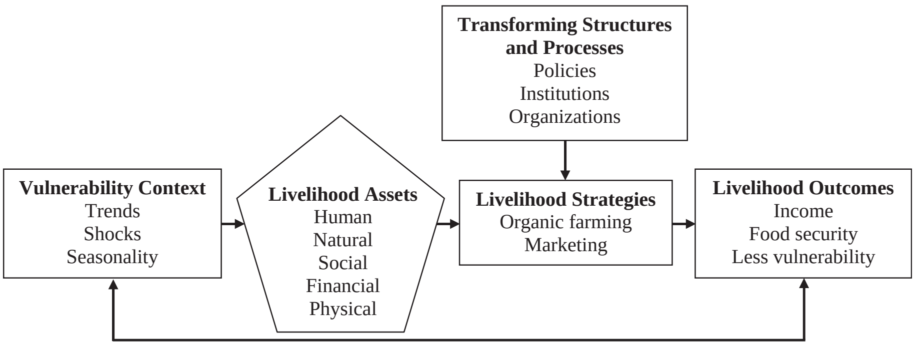

Fig. 1. The sustainable livelihoods framework (adapted from DFID, 1999; Rabbani et al., 2006; Ahmed et al., 2009).

development goals, reduce their vulnerability to unpredictable events, improve food security, and ensure their activities are compatible with maintaining the natural resource base (Allison and Horemans, 2006).

3. Methods

Research for this article was conducted in the Satkhira district, a salinity-affected coastal area of the Bay of Bengal, situated in the southwestern part of Bangladesh (Fig. 2). The SW regions of Bangladesh (Khulna, Bagerhat, and Satkhira Districts) operate 80% of the country's shrimp farms (Alam et al., 2005; Pokrant, 2006). Satkhira has been identified as the most promising area for brackish water shrimp culture due to year-round moderate to high water salinity (Alam and Phillips, 2004). Shrimp is cultivated in this area mostly between February and November when the water of the surrounding rivers becomes saline. According to WAB biweekly routine sampling in the year 2009, the salinity range of the surrounding rivers/coastal waters varied from 2–12 ppt during the culture season (Feb–Nov). The dry season from November to February is hardly suitable for shrimp cultivation due to scarcity of water and its very high salinity. During the summer monsoon from July to October, some farmers grow rain-fed transplanted rice as the overall water salinity becomes low (Ali, 2006). The Satkhira district is divided into seven subdistricts. Among them, only Kaliganj and Shyamnagar subdistricts have been considered in this study, because the available saline water and the closeness to the river channels allow them to operate a large number of shrimp farms. Both subdistricts are located close to the world's largest continuous mangrove forest and an OSP is implemented here by WAB Trading International. The 200 staff members of the OSP are mainly farmers but a few are well educated. The OSP works according to an internal control system; that is, quality management procedures, training, and inspections are performed by OSP staff to prepare for independent third party inspection and certification by the Institute of Market Ecology. An internal trainer in the OSP cannot be an inspector and vice versa. The external inspection and certification are based on current legislation for organic farming and organic aquaculture in the countries of import.

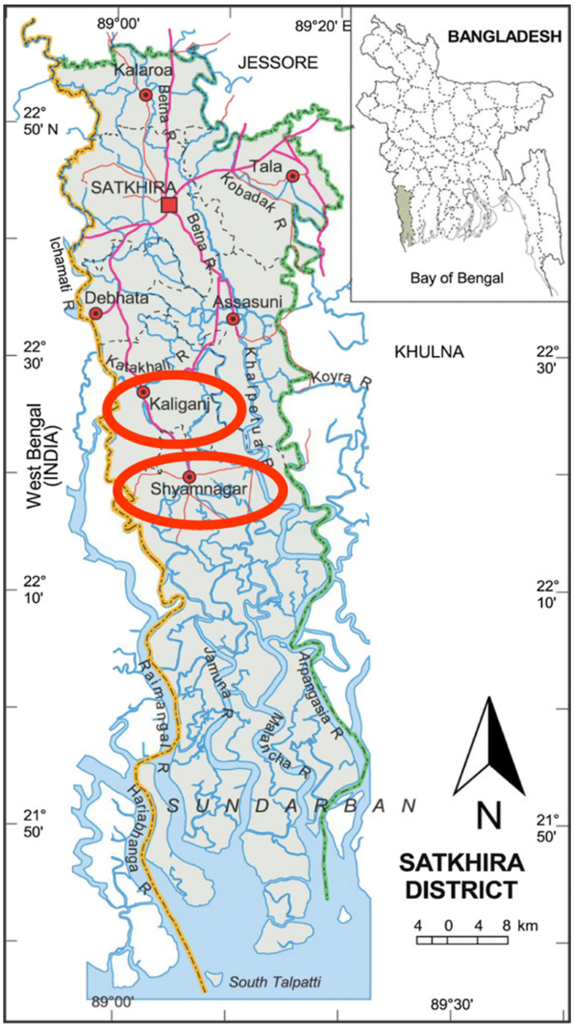

Fig. 2. The study areas (red circles) of Kaliganj and Shyamnagar in SW Bangladesh (Sathkira district) (Banglapedia, 2006).

Data were collected between October and December 2009 during the late harvesting season of shrimp farming. This study applied the quantitative and qualitative data collection methods reported in Ahmed et al. (2010). These are described here briefly. WAB cooperates with 160 organic farmers' groups (15–40 farmers per group) in Kaliganj and Shymnagar subdistricts and 3379 individual organic farmers. From these 160 groups, 12 per subdistrict (a total of 24 groups from both subdistricts, that is, 15% of the 160 groups) were selected through a stratified random sample (stratum = subdistrict). In every group, farmers were again selected through stratified purposive random sampling based on the strata *gher* size (small, medium, and large) (Table 1). A total of 144 organic shrimp farmers (4.3% of all the organic shrimp farmers associated with WAB), 72 in each stratum from each subdistrict, 24 in each stratum from each farmer's category, were sampled.

At the beginning of the study, 10 transect walks (Chambers, 1992) were performed systematically with shrimp farmers by walking across the *gher* sites to build rapport. Transect walks allow researchers to speak with farmers and observe directly the sites relevant to the research (Chambers, 1994). This method of direct interaction with the farmers generated on-the-spot questions that gleaned informal information on resource use patterns and helped the researchers to understand the farming practices and daily livelihood activities of the farmers. The transect walks were also used to validate farmers' answers in the questionnaires.

Primary data were collected during a face-to-face field survey using a pretested, finalized questionnaire that contained both precoded and open-ended questions. Pretests were done with six nonsampled shrimp farmers. The pretested questionnaire (a brief list of questions is included in the Appendix) contained both precoded and open-ended questions. The questionnaire was developed in English and then translated into Bengali by the first author to ensure efficient communication with farmers during interviews. All respondents were male and were actively involved in *gher* farming. Each respondent was given a brief introduction about the nature and purpose of the study before the interview

Table 1
Farm categories and sample size of shrimp farms based on *gher* size with their distribution in the study areas Kaliganj and Shyamnagar (Bangladesh).

Farms category	*Gher* size	Sample size (farms)	
		Kaliganj (12 groups)	Shyamnagar (12 groups)
Small farms	≤0.67 ha (≤5 bighas[a])	24	24
Medium farms	0.68–2.00 ha (5.1–15 bighas)	24	24
Large farms	≥2.01 ha (≥15.1 bighas)	24	24
Total farms		72	72

[a] The *bigha* is a unit of measurement of area of a land in Bangladesh (1 ha = 7.48 bighas).

commenced. During the ~40-min interview, questions were asked in sequence, with replies being recorded directly in the questionnaire.

As a means of triangulating the data derived from questionnaires, several topics relevant to the study, such as farmer's views and experiences in shrimp culture activities, were presented and discussed in focus groups (Morgan, 1997; Krueger and Casey, 2009). Eight focus group discussions were conducted in Kaliganj and Shyamnagar subdistricts (four in each). Each focus group session comprised 8–12 individuals and the duration of each discussion was approximately an hour. Focus group discussions were conducted only with organic shrimp farmers. The discussions were recorded with a digital voice recorder, and organized with the help of WAB staff members. Focus group discussions were held inside collection centres of WAB and in farmers' residences with the first author acting as moderator of the sessions. WAB staffs were not present at focus group meetings.

Questionnaire interview data were coded and entered into a database using MS-Access (Microsoft 2003). The statistical package for social science (SPSS™15.0 for Windows) was used to produce descriptive statistics. Data were analysed in accordance with the sustainable livelihood framework that seeks to understand why farmers adopt organic farming and what factors impact rural livelihoods. Factors that influence the income from organic shrimp aquaculture were determined through multiple regression analysis (Field, 2005) using the formula:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + \varepsilon', \quad (1)$$

where Y is the dependent variable (here, income from organic shrimp production); b_0 is the intercept and b_1, b_2, b_3, b_4, b_5 and b_6 are the slope parameters of the model. X_1 is the age in years of the organic shrimp farmer, X_2 is the number of persons in the household, X_3 is the number of years of school attendance, X_4 is the number of years of experience with shrimp farming, X_5 is the number of labour including family and wage, X_6 is the total *gher* area in hectares, and ε is an error term.

The term "farmer" hereafter refers to organic shrimp farmer. The conversion of taka (Bangladesh currency) to U.S. dollars ($) was calculated based on the rates on December 2009 ($US1 = 70 taka).

4. Results

4.1. Shrimp production systems

The 144 farms investigated—Kalindi, Uzirpur, Chuna, Ghoalghashia, Khaksihali, and Boyar beel—are in the intertidal range of the local river. The farms (the edge nearest the river) are mostly rectangular or irregular with irregular bottom topography. All the farms are within three kilometres of the river in the subdistricts Shymnagar and Kaligonj. The average size of *gher* under organic shrimp production of the studied farmers is 2.32 ha (median of 1.07 ha). The largest *gher* size is 26.72 ha and the smallest is 0.069 ha. Organic shrimp farming takes place predominantly from February to November (Fig. 3). The water level is maintained between 0.305 and 1.829 m during the whole production period. All farmers exchange water fortnightly during full and new moons. Farmers estimated an exchange of 20–30% of the total volume of water from the *gher* during each lunar cycle. During rainy seasons farmers drain excess water. Farmers exchange water through wood or concrete sluice gates controlled by wooden shutters. The same gate is used for drainage and for flushing purposes; few farmers have separate inlets and outlets. All farmers stock shrimp post-larvae between mid January and February for the first time. Restocking takes place continuously more than eight times until September. The stocking density is reduced after the first-time stocking. Harvesting and marketing take place between April and December (Fig. 3).

The farmers follow a polyculture system, that is, shrimp are housed together with a range of finfish (different species of tilapia,

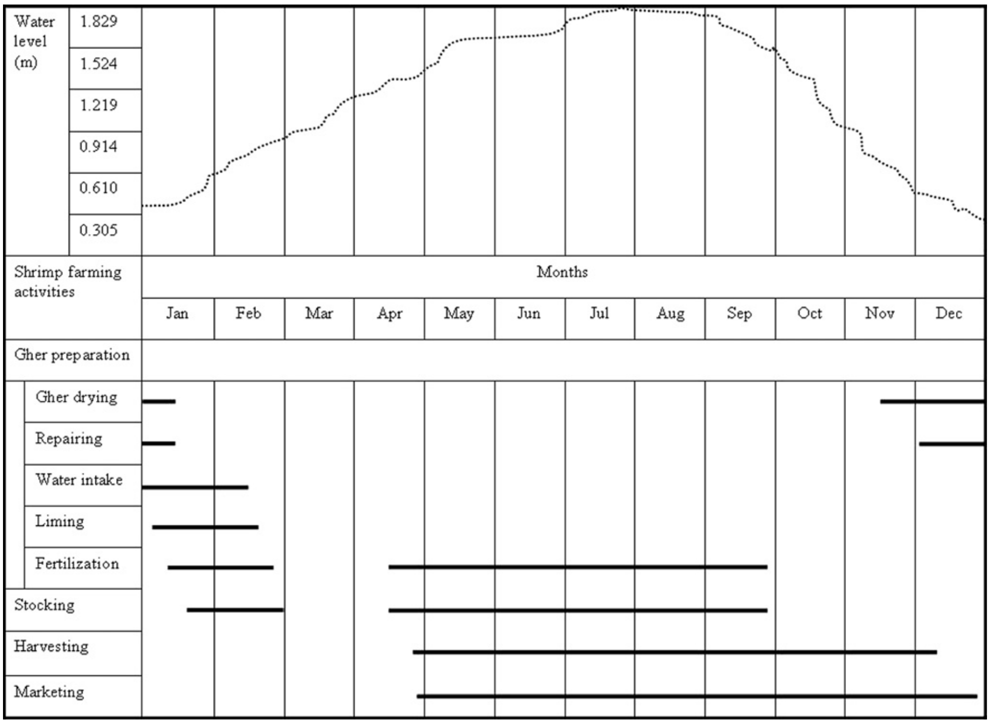

Fig. 3. Time schedule of organic shrimp farming activities in Bangladesh (Source: present study: questionnaire responses of 144 organic shrimp farmers).

Mugil parsia, *Lates calcarifer*, and the catfish *Mystus gulio*). Tilapia and *Mugil parsia* are stocked from outside but other finfish naturally enter the *gher* during saline water exchange. Farmers allow natural vegetation to grow on approximately 70% of the total dyke surrounding the *gher*. The average stocking density is 8128 post-larvae ha^{-1} ranging from 3750 to 15,000 post-larvae ha^{-1} month^{-1}. Farmers are not allowed to stock wild catches of post-larvae, instead they release native shrimp post-larvae from nurseries nominated by WAB. The nurseries collect hatchlings from hatcheries located in Cox's Bazar in the southeastern part of Bangladesh. However, various species of shrimp and finfish enter the *gher* from the wild via water exchange, although this is controlled strictly using fine sieves in the pipe inlets. The shrimp are nourished by natural food produced from processed cow dung or compost. No additional feeding and chemical fertilizers are used by the farmers. The shrimps are grown following traditional management, which uses the tides to control the water quality and to harvest the *ghers*. There are small ditches inside the *gher* to acclimatize post-larvae before they are released to the main *gher*. Eighty percent of the organic farmers reported that the yield of organic shrimp has increased compared with their past experience as conventional aquaculturists. Ninety-one percent of the organic farmers stated that production cost has decreased since they do not use fertilizers, additives, supplementary feeds, or vitamins in the organic shrimp farm.

Table 2
Distribution of labour (number of persons working) in organic shrimp farms.

Type of labour	Activity	Arithmetic mean	Standard deviation	Percentage ($n = 144$)
		Number of persons working		
Family labour	Dyke maintenance, land levelling, *gher* preparation	1.38	1.33	69.7
Wage labour (seasonal)	Dyke maintenance, land levelling, weeding, carrying post-larvae	4.51	2.65	93.7
Wage labour (permanent)	Guarding, water exchange, carrying, harvesting, transporting, marketing	0.69	1.14	41.0

4.2. Livelihood asset portfolios

4.2.1. Human capital

The age of the studied organic shrimp farmers ranged from 19 to 82 years; 34% were over 45 years old and only 19% were under 30 years old. The mean household size of the organic shrimp farmer was 5.6 persons and 62% of the households consisted of 5 or less than 5 members. The mean household size was slightly higher than the national average of 4.9 persons (DoF, 2009a). Among the total organic shrimp farmers, 15% were illiterate. Eighty-five percent of the organic shrimp farmers had a formal education but only 10% of the organic farmers held a bachelor or higher academic degree. Each organic farmer built up skills employing his knowledge from past shrimp culture. Farmers had an average of 14.4 years of shrimp farming experience and 55% of the organic shrimp farmers had more than 12-year experience.

Only 5.6% of the organic shrimp farmers lived close to the subdistrict health complex. Eighty-six percent stated that the health facility was "okay" but not easily accessible; 7.6% of the farmers did not have access to a health facility because of its remoteness or their financial insolvency. The shrimp farmers studied did not visit doctors in preliminary stages of disease and mostly depended on local pharmacies, untrained village doctors or paramedics, and traditional treatments such as *kabiraj*, *ojha*, *boidya*.

Shrimp farming requires a combination of family and wage labour. The family members of all organic shrimp farmers are involved in shrimp farming activities but family labour is not recognized as having monetary value by the prevailing social structure in Bangladesh. Family labour is mostly used for activities such as releasing post-larvae, harvesting, guarding farms, transport, and year-round marketing. The use of family labour depends on the individual farmer's financial situation. Among the organic shrimp farmers studied, 69.7% of the family labour was assigned to physical work. Shrimp farms recruit both permanent and seasonal labour (Table 2). Fifty-nine percent of organic shrimp farmers did not recruit permanent wage labour whereas 24% and 13% recruited one and two permanent workers, respectively. However, 93.7% of the farmers employed seasonal wage labour with a mean recruitment of 4.51 persons (Table 2). Seventy-nine percent of the farmers recruited three people or more as seasonal wage labourers. Forty-one percent of the farmers employed permanent wage labour for maintaining daily activity (Table 2). Seasonal labour was contracted on a daily basis and wages varied between $US1.2 and 1.8 without food. Permanent labour contracts ranged from US 21.5 to 43.5 per month without food and from $US71.5 to 171.5 per year with food. Permanent wage labourers contracted without food were employed mainly for guarding the farms.

4.2.2. Natural capital

On average, organic shrimp farmers owned 1.24 ha of land, almost half of the land under *gher* operation (2.31 ha) by organic farmers. Of the totally owned land, 70% was used for organic shrimp production and 19% was used for agricultural activities. Traditionally, agriculture is the main occupation of the rural population of Bangladesh. Only 8% of the land is used for homestead purposes where human habitats are constructed. Surrounding homestead land is used for producing rice and vegetables due to a deficit in agricultural land. Three percent of the land was used as ponds for producing finfish. Ninety-three percent of the farmers collected saline water from rivers or canals for shrimp production. Only 7% of farmers collected saline water using pumps or obtained saline water from a neighbour's *gher*, because their *ghers* were not situated close to canals or rivers.

According to focus group discussion participants, organic shrimp cultivation relies fully on natural sea water exchange, so several aquatic fauna and flora, fishes, and different shrimp species enter the *gher*. The abundance of those species can increase in the *gher* due to the ban on pesticides. Organic shrimp aquaculture depends on the availability of post-larvae. Two types of post-larvae are available in Bangladesh, natural post-larvae and hatchery post-larvae. Seventy-nine percent of the farmers reported that natural post-larvae are hardly available (often not found due to scarcity), and 14% claimed moderate availability (often found, but not in high enough quantities). On the other hand, 94% of the farmers stated that hatcheries post-larvae are sufficiently available for shrimp cultivation. Ninety-nine percent of the organic shrimp farmers studied stocked hatchery-produced post-larvae.

4.2.3. Social capital

All surveyed farmers had received training in organic shrimp farming at least three times for 2–3 h each from WAB. Organic shrimp production is monitored by WAB, and all organic farmers have an identification number supplied by WAB. No farmer can sell shrimp to WAB-established collection centres without showing an identification number.

Traditionally, large landowners in Bangladesh have offered employment to the rural poor. Nowadays, 100% of the large and medium shrimp farmers, and 91% of the smaller farmers employ rural poor because organic farmers have become more financially capable. OSPs generate a substantial amount of employment and diversified work opportunities for educated people in Bangladesh.

Focus group discussion participants reported that shrimp farmers donate cash to local mosques and temples from their substantial earnings after good harvests. Due to the expansion of shrimp farming, farmers compete for positions on governing bodies in local schools, colleges, *madrassas*, local markets, and committees. Membership in such organizations gives the farmers political influence and is thus helpful in maintaining sluice gates, accessing water resources, settling land related disputes, and obtaining credit from government banks and NGOs.

4.2.4. Financial capital

The mean annual household income of an organic shrimp farmer was calculated as $US 5,733 based on all income generating activities and including all household members' incomes. The mean annual income of an individual was $US 1,126. Calculation of the household income considered only earnings and did not take into account expenditures such as post-larvae, labour, leasing, and input costs. Aquaculture activities of the interviewed farmers generated more than 75% of their total annual income, and shrimp alone generated about 63.3%. Farmers earned 10.2% of their income from fish and other shrimp species (Table 3). Income from agriculture was 3.8% of the total income. Of the total incomes, 12.1% of earnings came from multiple sources including remittances, pensions, wage labour, and driver services, and 7.7% came from business sectors including shop keeping, petty trading, and shrimp purchasing and selling.

Twenty-six percent of the organic shrimp farmers did not use credit for costs involved in their business; the remaining 74% received loans from sources such as NGOs, money lenders, shrimp traders, and banks. Forty-two percent of the farmers received loans from NGOs at 12–15% yearly interest at a flat rate. Seventeen percent of the farmers received loans from local branches of the local government and private banks at a 12% yearly interest rate. Traditional money lenders provided loans to 6% of the organic farmers at an interest rate of 10–15% per month. Focus group discussion participants reported that they intended to pay back loans through the continuous selling of shrimp.

4.2.5. Physical capital

Transport, irrigation machines, power tillers, shelters, markets, electricity, drinking water sources, health, and sanitary facilities enable farmers to pursue their livelihood strategies. According to the organic shrimp farmers, physical capital has increased over the last 10–15 years (Table 4). Eighty-nine percent of the farmers report improvements in the condition of their dwellings. Nearly 97% of the farmers now have safe and hygienic latrines. Forty-eight percent of the farmers now have electricity compared to 3% 10–15 years ago. About 92% of the farmers now have access to the government health complex and 89% of the farmers now travel on bitumen-layered roads compared to the unpaved roads of the past. Vehicles used in shrimp cultivating areas are mainly bicycles, van, auto-rickshaws and motorbikes. Fifty-three percent of the farmers' drinking water sources are ponds and 43% of the farmers depend on either tube wells or rain for drinking water. Only 17% of the farmers have installed tube wells at their own expense.

Table 3
Sources of household annual income of organic farmers in Shymnagar and Kaligonj subdistricts of Satkhira district (Bangladesh).

Source of income	Mean annual household income ($US)	Standard deviation	Percentage of annual income ($n = 144$)
Shrimp	3628	5996	63.3
Prawn	64	171	1.1
Fish and others	587	1003	10.2
Agriculture	217	872	3.8
Livestock	30	101	0.5
Business	442	825	7.7
Job	73	425	1.3
Other	692	963	12.1
Total	5733	7636	100.0

4.3. Vulnerability context

Organic shrimp farmers identified several problems that increased their vulnerability as conventional farmers in past years (Table 5). Farmers identified shrimp diseases as the most important problem in conventional farming (96%), followed by the high price of inputs (85%). Eighty-five percent of the farmers reported that the quality post-larvae is not a problem for conventional shrimp farming.

Table 6 lists shocks, trends, and seasonality that can impact the livelihood of organic shrimp farming communities.

Shocks affecting farmers refer to sudden events that undermine household livelihoods. Natural disasters such as cyclones, floods, and heavy rains are unpredictable and beyond the control of the farmer. They can affect both organic and conventional shrimp farming. Diseases have not yet been found in organic shrimp production but farmers felt uncertain about the future development of this topic. Production may fail due to disease occurrence. No organic farmer has installed a saline water treatment system. Hence, contamination of saline water may occur due to the sudden entry of untreated saline water during water exchange. There are no local markets for organic shrimp in Bangladesh. The commercialization of organic shrimp is a big concern of the farmers as a ban imposed by a buyer or a decline of demand for organic shrimp on the global market would negatively affect the livelihoods of shrimp farmers in Bangladesh. Farmers also cited conflicts that have emerged between large and small *gher* owners over the control of water and land resources. These conflicts can erupt suddenly, for example, upon provision of leasing money.

Trends refer to changes over time in natural resources stocks and quality, or in other factors unrelated to aquaculture that impact an organic farming household. A major change, reported by the farmers, has taken place in the use of land in the study area. All *ghers* have been converted from agricultural lands previously used for crop cultivation. This conversion has mainly taken place due to poor crop yields and soil fertility deterioration due to saline water seepage from surrounding *ghers*. Livestock resources have decreased due to salt water intrusion in the study area. As most of the lands are now used for shrimp cultivation, production of rice and vegetables has decreased. Farmers stated that cooking fuel is going to disappear as rice production and livestock production has decreased. Most of the farmers used to employ straw and cowdung for cooking fuel. Now they depend on wood from the neighbouring mangrove forest, Sundarban.

Seasonality refers to seasonal changes that constrain the livelihood choices of people. Seasonal shifts in sources for post-larvae are an important factor mentioned by the surveyed farmers. In Bangladesh, there are more than 60 shrimp hatcheries, but none is situated in the southwestern region. Farmers face the problem of stocking post-larvae in their *gher* due to an increase in the price of post-larvae during the early season. Hence, the price and quality of post-larvae fully depend on the hatchery. Farmers often lose

Table 4
Conditions of physical assets of organic shrimp farmers now and 10–15 years ago.

Physical assets	Situation	Material/type/accessibility/position	Present condition (%) ($n = 144$)	Condition 10–15 years ago (%) ($n = 144$)
Dwelling	Good	Brick wall and tin roof or better	45	9
	Ok	Tin wall with wooden pillars and frames with tin roof	44	19
	Not good	Earthen or bamboo fence wall and tin roof	11	72
Sanitation facility	Good	Brick with good drainage	53	4
	Ok	Wood/galvanized metal with inadequate drainage	44	15
	Not good	Bamboo with leaf shelter and inadequate drainage	3	81
Electrical facility	Good	Electric lighting, fans	45	2
	Ok	Electric lighting	3	1
	Not good	No electrical connection	52	97
Medical facility	Good	Close to govt. health complex	5	0
	Ok	Far from govt. health complex but access possible	87	3
	Not good	No access to govt. health complex	8	97
Transportation	Good	Wide bitumen layered road	39	0
	Ok	Narrow bitumen layered or brick road	50	3
	Not good	Earthen road	11	97

income when there is a decrease in buyer demand. In Bangladesh, 142 processing plants have been established. Among them, only 62 hold a licence from the European Commission to export their products. The remaining plants are idle because of insufficient raw material. Only one processing plant is responsible for buying organic shrimp from WAB-governed farmers.

In addition, although shrimp farming is a year-round activity, employment opportunities for the local population face seasonal variations and are especially scarce in lean seasons.

4.4. Factors that influence income from organic shrimp aquaculture production

Livelihood strategies are likely to focus on activities that generate income. The occupational pattern shows that all farmers have more than one livelihood activity. Of the total farmers, 82.6% considered shrimp farming to be their main activity and primary source of income, followed by 7.6% that saw business, and 3.5% that saw agriculture as their main activity. Shrimp farming as a secondary activity and secondary source of income was reported by 17.4% of the farmers.

The income from shrimp production relies on different factors. The coefficient of multiple determinations (R^2) for income from organic shrimp production is 0.717, indicating that 71.7% of the total variation can be explained by the six independent variables included in the model in Eq. (1). The organic shrimp industry income depends mainly on the *gher* area under operation and the aquaculture experience of the farmers (Table 7). This implies that the income of organic farmers has increased due to the operation of larger *ghers*. The larger the *gher* area in operation, the larger is the possibility to increase income. Past experience with shrimp farming increases farmer skills and improves the management efficiency of organic cultivation. Labour plays a significant role in generating income from organic shrimp aquaculture, that is, cultivation of organic shrimp is labour intensive. The independent variables age, household size, and education do not have a statistically significant impact on income from organic shrimp farming.

Table 5
Problems faced by the organic shrimp farmers during earlier conventional shrimp farming.

Problems	Response (%) ($n = 144$)	
	Yes	No
Shrimp diseases	96	4
High price of inputs/production cost	85	15
Natural disasters (cyclone, flood)	84	16
Heavy rain	81	19
Salt water intrusion in rice field[a]	81	9
Productivity of soils	75	25
Wastewater	70	30
Oxygen deficiency	68	32
pH fluctuations	68	32
Salinity increase in *gher*	66	34
Organic matter (black soil)	63	37
Turbidity	50	50
Irrigation due to saline water[b]	42	25
Quality post-larvae	15	85

[a] 10% of the farmers did not comment on this issue.
[b] 33% of the farmers did not comment on this issue.

Table 6
Vulnerability contexts such as shocks, trends, and seasonality faced by organic shrimp farmers (Qualitative data from focus group discussions; $n = 80$).

Vulnerability context	Examples of shocks, trends, and seasonality faced by organic shrimp farmers
Shocks	Occurrence of natural disaster (cyclones, floods, heavy rain)
	Uncertain shrimp diseases
	Production failure
	Contamination of saline water
	Ban on marketing
	Demand fluctuation
	Conflicts involving control of water and land resources
Trends	Inadequate saline water supply
	Land use change
	Decrease in livestock resources
	Decrease in vegetable production
	Shortage of cooking fuel
Seasonality	Sources of post-larvae
	Dependency on hatchery
	Dependency on processing plant
	Alteration in employment opportunities

Table 7
Multiple regression analysis on income from organic shrimp production ($n = 144$).

Dependent variable	Independent variables	Coefficients	*t*-ratio	*p*-value
Income from organic shrimp	Age in years	0.000	−0.139	0.890
	Household size in persons	−0.016	−1.776	0.078
	Years of school attendance	0.008	1.608	0.110
	Shrimp farming experience	0.019	5.341	0.000**
	Labour	0.018	2.550	0.012*
	Total *gher* area	0.082	13.769	0.000**
Y-Intercept		2.723	26.381	0.000**
$R^2 = 0.717$, Adj. $R^2 = 0.705$, $F = 57.866$, P-value $= 0.000$, $n = 144$				

*, **Significant at 0.05 and 0.01 levels of probability, respectively.

5. Discussion

5.1. Organic shrimp farming can be integrated into a livelihood strategy

Environmental and socioeconomic impacts limit conventional shrimp farming (Paul and Vogl, 2011). Organic shrimp farming might mitigate some of these impacts and thus be integrated into the conventional farmers' livelihood system. However, little is known about the impact organic farming will have on a conventional shrimp farmer's livelihood. As assets play a leading role in developing and understanding the livelihood strategies which may cause an improved livelihood situation (Rakodi, 1999; Ellis, 2000), farmers can combine human, natural, social, financial, and physical capital assets in a livelihood asset portfolio to assess livelihood outcomes (Carney, 1998; Farrington et al., 1999; Ellis, 2000). Organic farming relies on these five capital assets, which contribute to agricultural sustainability over time (UNCTAD/UNEP, 2008).

Human capital is increasingly vital in organic farming, particularly for individuals and communities in Africa, as increased human knowledge and skills increase food yields and improve access to food (UNCTAD/UNEP, 2008). Greater age, higher level of education, and past aquaculture experience can increase the efficiency of organic shrimp farms (Paul and Vogl, 2012). The livelihoods of organic shrimp farmers depend mainly on the utilization of land and water resources and the protection of other natural capital. Organic shrimp farmers must consider stocking density, soil quality, water quality, post-larvae quality, and polyculture techniques. Organic farmers seek to maintain a healthy soil quality and a sustainable use of water resources (Willer and Kilcher, 2010). The dependency on hatchery post-larvae protects natural stocks of post-larvae from overexploitation, allowing the natural production of shrimp and fish to increase. Increased shrimp production from capture fisheries can provide a livelihood to poor people not involved in aquaculture. Social capital accumulates when organic shrimp farmers donate cash to institutions. Donors not only establish themselves as influential individuals, they help to create social bonds and networks within the community. The working strategy of an OSP is the formation of farmers' groups for the sharing of knowledge and experience that increase shrimp production and lower the costs of working (Paul and Vogl, 2012). Social capital can facilitate access to resources and transform them into income (Ellis, 2000; Pretty, 2003).

According to DFID (1999), available financial capital provides people with different livelihood options. The organic shrimp farming option has expanded because of the availability of financial capital. This capital facilitates the financing of working capital. The mean income of an individual organic shrimp farmer was higher than the per capita gross national income of $US 690 in the financial year of 2008–2009 (BBS, 2009), and aquaculture activities comprised an average of 75% of the total income. The percentage distribution of income indicates that organic shrimp farming has a positive impact on household livelihoods in the study area. It is also assumed that the land under shrimp cultivation is only suitable for *gher* activities as the high the salinity does not favour rice cultivation. While some organic shrimp farmers use their own financial resources to operate their business, the majority receives loans from various sources. Focus group discussion participants suggested that it is difficult to acquire loans from government banks, especially for small farms and poor farmers. A few participants applied for loans but failed, discouraged by the documentation required by government banks. Local NGOs sometimes refused to lend money to small farmers because of repayment uncertainty. Small farmers that obtain loans to finance *gher* operations are usually subjected to the higher interest rates of money lenders. However, organic farming can increase household income and has a positive impact on poverty in a variety of ways, including cash savings and additional income gained by selling surplus produce and value added products (UNCTAD/UNEP, 2008).

Physical capital endowments are an important means of accelerating growth in household incomes (DFID, 1999). The influx of road networks and the advent of electricity have enabled farmers to carry their harvested shrimp to collection centres which can protect the shrimp from deterioration in quality. New and better transportation systems have also created employment opportunities beyond shrimp farming for local people. Improvement of sanitation and medical facilities has reduced the number of farmers suffering from diseases. However, about half of the farmers depend on ponds for drinking water and have no good access to safe drinking water resources. Farmers now access up-to-date market information using their motorbikes and mobile phones. Current market information enables the farmer to earn premium prices from organic produce.

Agriculture is a primary livelihood strategy in Bangladesh (Hallman et al., 2003). Organic shrimp farming is a primary livelihood activity in the study area but provides neither full-time employment nor food security; organic shrimp farmers must rely on multiple sources of income to feed their families. Multiple livelihood activities provide a safety net to organic shrimp farmers to cope with production failure and price shock due to demand fluctuation in international markets. Livelihood strategies are the range and combination of activities and choices that people make in order to achieve their livelihood goals (Carloni and Crowley, 2005). A few years ago, many of the organic shrimp farmers interviewed converted to shrimp farming for employment and adapt new cultivation techniques. Organic farming generated employment while promoting local resources and locally adapted production methods (Buck et al., 1997; Kilcher, 2007). New industries have been generated by the shrimp industry in Bangladesh, including production of bamboo-made screens, traps and baskets, net making, sluice gate building, cock-sheet box supplying, post-larvae trading, and van pulling. Hatcheries, nurseries, ice plants and processing plants have been established to accommodate shrimp cultivation (BSFF, 2008). Marketing of organic shrimp is a viable livelihood activity for people in this area. Shrimp purchased from the farm can be carried to the processing plant applying quality control measures. This marketing occupation is a niche that could be further developed by providing adequate training to prospective candidates. Shrimp marketing is a year-round activity that could augment the income of seasonal workers.

Income diversification according to occupation is the best indicator of the socioeconomic position of a household (Ellis, 2000). Organic shrimp farmers commonly use their land for shrimp farming because it generates multiple employments (post-larvae trading, bamboo-made screens, traps and baskets, net making, sluice gate building, cock-sheet box supplying and van pulling) and therefore more opportunity to achieve higher income diversification. Distribution of landholdings and size of land under *gher* operation in the organic shrimp sector play a significant role in Bangladesh (Paul and Vogl, 2012). Shrimp farming experience and *gher* size influence income level and in turn the livelihood of local people who are inspired to convert their farms to organic shrimp cultivation. In Bangladesh, the mean yield from organic shrimp farming is higher ($320\ kg\ ha^{-1}\ yr^{-1}$) than from conventional farming because of improved husbandry conditions and the use of multitrophic aquaculture (Paul and Vogl, 2012). The multitrophic aquaculture concept is now used in different parts of the world as it enhances ecosystem functions by allowing biological and chemical processes to balance each other. That is, the by-products, including waste, from one aquatic species are used as nutrient inputs (fertilizers, food) for another species (Chopin, 2006). As organic shrimp farming is polyculture based and is dependent on the natural food cycle, multitrophic aquaculture can achieve higher yields in Bangladesh. Yields from conventional shrimp farming in Bangladesh have been reported to be $260\ kg\ ha^{-1}\ yr^{-1}$ (Alam, 2009), $146\ kg\ ha^{-1}\ yr^{-1}$ (Alam et al., 2007), and 80–200 $kg\ ha^{-1}\ yr^{-1}$ (Islam et al., 2005). Apparently, agricultural yields remain stable when a farmer converts to organic from conventional systems (UNCTAD/UNEP, 2008).

5.2. *Adopting organic shrimp farming can decrease vulnerability to risks*

Organic shrimp farmers are vulnerable to events over which they have no control and that can cause negative effects to their livelihood. It is therefore important to identify means by which the negative effects of the vulnerability can be minimized, including building greater resilience and improving overall livelihood security (Ahmed et al., 2008). For instance, planting mangroves can protect and stabilize coastal land from natural disasters such as cyclones and storm surges (Saenger and Siddiqi, 1993; Islam and Wahab, 2005; Iftekhar and Takama, 2008), and potentially conserves fisheries resources (Islam and Haque, 2004). Organic aquaculturists are not allowed to damage mangrove forests to construct or expand shrimp farms (Naturland, 2011) as mangroves hold the soil in place, preventing erosion. In order to stabilise and enhance the ecological system, 50% of the total dyke surface is covered by plants (Naturland, 2011). This dyke can also be used for vegetable production. Farmers can also grow grass for rearing livestock. The increments of livestock resources directly contribute to solve the lack of cooking fuel.

The occurrences of shrimp diseases have the potential to reduce economic returns in Bangladesh (Alam et al., 2007). Adequate management and limited stocking density in organic farming minimize the extent of shrimp loss due to disease (Paul and Vogl, 2012). Management practices in organic aquaculture can achieve a high level of disease resistance and prevention of infections (Tacon and Brister, 2002). Safe saline water is an important factor in shrimp health; the health of all shrimp is vulnerable to pollution and degraded water quality (Islam, 2003; Islam et al., 2004a).

Farmers tend to sell their shrimp to WAB-established collection centres where processing companies offer premium prices after weighing. The studied farmers reported that the prices for organic shrimp were higher than those for conventional shrimp. The average price of shrimp from conventional aquaculture in local markets varied from $US 5 to $US 7 kg^{-1}, while organic farmers received close to one dollar more. This market chain has eliminated a number of intermediate stakeholders and delivers organic shrimp immediately to the processing plant. Organic farmers argued that they incur a financial loss when the shrimp are not available for purchase by international buyers. Despite the advantage of being free from middlemen, farmers can be negatively affected by limited marketing opportunities. Bans imposed without prior notice by international buyers can cause economic loss to farmers. Organic shrimp farmers and conventional farmers are equally affected by price declines. A ban imposed by the EU in 1997 for shrimp export from Bangladesh hurt the country's economy as well as individual farmers (Yunus, 2009). The Fair Trade agreement (FairTrade, 2011) ensures that buyers guarantee a minimum price for the shrimp harvest; price premiums are set on the basis of the current market price. The OSP can implement the concept of Fair Trade minimum price and organic premiums for farmers in Bangladesh. Continuous marketing, buyers at collection centres (farm gate), and price premiums help organic farmers to reduce their vulnerability to loss of income.

Farmers in the OSP are organized as an independent group. Organic production is under internal control and audits are provided by an external body (Institute of Market Ecology). The group format helps farmers to make business and social connections and take initiatives to manage conflicts. Low-level conflicts have arisen in shrimp farming areas in India's fragile Sundarbans archipelago due to the farmers being locals, the low-intensity cultivation practice, and the small area of land under operation (Knowler et al., 2009). Group organization plays an important role in creating trust, reciprocity, and cohesion within the society as members follow local norms and share values and attitudes (Pretty and Ward, 2001; Pretty, 2003). WAB training helps farmers to optimize cultivation practices and provides opportunities to share unexpected incidents and conflicts. Group meetings build good relations within the OSP, which can then help to build social capital. Access to social capital helps organic farmers to reduce vulnerability to assorted risks. Social capital can facilitate access to resources, create household livelihood capabilities, and play a significant role in sustainable rural development (Woolcock, 1998; Bebbington, 1999; Lin, 1999; Ellis, 2000; Pretty, 2003).

Organic farmers are fully dependent on hatchery sources for post-larvae (Paul and Vogl, 2012). Collections of post-larvae from natural sources are strictly prohibited by the Bangladesh government. Organic shrimp farming preserves the natural biodiversity by not stocking natural post-larvae in *ghers*. An estimated 60–75% of shrimp post-larvae are produced in hatcheries, although current data for Bangladesh do not exist (Islam et al., 2004b). Post-larvae collection from natural sources causes huge mortality of shrimp and other aquatic species incurring a biodiversity loss (Naylor et al., 2000; Hoq et al., 2001). In Bangladesh, export organizations and the processing industry are the most important transforming structures. The choices for selling organic shrimp are limited for farmers in Bangladesh. The markets for certified organic shrimp depend mainly on demand of western countries (Biao, 2008). The Government of Bangladesh has amended several policies, laws, rules, acts, and ordinances such as saline water take-up, seasonal ban on post-larvae collection from natural sources and ban on post-larvae import. To obtain licences, farms must be registered with the Department of Fisheries. The use of chemicals and drugs is now regulated, directly encouraging organic farming practices. WAB has developed an internal control system as prescribed by European Commission regulations that can help organic farmers to reduce their vulnerability. Hence, the conversion to organic shrimp farming can be recognized as a strategy to cope with the past vulnerability experienced by the farmers when they practiced conventional shrimp farming.

5.3. *Organic shrimp farming can be an innovation*

In Bangladesh, the conversion to organic shrimp farming is relatively new and under development. The development of organic shrimp farming in Bangladesh is mainly driven by the farmers with the involvement of international importing organizations. According to Padel (2001), conversion to organic farming is a typical example of the diffusion of an innovation. Organic shrimp farmers can be considered innovators or early adopters. According to the adoption model, innovators are venturesome, interested in developing cosmopolitan social relationships, and communicate with a clique of other innovators, often not considering geographical distance (Rogers, 2003). Innovators must be able to cope with a high degree of uncertainty and have an ability to understand as well as apply complex technical knowledge. Adopters usually have a degree of opinion leadership and have potential communication with information sources. The role of early adopters in the diffusion process is to help trigger the innovation to an acceptable critical mass (Rogers, 2003).

The adoption model accommodates socioeconomic characteristics such as age, education, income level, farm size, personality, and communication behaviour as well as innovativeness (Rogers, 2003). Likewise, studies on the conversion to organic farming have looked at socioeconomic characteristics (Tovey, 1997; Duram, 1999; Rigby et al., 2001; Koesling et al., 2008; Kallas et al., 2010). The adoption of organic shrimp farming requires initial investment that can be supplied from multiple income options. Higher household income gave organic farmers an opportunity to make contact with WAB officials frequently, to acquire the necessary know-how, and to upgrade their skills for managing their farms organically. By adopting organic shrimp farming, farmers can reduce the negative effects of vulnerability and livelihood goals may be achieved. The conversion to organic shrimp farming may lead to the adoption of a different set of activities such as using hatchery post-larvae; applying polyculture techniques; applying compost; and may facilitate the greening of the area surrounding the *gher*. If organic farming is successfully adopted in the study area, it can diffuse very quickly to neighbours. Organic technology will be more readily diffused if social bonds are developed within the communities. In this connection, organic farmers can improve their living standards, can enhance their purchasing power, and can increase their capability to access the natural resource base.

6. Conclusion

Organic shrimp farming has a potential to improve the livelihoods of Bangladesh farmers through increased export earnings and improved social status. Because the practice is gentle to the environment, these improvements are sustainable. Currently, a single buyer exports organic shrimp in Bangladesh, but development of the OSP can inspire international buyers and a domestic market will emerge in the future. Organic shrimp farming can be a source of sustainable household livelihood; it offers positive social and economic benefits, and the risk of shrimp disease is manageable. The income gained from organic shrimp farming has enabled farmers to diversify their income opportunities. This study has opened up a range of questions for further research. As policy becomes more sophisticated, interventions to minimize the vulnerability of organic farmers and improve their living conditions will naturally follow.

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Appendix

Brief list of questions:

1 Briefly describe the demographics of organic shrimp farmers.
2 How much land (*bigha*) of the various types does your household own or have access to?
3 Briefly describe the number, size, age, history, and culture system of *gher* cultivation.
4 What are the main sources of water and their distances from the *gher*?
5 What are the main sources of water for different purposes and their distances?
6 Could you describe the ownership and accessibility of the water sources?
7 What problems are faced during shrimp farming? How would you rate them?
8 How many labourers were used for 1 *bigha* shrimp and rice production in the last year?
9 Could you give information about the shrimp post-larvae (PL)?
10 Have you obtained a licence from the Government to do shrimp production?
11 Describe the type of inputs, their frequency, and their quantity that you apply in your shrimp pond.
12 What is your source of income? What were the shrimp production and shrimp price last year?
13 Please indicate the livestock resources you own.
14 Please indicate the condition of your physical assets due to shrimp aquaculture.
15 Have you ever received credit? If so, from whom did you take credit?
16 Have you ever received any training for organic shrimp farming? If so, please indicate the name of the organization and the duration of the training.
17 How did you first hear about organic shrimp farming?
18 What was the reason you decided to take up organic shrimp farming?

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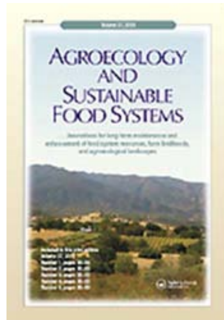
Paper – 4

A comparison of aquaculture systems: The case of shrimp farming in southwest Bangladesh

Brojo Gopal Paul and Christian Reinhard Vogl

Division of Organic Farming, Department of Sustainable Agricultural Systems, University of Natural Resources and Life Sciences (BOKU), Vienna, Austria

I collected data from the field, conducted the data analysis, and prepared a first draft of the paper. I revised the draft paper with inputs from Christian Vogl. The paper is under review in the Journal of Agroecology and Sustainable Food Systems (Previously named as Journal of Sustainable Agriculture).



A Comparison of aquaculture systems: The case of shrimp farming in Southwest Bangladesh

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Abstract

Black tiger shrimp farming is an important economic activity in Bangladesh for the generation of employment and income, and the earning of foreign exchange. Data were collected in 2009 from 144 organic, 60 conventional, and 60 integrated (with fish and rice) shrimp farmers in Bangladesh through questionnaire interviews, transect walks, and focus group discussions. The mean productivity of organic shrimp farming in the area was 320 kg ha^{-1} yr^{-1}, compared with a mean productivity of 226 and 196 kg ha^{-1} yr^{-1} for conventional and integrated shrimp farming, respectively. Organic farmers are more likely to have higher monthly incomes and lower aquaculture experience than conventional farmers, and higher aquaculture experience than integrated shrimp farmers. Organic shrimp farming requires lower input than conventional and integrated shrimp farming, thus organic shrimp farmers obtain higher shrimp yields and higher income with lower production costs. Government policies are required to promote sustainable organic shrimp aquaculture.

Keywords: organic shrimp, organic aquaculture, production, c, labour, Bangladesh.

1. Introduction

Aquaculture, the fastest growing sector in animal food production, is growing at an average rate of 6.6 percent annually (FAO 2010) and now comprises 46% of the total worldwide food fish. It has left behind the agriculture sectors in terms of both quantity and diversity of certified organic produce (FAO 2002; Brister and Kapuscinski 2001). However, organic agriculture presently uses 35 million hectares of agricultural land, whereas organic aquaculture uses only 0.43 million hectares (Willer and Kilcher 2010). Organic aquaculture has attracted considerable attention due to consumers' awareness of overfishing, environmental degradation, health risks, sustainability, and animal welfare (Biao et al. 2003; Biao 2008; Lien and Anthony 2007). The growth in global demand for organic foods is currently estimated at 20% per annum (Pelletier 2003) whereas estimates range from 20% to 30% annually for the growth rate of organic aquaculture products (Ruangpan 2007). It is predicted that organic aquaculture production will increase 240-fold by 2030, that is, to an equivalent of 0.6% of the total estimated aquaculture production (FAO 2002). Compared to organic crop farming and livestock raising, organic aquaculture is still a relatively new concept and remains under development (Cottee and Petersan 2009; Boehmer et al. 2005; Pelletier 2003). The initial legislative framework for organic aquaculture was the European Union Dangerous Substances Directive 2092/91/EEC which has been recently replaced by Directives 834/97/EC, 889/08/EC, and 710/09/EC; the latter introduced rules for organic aquaculture (EU 2007, 2008, 2009). At the same time, guidelines for the production, processing, labelling, and marketing of organically produced foods (FAO/WHO 2001) as well as support material regarding organic agriculture, environment, and food security to enhance the organic agriculture movement (FAO 2002) were published. The basic standards for organic production and processing were formulated in 2005 by the International Federation of Organic Agriculture Movements (IFOAM 2007).

The annual contribution from aquaculture production in Bangladesh increased from 0.593 to 1.005 million tonnes between 2000 and 2008 (FAO 2010). Shrimp is one of the most important species considering export earnings and employment generation. In the financial year 2007–2008, Bangladesh exported 49,907 tonnes of shrimp and prawn (*Macrobrachium rosenbergii*) valued at US$409 million; the sector contributes about 4.04% to total export earnings and 3.74% to GDP (DoF 2009). The shrimp industry employs approximately 1.2 million people in Bangladesh for production, processing, and marketing activities; 4.8 million household members rely on this sector for their livelihood (USAID 2006).

Demand for high quality, safe shrimp products has increased tremendously from major importing countries that set strict standards and regulations to ensure quality and safety. However, shrimp aquaculture has led to the destruction of natural habitats and the displacement of traditional livelihoods and has therefore been criticized by environmental and social scientists around the world (Primavera 1997; Paul and Vogl 2011; Lebel et al. 2002). The sector also faces issues such as low yields, lack of adequate technology, price fluctuations in international markets, bans imposed by the European Union, and lack of government stimulus (Paul and Vogl 2011; Deb 1998; Chowdhury et al. 2006; Alam et al. 2007; Yunus 2009). Consequently, the organic aquaculture of shrimp has been attracting considerable attention for in Bangladesh as an alternative culture technique. The involvement of international corporations has triggered an expansion of the organic shrimp project (OSP) in Bangladesh which is certified by Naturland, a German private organic farmers' association that runs an aquaculture scheme. In Bangladesh, shrimp farming takes up 167,877 ha of coastal land area (DoF 2009). WAB Trading International owns approximately 4,000 ha that are managed by 3,379 individual farmers, all of whom have converted from conventional to organic shrimp aquaculture. Conventional and integrated (shrimp-fish-rice) shrimp farming methods have been practiced in Bangladesh for the past three decades (Azad et al. 2009; Ahmed and Garnett 2010).

Conventional aquaculture systems result in the destruction of natural ecosystems because of intensive cultivation, high stocking density, use of chemicals and antibiotics, and the cultivation of nonnative species (Biao et al. 2009; Biao 2008). In integrated shrimp farming systems, shrimp, fish, and rice are grown simultaneously with the use of compost and synthetic fertilizers (Glover et al. 2000; Reganold et al. 2001). Conventional, integrated, and organic shrimp farming systems in Bangladesh are described in Table 1.

Table 1

Shrimp cultivation is an economically important, labour and input intensive Bangladesh industry. To our knowledge, a comparison of conventional, integrated, and organic shrimp farming systems has not been addressed in the literature. In this article a comparison is performed on the basis of farm characteristics including land and labour distribution, product yields, inputs applied, and income generated.

2. Methods

The study was conducted in the Satkhira district, a salinity-affected coastal area of the Bay of Bengal situated in southwestern Bangladesh (Figure 1). Eighty percent of the country's shrimp farms are situated in Khulna, Bagerhat, and Satkhira districts (Alam et al. 2005; Pokrant 2006). Satkhira has been identified as the most promising area for brackish water shrimp culture due to year-round moderate to high water salinity (Alam and Phillips 2004). Shrimp is cultivated in this area mostly between February and November when the surrounding rivers become saline. The dry season from November to February is hardly suitable for shrimp cultivation as water is scarce and too saline. From July to October (summer monsoon) some farmers grow rain-fed transplanted rice as the overall water salinity becomes low (Ali 2006). Of the seven subdistricts in the Satkhira district, only Kaliganj and Shyamnagar are included in this study because they accommodate a large number of shrimp farms due to available saline water and their closeness to the river channels and the world's largest continuous mangrove forest. In the Satkhira district an OSP is implemented by WAB Trading International. The OSP has about 200 staff members whose education levels vary from secondary school to doctoral degrees. Most of the staff members are local farmers. The internal control systems (ICS) of the OSP include internal quality management procedures, internal training, and internal inspections done by the staff as a means to prepare for an external, independent, third party inspection by the Institute of Market Ecology (IMO). Internal WAB trainers cannot be inspectors and vice versa.

Figure 1

Data were collected between October and December 2009 during the late harvesting season. This study applied quantitative and qualitative data collection methods reported in Ahmed et al. (2010). Researchers collaborated with WAB Trading International to identify questionnaire respondents. WAB cooperates with 160 organic farmers' groups (15–40 farmers per group) and 3,379 individual organic farmers. From these 160 groups, 12 groups per subdistrict were selected through a stratified random sample (stratum = subregion). In every group, six farmers were again selected through purposive stratified random sampling based on *gher* size (a *gher* is a modified rice field or a pond used to cultivate shrimp and fin fish): small ≤ 0.67 ha, medium = 0.68–2.00 ha, and large ≥ 2.01 ha. A total of 144 organic (72 in each study area), 60 conventional (30 in each study area), and 60 integrated (30 in each study area) shrimp farmers were sampled (Table 2).

Table 2

Primary data were collected during a face-to-face field survey using a questionnaire pretested in the beginning of October 2009 with six nonsampled shrimp farmers. The questionnaire contained 30 questions, some precoded and some open-ended. The questionnaire was developed in English and then translated into Bengali by the first author to ensure efficient communication with farmers. In an interview of about 40 minutes, the respondent was given a brief introduction to the nature and purpose of the study, then the questions were asked in sequence, with replies being recorded directly onto the questionnaire.

As a means of triangulating the data derived from the questionnaires, several topics relevant to the study were presented and discussed in focus groups (Morgan 1997; Krueger and Casey 2009) moderated by the first author. Focus group discussions were conducted separately with organic, conventional, and integrated shrimp farmers to get an overview of the farmers' socioeconomic situation, trends in resource use patterns, farming practices, seasonal variation, and the problems and potentials of shrimp farming. Twelve focus group discussions were conducted in each subdistrict. Each focus group session comprised 8–12 individuals and the duration of each discussion was approximately an hour. The discussions were recorded with a digital voice recorder, and convenient venues and times were selected with the help of WAB staff. The focus group discussions were held inside WAB collection centers and in farmers' residences. WAB staffs were not present during focus group sessions.

To build rapport at the beginning of the study, 10 transect walks (Chambers 1992) were performed by walking across relevant *gher* sites with shrimp farmers and informally discussing resource use patterns, farming practices, and daily livelihood activities (Chambers 1994). Information gathered in the transect walks was useful in validating farmers' answers to questions in the questionnaire.

Questionnaire interview data were coded and entered into a database system using Microsoft Access 2003. Statistical Package for the Social Sciences (SPSS 15.0 for Windows) was used to produce descriptive statistics. Comparisons among farmers' categories were made by the ANOVA F-test and the Spearman Rank Order Correlation. The ANOVA was followed by a Tukey Post-hoc comparison of means. Differences of $p \leq 0.05$ were considered significant. In some cases, data were normalized using the log transformation. The results from focus group discussions were identified manually using marker pen for highlighting on the transcription sheet. The findings from focus group discussions were used to complement the quantitative output.

3. Results

3.1 Socioeconomic characteristics of shrimp farmers

Socioeconomic variables (Table 3) varied significantly among the three groups of shrimp farmers whose aquaculture systems were examined. Thirty-four percent of the organic farmers were over 45 years old and only 19% were under 30 years old. In the two other groups tested, more than 25% of the farmers were 18–30 years old. The group mean ages indicated that organic farmers (42.0 yrs) were relatively older than conventional farmers (39.0 yrs), and integrated farmers (39.7). Farmers in the three groups had similar education. Fifteen percent of the organic farmers were illiterate whereas 23% of the conventional and 12% of the integrated farmers was illiterate. Only 10% of the organic farmers held a bachelor or higher academic degree whereas 13% of the conventional and 7% of the integrated farmers were educated to that level. Household sizes varied significantly among the three groups. Sixty-two percent of the organic farmers had five or fewer family members, compared to 70% of conventional and 45% of integrated farmers. Conventional farmers had significantly higher aquaculture experience (in years) than organic and integrated farmers, as the latter groups adopted aquaculture more recently. Fifty-five percent of the organic farmers had more than 12 years' experience with shrimp, compared to 74% and 45% of conventional and integrated farmers, respectively. The monthly income of organic shrimp farmers was significantly higher than that of conventional and integrated shrimp farmers. Only 5% of the organic farmers had a monthly income of less than US$100 compared to 10% of conventional and 12% of integrated farmers.

Table 3

All groups of farmers had more than one livelihood activity. Eighty-three percent of the organic farmers, 90% of the conventional farmers, and 72% of the integrated farmers considered shrimp farming to be their main activity and primary source of income (Figure 2). All groups of farmers had earned money from a secondary activity. Livelihood activities such as agriculture, business, and shrimp purchasing and selling were important secondary sources of income.

Figure 2

3.2 Patterns of land and labour distribution

Organic shrimp farmers owned comparatively more land (1.24 ha) than either conventional (1.13 ha) or integrated (1.04 ha) farmers (Table 4). Conventional shrimp farmers used a higher percentage of land (78%) for shrimp farming compared to organic (70%) and integrated (60%) farmers. Organic shrimp farmers utilized more land for agriculture (0.26 ha) than conventional (12 ha) and integrated (24 ha) farmers. Organic and integrated farmers used more land (0.11 ha and 0.15 ha, respectively) for their homesteads than conventional farmers (0.09 ha). Sixty-nine percent of the organic farmers, 68% of the conventional farmers, and 52% of the integrated farmers did not own agricultural land for crop production. Twenty-seven percent of the organic farmers, 37% of the conventional farmers, and 22% of the integrated farmers did not have ponds for producing fin fish for their own consumption. Because of a lack of agricultural land, homestead land was often used to produce rice and vegetables.

Table 4

Considering all three groups, 47% of the farmers had more than one hectare of land for *gher* operation. All three groups of farmers operated a larger area of land for shrimp production than they owned. Most farmers depended on leased land to extend their *gher*. Organic and conventional farmers operated a significantly larger area of *gher* than integrated farmers. Twenty-two percent of the organic farmers did not own any land for shrimp farming, compared to 36.7% of conventional and 13.3% of integrated farmers. Twenty-eight percent of the organic shrimp farmers did not lease land for *gher* operation compared to 25% of conventional and 40% of integrated shrimp farmers, as they operated the *ghers* themselves or jointly. Conventional farmers used a larger size of leased land for shrimp production compared to the other two groups. Eighty-three percent of the organic farmers did not lease out their land, as opposed to 67% of conventional and 62% of integrated farmers. Organic farmers performed shrimp farming on larger size plots of owned land and conventional farmers leased larger sized plots than other farmer groups (Table 5). Leasing periods varied from one to five years. Leasing values depended on location, not on farming systems, and ranged from US$426 to US$748 per hectare.

Table 5

Shrimp farming uses a combination of family and wage labour (Table 6). Shrimp farms require labour for activities such as *gher* preparation (drying, clearing, and levelling of land, trench excavation and levee construction, liming, manuring, letting in saline water), carrying and releasing postlarvae, weeding, guarding, and harvesting, transporting and marketing shrimp and fish. All such work is seasonal or semipermanent. Twenty-five percent of all farmer respondents used daily-paid casual workers or contracted workers rather than family members in *gher* preparation-related activities. Only 5% of the farmers did not hire wage labour on a seasonal basis. Seasonal wage labour was mostly used for heavy work such as clearing and levelling of land, trench excavation, and levee construction for the *gher*. Seasonal wage labour employment varied significantly among the three groups of farmers; on average, 6.61 seasonal wage labourers were employed in the study area per production cycle. Family labour was generally used for taking care of the prepared *gher*. *Gher* care by permanent hired labourers was performed by an average of 0.50 persons per respondent per season for all three groups of farmers. Permanent wage labour was significantly higher for organic (0.69) shrimp farmers than for conventional (0.48) and integrated (0.08) shrimp farmers (Table 6).

Table 6

3.3 Yield

The mean yield of shrimp was 270.3 kg ha^{-1} year^{-1} in the study area. Organic shrimp production was significantly higher (319.6 kg ha^{-1} year^{-1}) than production of organic prawn (6.2 kg ha^{-1} year^{-1}), organic fish, and other seafood species (17.8 kg ha^{-1} year^{-1}) (Table 7). Fifty-eight percent of organic shrimp farmers produced a yield of shrimp above the average yield in the study area, while conventional and integrated shrimp farmers produced 17% and 15%, respectively. Seventy-six percent of the organic farmers did not stock prawn in *ghers* due to high salinity, compared to 70% and 77% of conventional and integrated farmers, respectively. The remaining farmers stocked prawn during the rainy season only. Conventional farmers produced higher prawn yields (14.9 kg ha^{-1} $year^{-1}$) compared to organic (6.2 kg ha^{-1} $year^{-1}$) and integrated (6.1 kg ha^{-1} $year^{-1}$) farmers. Most fish and other shrimp species found in *ghers* enter during water exchange, although a few farmers stock them. Fifty-three percent of the integrated farmers harvested significantly higher yields of fish and other seafood species compared to 26% and 33% of organic and conventional farmers, respectively. Farmers of all groups benefited from shrimp farming, whether directly from the shrimp yield or from the yield of a combination of shrimp and other seafood species.

Table 7

3.4 Cultivation practices

Fourteen different types of input to shrimp farming systems are recorded in Table 8. Cowdung, lime, rice bran, mustard oil cake, dolomite, and rotenone were commonly used by the three categories of farmers studied. Conventional shrimp farms applied higher doses of cowdung, lime, mustard oil cake, and dolomite compared to organic and integrated farming systems. Organic farmers did not apply chemical fertilizers, poultry drops, pesticides, bleaching powder, or hormones. Organic farms typically used processed cowdung, lime, and rotenone during *gher* preparation and before stocking postlarvae for entering the next production cycle. Conventional and integrated farmers additionally applied urea, TSP, poultry drops, and bleaching powder to fertilize the *gher* during preparation. The frequency of application of compost by organic farmers was higher, but the mean quantity was lower than that of conventional and integrated farmers. The frequency of application and mean quantity of rice bran and mustard oil cake used to supplement the *gher* food supply were lower for organic shrimp farmers than for conventional and integrated shrimp farmers. Bleaching powder and rotenone were used to control unwanted larvae and snails; lime and dolomite were applied to control plankton and for cleaning the water.

Table 8

Ninety percent of organic farmers exchanged water from natural saline water sources (river and canal) compared to 83% of conventional farmers and 53% of integrated farmers. The remaining farmers in the three farming systems did not exchange water because they lacked the necessary facilities or had no access to natural saline water sources. The distance to saline water sources varied from 10 metres to 3 kilometres. The tidal flows of saline water are regulated through sluice gates.

Shrimp aquaculture depends on the availability of postlarvae. Two types of postlarvae are available in Bangladesh, i.e., natural postlarvae and hatchery postlarvae. Seventy-nine percent of organic farmers reported that wild postlarvae were often scarce, and 14% claimed moderate availability of wild postlarvae (often found, but not in sufficient quantities). Organic shrimp farmers are not allowed to stock wild postlarvae in the *gher* for cultivation. Ninety-four percent of the organic farmers stated that hatchery postlarvae were sufficiently available for shrimp cultivation. Thirty-seven percent of conventional farmers depended on both wild and hatchery sources for postlarvae supply, and the remaining conventional farmers depended fully on hatchery sources. Integrated farmers obtained 98% of postlarvae from hatcheries. The average postlarvae stocking density was 8,128 ha^{-1} for organic shrimp farmers, 9,437 ha^{-1} for conventional shrimp farmers, and 9,223 ha^{-1} for integrated shrimp farmers. Postlarvae stocking density varied from 3,750 to 15,000 postlarvae ha^{-1} $time^{-1}$ in organic farming and 3,750 to 22,440 postlarvae ha^{-1} $time^{-1}$ in conventional and integrated farming. Seventy-four percent of organic farmers received postlarvae from nurseries on credit, paying after the beginning of harvest. Postlarvae can be restocked after payment is made for the earlier delivery. However, 60% of conventional shrimp farmers and 62% of integrated shrimp farmers got credit from nurseries to stock postlarvae in their *ghers*.

3.4 Correlation of annual income with different factors

Aquaculture activities (including shrimp, prawn, fish, and other kinds of seafood species) generated more than 68% of the total annual income for the three groups of farmers studied, and shrimp aquaculture alone generated about 57.7%. The income from shrimp was above the average annual income of all farmers for 30% of the organic farmers, 32% of the conventional farmers, and 3% of the integrated farmers. Organic farmers earned significantly higher income from fish and other shrimp species than integrated farmers. Integrated farmers earned significantly higher income from agriculture than organic and conventional farmers. Integrated farmers earned more from other sources of income than organic and conventional farmers.

Income from shrimp and size of *gher* under operation showed strong positive correlations with the annual income in all three farming systems (Table 9); that is, shrimp income and operational *gher* size contributed substantially to annual income. Age had an insignificant positive influence on annual income and education had a significant moderate positive influence on the annual income of organic shrimp farmers. Family size had a significant moderate positive correlation with annual income in all three farming systems. A moderate to strong positive correlation with income in organic systems was found in terms of ownership of total land, *gher* operated only in owned land, leased land, and wage labour. The annual income of conventional shrimp farmers showed a strong positive correlation with *ghers* operating on leased land (Table 9).

Table 9

4. Discussion

The organic, conventional, and integrated shrimp farmers studied here differed significantly in household size, aquaculture experience, and monthly household income. Most of the organic shrimp farmers in the study were middle aged and 85% had some schooling; about one-third had obtained a secondary school certificate or above. The average number of household members was significantly higher for integrated farmers because integrated farmers require more manpower to manage rice-shrimp cultivation. Organic farmers had more aquaculture experience than integrated farmers but less aquaculture experience than conventional farmers, as conventional farmers were early adopters of shrimp farming in Bangladesh. Organic farmers recently converted and implemented new farming schemes. According to Padel (2001), conversion to organic farming is a typical example of the diffusion of an innovation, thus, organic farmers can be considered as innovators or early adopters (Rogers 2003). Information from WAB Trading International indicated that farmers with high monthly household incomes are prone to convert to organic shrimp production due to their financial ability to experiment with new techniques. Lack of information and lack of necessary skills can be a major barrier to the adoption of organic agriculture (FAO 2002). Studies from different countries have reported that organic agriculture farmers hold high levels of academic education, are younger, have less farming experience, and have urban backgrounds (Padel 2001; Rigby et al. 2001; Koesling et al. 2008) than conventional agriculture farmers. Similar notions were echoed in consumer studies that showed that households with high levels of education and income are more likely to purchase organic foods (GLOBEFISH 2005; Roitner-Schobesberger et al. 2008; Dettmann and Dimitri 2010). Academic education and farming experience can help farmers to transform technology to suit their needs (Lebel et al. 2002).

Organic shrimp farmers held more land than conventional and integrated farmers. On average each shrimp farmer owned 1.24 ha of land, whereas the cultivated land per farm household in Bangladesh is only 0.6 ha (Saha 2002). In Bangladesh, most farmers rely on combining owned and leased land for shrimp aquaculture (Ito 2002; Ahmed 2006). The mean sizes of land under *gher* operation and owned land used for *gher* operation were significantly bigger in organic shrimp farming than in conventional and integrated shrimp farming.

Organic farming does not utilize heavily mechanized growing techniques which are labour intensive (Buck et al. 1997). However, shrimp farming relies on labourers, especially family members, who do not require special training. Organic shrimp farming is a recent practice in Bangladesh, so the *gher* conditions are still good. Hence, organic farmers do not require seasonal labour as much as conventional and integrated farmers do. Organic farming does not require fertilizers, preventive medicines, or formulated feed, further reducing the need for seasonal labour. Organic farmers save money by contracting permanent labourers, as the pay rates for long term labour contracts are lower than the daily wage rates in Bangladesh (Ito 2002). Because chemicals and fertilizers are not applied, organic shrimp farming is safer than conventional and integrated farming (Buck et al. 1997).

A mean yield of organic shrimp of 320 kg ha^{-1} yr^{-1}, ranging from 120–711 kg ha^{-1} year^{-1}, compared with a mean shrimp productivity of 226 and 196 kg ha^{-1} yr^{-1} in conventional and integrated shrimp farming, respectively, was recorded in the studied area. Certified organic shrimp yields were 227 kg ha^{-1} in Indonesia and Vietnam (recorded on 2 farms) and 2,000 kg ha^{-1} in China (1 farm) (Biao 2008). The highest production of certified shrimp s found in Thailand, 3 tonnes per hectare from Sureerath farm (Ruangpan 2007). The high variation in organic shrimp yield might be due to different production intensities and different technological knowledge. The yield of organic shrimp is comparatively higher than that of conventional shrimp in Bangladesh. Other yields for conventional shrimp have been reported: 260 kg ha^{-1} yr^{-1} (Alam 2009), 146 kg ha^{-1} yr^{-1} (Alam et al. 2007), 80–200 kg ha^{-1} yr^{-1} (Islam et al. 2005) in Bangladesh, and 91–250 kg ha^{-1} yr^{-1} (Balasubramanian et al. 2005) in India. The increase in shrimp yield that is possible with organic aquaculture practices encourages conventional shrimp farmers to shift to organic shrimp farming in Bangladesh. Strict adherence to organic standards: low stocking density, regular water exchange for four to six days at full and new moons every fortnight and frequent weeding leads to a higher shrimp production rate. Organic shrimp farmers used adequately processed cowdung and compost more frequently than conventional and integrated shrimp farmers. Adequate manuring is important in organic shrimp farming as supplementary feeding and synthetic fertilizers are not allowed. Conventional farmers obtained a higher yield of prawn; because they stocked relatively higher prawn postlarvae to compensate for the loss of shrimp. Integrated farmers obtained higher yields of fish and other kinds of seafood because they stocked fish as a main crop during rice cultivation in the *gher*, as the salinity of the water is low during rice harvest.

Worldwide sales of organic products have increased to over US$5 billion a year (Willer et al. 2008). Because of higher market prices and lower production costs, organic shrimp farming offers a higher total annual income than conventional and integrated shrimp farming. Nevertheless, there is no local market for organic shrimp in Bangladesh and farmers depend on exports. The major market for certified organic shrimp is limited to Western countries like

North America, Europe, Australia, and Japan (Biao 2008) and the choice of exporters is limited. Farmers get comparatively higher prices when WAB-nominated processors purchase shrimp directly from farmers in different collection centres. The price of organic shrimp depends on the buyers' demand and is also influenced by size and seasonality. A premium price is important to sustain organic production (Ramesh et al. 2010) but an increasing number of consumers are willing to pay premium prices and this reduces economic and environmental pressures on shrimp farmers (Sundrum 2001).

Organic farming promotes local resources and generates neighbourhood employment (Buck et al. 1997; Kilcher 2007). In Bangladesh, organic shrimp aquaculture provides working opportunities diversified from conventional and integrated shrimp farming such as production of bamboo-made screens, traps and baskets, net making, sluice gate building, cock-sheet box supplying, postlarvae trading, and van pulling. Hatcheries, nurseries, ice plants, and processing plants have been established to accommodate shrimp cultivation (BSFF 2008). Antibiotic-free postlarvae are reared in local hatcheries and are distributed to farmers according to demand. The government of Bangladesh has banned the collection of natural postlarvae from canals and river channels because of its negative impact on local biodiversity (Hoq et al. 2001); collection of natural postlarvae increases mortality of other shrimp species' larvae, finfish larvae, and microzooplankton (Alam et al. 2005). Natural sources of shrimp collection are threatened by environmental pollution and overexploitation, causing a severe scarcity of wild postlarvae supply (Islam et al. 2004; Hoq 2007). Shrimp post larvae stock is harvested exclusively by women and children in estuaries and coasts, using a variety of fine-mesh hand-handle push nets. Men do not usually harvest post larvae, except by boat.

422 All aquaculture contributes to environmental degradation due to habitat destruction, waste disposal, and exotic species and pathogen invasions. However, conventional aquaculture requires large volumes of fishmeal and fish oil to produce aquatic feed (Naylor et al. 2000; Neiland et al. 2001; Primavera 2006). Organic shrimp aquaculture has lower production costs, as fertilizers, supplementary feeds, feed additives and hormones, and antibiotics are not allowed. The use of certain antibiotics in aquaculture can cause the development of antibiotic resistance among pathogens, which compromises the health of the cultivated animals and humans (Holmström et al. 2003). Chloramphenicol, erythromycin, oxytetracycline, furazolidone, prefuran, and nitrofuran, which are effective against Gram-positive and Gram-negative bacteria, are synthetic agents commonly used as antibiotics in hatcheries (Uddin and Kader 2006). Nitrofuran is a suspected carcinogen and its use on food animals is prohibited in the European Union (GESAMP 1997). Chloramphenicol can cause aplastic anemia in humans (GESAMP 1997). Some chemicals used in shrimp farming (e.g., organotin compounds, copper compounds, and toxic residues) can have a negative impact on the environment (Gräslund et al. 2003). The commonly used disinfectant chlorine is applied to kill bacteria and viruses and pesticides are applied in shrimp ponds to kill unwanted organisms such as fish, crustaceans, snails, fungi, and algae (Gräslund et al. 2003). As none of these chemicals are used in organic shrimp farming, so the organic method is environmentally friendly. While the production of fertilizers and feeds uses energy and emits CO_2, organic shrimp farming uses 30–40% less energy and thus entails lower greenhouse gas emissions than conventional practices (Ruangpan 2007).

444 Despite its advantages, global organic aquaculture production lags behind conventional aquaculture due to an absence of universally accepted standards, accreditation criteria, and third party certification (FAO 2002; Hatanaka 2010; Biao 2008; Perdikaris and Paschos

2010). Naturland was the first to develop the organic aquaculture standards that are applied in Bangladesh and are closely monitored by the WAB ICS team. In Bangladesh, farmers comply with Naturland standards which promote the use of local resources, and because of this, local knowledge has not been marginalized. The OSP paid the cost of organic certification to accredit the farmers. However, until the Bangladesh government develops organic standards and certification and accreditation bodies that allow organic shrimp to be exported to other countries, farmers can explore new markets for organic produce only in third world countries where standards and certification schemes similar to those of Bangladesh are accepted. The Bangladesh government could also apply to be a member of the International Federation of Organic Agriculture Movements (IFOAM) to enhance the sustainable production of Bangladeshi organic shrimp.

5. Conclusion

Three shrimp farming systems in Bangladesh—organic and conventional aquaculture and integrated culture—have been studied in this project. The prospects of organic shrimp aquaculture are positive considering yield, income, input use, land and labour suitability, and farming experience. Organic shrimp farming can ameliorate some of the negative environmental impacts of conventional and integrated farming systems. Nevertheless, the future of organic shrimp farming depends not only on farmers, premium prices, and export markets, but also on government stimuli, publicity, technological improvements, universal standards for production, universally accepted certification and accreditation, and consumers' health awareness. Organic shrimp farming in Bangladesh has recorded higher yields compared to conventional and integrated farming systems, but is still low-yielding compared to other shrimp producing countries. The success of organic shrimp farming depends on farm characteristics and the farmers' willingness to follow the principles of organic farming that focus on sustainability.

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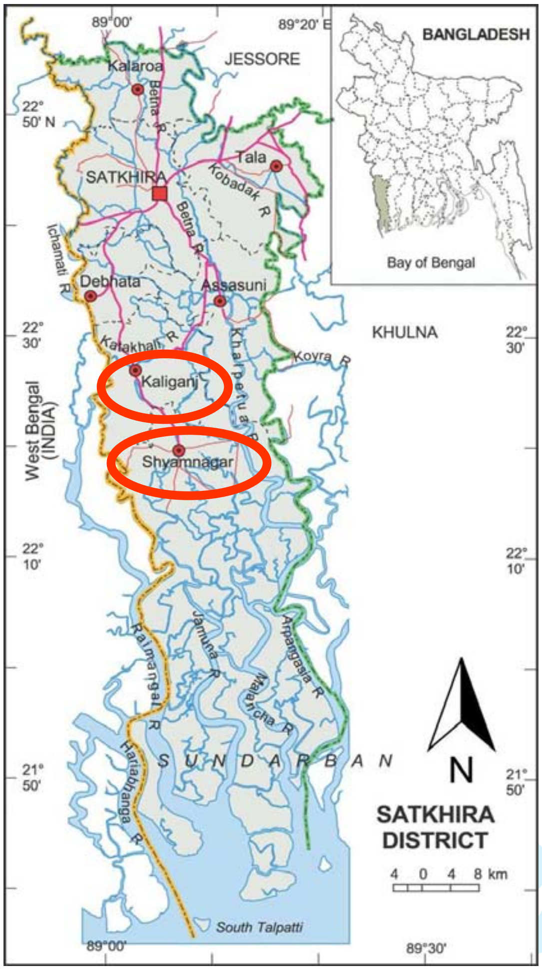

Figure 1: The study areas (red circles) of Kaliganj and Shyamnagar in SW Bangladesh (Sathkira district) (Banglapedia 2006).

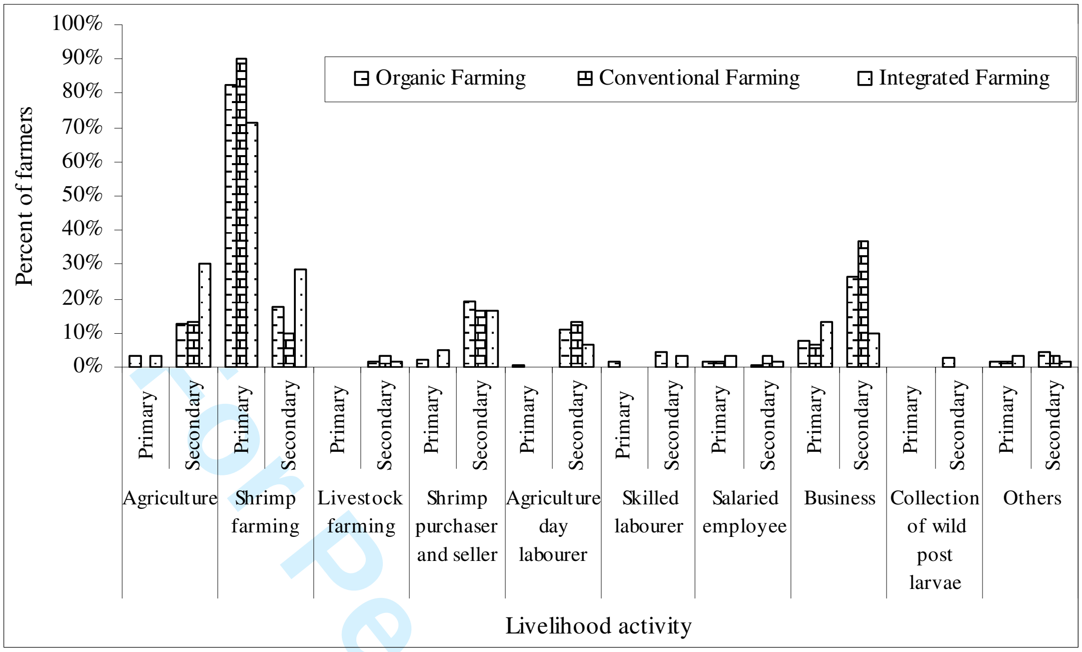

Figure 2: Distribution of livelihood activities among the categories “primary” and “secondary” source of income as perceived by the three groups of farmers (n = 100 %)

Table 1: Characteristics of conventional, integrated, and organic shrimp aquaculture systems in Bangladesh.

Criteria	Conventional aquaculture	Integrated aquaculture	Organic aquaculture
Farming techniques	Polyculture (shrimp and fish)	Polyculture (shrimp, fish and rice)	Polyculture (shrimp and fish)
Stocking density	High (3-5 post larvae/ m^2)	Medium (2-3 post larvae/ m^2)	Low (1-2 post larvae/ m^2)
Dependency on feeding	Natural and supplementary feeding	Natural and supplementary feeding	Natural feeding
Uses fertilizers	Organic and synthetic	Organic and synthetic	Organic
Uses pesticides	Yes	Yes	Prohibited
Uses antibiotics	Yes	Yes	Prohibited
Sources of post larvae	Wild and hatchery post larvae	Wild and hatchery post larvae	Hatchery post larvae
Uses species	Native and exotic	Native and exotic	Native
Mode of saline water exchange	Sluice gate and pump	Sluice gate and pump	Sluice gate

Table 2: Number of farmers in different shrimp farming systems in the study areas of Kaliganj and Shyamnagar subdistricts in Bangladesh

Farmers category	Sample size (farmers)		
	Kaliganj	Shyamnagar	Total
Organic farmers	72	72	144
Conventional farmers	30	30	60
Integrated farmers	30	30	60
Total	132	132	264

Table 3: Arithmetic mean (standard deviation) of socioeconomic variables of surveyed respondents

Variables	Organic farmers (n = 144)	Conventional farmers (n = 60)	Integrated farmer (n = 60)	All farmers (n = 264)	Standard error	F-statistics	Significance level
Age in years	42.0a (11.8)	39.0a (12.6)	39.7a (12.9)	40.8 (12.3)	0.757	1.559	ns
Household size in number of persons	5.6a (2.4)	5.2ab (2.6)	6.3b (2.5)	5.7 (2.5)	0.155	3.027	*
Years of school attendance	7.1a (4.3)	6.5a (4.6)	6.6a (4.0)	6.8 (4.3)	0.265	0.514	ns
Experience with shrimp farming in years	14.4a (6.0)	19.9b (6.8)	11.8c (5.6)	15.0 (6.7)	0.414	28.358	**
Monthly income in US$[a]	481.2a (636.2)	387.7ab (351.5)	243.3b (151.1)	405.9 (405.9)	31.510	4.754	**

[a] In 2009, US$1 was equivalent to about 70 taka (Bangladeshi currency).

* and ** denote significance at ≤ 0.05 and ≤ 0.01, respectively; ns = not significant.

Same letters of each row indicate no significant difference ($p < 0.05$).

Table 4: Land use patterns of respondents in different farming systems

Land use pattern	Organic farmer (n = 144)		Conventional farmer (n = 60)		Integrated farmer (n = 60)		All farmers (n = 264)	
	Mean (ha)	% of land use	Mean (ha)	% of land use	Mean (ha)	% of land use	Mean (ha)	% of land use
Shrimp farming	0.98	70	0.89	78	0.63	60	0.88	71
Agricultural land	0.26	19	0.12	11	0.24	23	0.22	18
Homestead land	0.11	8	0.09	8	0.15	14	0.11	9
Ponds	0.04	3	0.03	2	0.03	3	0.03	2
Total	1.24	100	1.13	100	1.04	100	1.24	100

Table 5: Distribution of mean land size (ha) (standard deviation) according to tenancy pattern of *ghers* in different farming systems

Gher tenancy pattern	Organic farmers (n = 144)	Conventional farmers (n = 60)	Integrated farmers (n = 60)	Mean total (n = 264)	Standard error	F-statistics	Significance level
Land under *gher* operation (ha)	2.31a (3.6)	2.15ab (3.5)	0.86b (0.7)	1.95 (3.2)	0.196	4.680	*
Gher operation in own land (ha)	0.85a (1.1)	0.54ab (0.7)	0.47b (0.6)	0.69 (1.0)	0.059	4.307	*
Gher operation in leased-in land (ha)	1.46a (3.2)	1.61ab (3.3)	0.39b (0.5)	1.25 (2.9)	0.178	3.567	*
Lease-out land for *gher* operation (ha)	0.13a (0.6)	0.35b (0.7)	0.16ab (0.4)	0.18 (0.6)	0.036	3.157	*

* and ** denote significance at ≤ 0.05 and ≤ 0.01, respectively; ns = not significant.

Same letters of each row indicate no significant difference at $p < 0.05$.

Table 6: Labour distribution pattern (mean person per season) of different farming systems

Type of labour	Activity	Organic farmers (n = 144)	Conventional farmers (n = 60)	Integrated farmers (n = 60)	Mean total (n = 264)	Significance level
Family labour	Drying, land leveling, liming, entering water,	1.38	1.57	1.72	1.50	ns
Wage labour (seasonal)	Dyke maintenance, land leveling, weeding, carrying post larvae	4.51a	8.12b	8.17b	6.16	**
Wage labour (permanent)	Guarding, water exchange, carrying, harvesting, transporting, marketing	0.69a	0.48ab	0.08b	0.50	**

* and ** denote significance at ≤ 0.05 and ≤ 0.01, respectively; ns= not significant.

Same letters of each row indicate no significant difference at $p < 0.05$.

Table 7: Arithmetic mean of yield (standard deviation) of aquaculture species in different farming systems

Variable (Yield)	Organic farmers (n = 144)	Conventional farmers (n = 60)	Integrated farmers (n = 60)	Mean total (n = 264)	Standard error	F-statistics	Significance level
Shrimp ($kg\ ha^{-1}\ year^{-1}$)	319.6a (136.42)	226.4b (53.49)	195.6b (69.77)	270.3 (122.05)	7.51	33.510	**
Prawn ($kg\ ha^{-1}\ year^{-1}$)	6.2a (13.54)	14.9b (33.88)	6.1ab (17.56)	8.1 (20.97)	1.29	4.090	*
Fish & other ($kg\ ha^{-1}\ year^{-1}$)	179.8a (117.18)	196.1ab (138.20)	267.6c (144.62)	219.6 (133.04)	8.19	9.981	**

* and ** denote significance at ≤ 0.05 and ≤ 0.01, respectively; ns = not significant.

Same letters of each row indicate no significant difference at $p < 0.05$.

Table 8: Mean quantity of input to three different shrimp farming systems

Input	Mean quantity (kg/ha/yr)			Significance level
	Organic (n = 144)	Conventional (n = 60)	Integrated (n = 60)	
Urea		71.43	99.23	**
TSP		116.19	128.53	**
Poultry drop		74.18	82.03	*
Cow dung	1022.27	1338.55	1220.24	ns
Compost	138.07	182.77		*
Lime	94.64	123.79	90.51	ns
Rice bran	42.23	39.89	48.87	ns
Mustard oil cake	75.53	106.59	52.48	ns
Pesticide		0.15	1.76	**
Dolomite	35.29	50.86	34.03	ns
Zeolite		235.50	68.69	ns
Bleaching powder		0.11	0.51	**
Rotenone	0.26	0.22	0.03	ns
Hormone			1.53	**

Table 9: Correlation of annual income of different shrimp farming systems with different factors

Factors	Annual income (r value)		
	Organic farmer (n = 144)	Conventional farmer (n = 60)	Integrated farmer (n = 60)
Age	0.076	-0.040	-0.002
Family size	0.155*	0.276**	0.345***
Education	0.317***	0.110	0.045
Farmer experience	0.455***	-0.158	0.213*
Income from shrimp	0.904***	0.843***	0.690***
Ownership of total land	0.599***	0.430***	0.322**
Size of *gher* under operation	0.852***	0.853***	0.682***
Gher operated on owned land	0.521***	0.400***	0.269**
Gher leased	0.539***	0.623***	0.401***
Wage labour	0.557***	0.493***	0.289**

*, **, and *** denote significance at .10, .05, and .01, respectively.

PART – 3

Discussion and Implications

6. General Discussion, Conclusion, and Policy Implications

6.1. General discussion

Organic farming emerged with the aim of solving a series of environmental, safety, and health problems faced by modern conventional agriculture farming. Conventional agriculture uses a large amount of chemical fertilizers, synthetic pesticides, and growth regulators, practices that result in a heavy reliance on nonrenewable resources and lead to reduced biodiversity, polluted water resources, chemical residues in food, soil degradation, and health risks to farm workers who handle pesticides—all these factors bring into question the sustainability of conventional farming systems (Matson et al., 1997; Drinkwater et al., 1998; Reganold et al., 2001; Tilman et al., 2002). The International Federation of Organic Movements (IFOAM) defines organic agriculture as the farming of animals and plants that promotes environmentally, socially, and economically sound production by working with local soil conditions and avoiding inputs that have adverse effects on the environment. Organic farming prohibits the use of synthetic chemicals, fertilizers, pesticides, pharmaceuticals, and feed additives, while encouraging reliance on internal farm resources, using natural ecological processes to sustain agricultural yields and disease resistance, and emphasizing preventive measures over treatments (IFOAM, 2008). Organic farming plays an important role in increasing soil fertility, minimizing input costs, and producing eco-friendly and safer products (Stolze et al., 2000; Offermann and Nieberg, 2001; Mäder et al., 2002; Lotter, 2003). As a major part of the agricultural sector, organic aquaculture has been impressively successful at increasing production quantities in recent years. The principles of organic aquaculture are based on protecting the environment, minimizing soil and water degradation, decreasing pollution, and optimizing biological diversity and productivity (Bergleiter et al., 2009).

The production processes and ecological production management systems of organic aquaculture promote and enhance biodiversity, biological cycles, and biological activity (Bergleiter et al., 2009). Ecological aquaculture is based on minimal use of off-farm inputs and on holistic management practices that restore, maintain, and enhance species diversity and natural harmony (Costa-Pierce, 2010). Prein et al. (2012) conclude that a key aspect of most organic aquaculture standards is the maintenance of biodiversity. For example, the avoidance of destruction or even the replanting of mangroves in coastal locations is a key element of aquaculture system design and management. Another common goal is the planting of pond dikes with local plant species, particularly for control of dike erosion; this practice prevents siltation and pond turbidity, and maintains natural productivity. Polyculture is the recommended system for organic aquaculture, where different species occupy distinctly separate feeding niches within the aquaculture ecosystem. Ponds and cages are the recommended rearing systems for organic aquaculture. Tank systems are permitted for hatcheries and nurseries but not for grow-out operations on farms. The stocking density of cultured species is limited and must be less than that of conventional aquaculture. The use of mechanical aeration is usually banned, while an exception is made for mechanical mixing and destratification of the water column for a limited number of hours per day with a small number of devices. Currently there are no detailed regulations for energy efficiency. Similarly, no requirements are stated for maximum levels of carbon equivalents per harvested product (CO_2/kg). Organic aquaculture requires that effluent quality be monitored to avoid negative impacts on the surrounding environment. Organic aquaculture aims to reduce instances of disease and emphasizes preventive treatments. Chemicals and antibiotics are not permitted treatments in shrimp farming, but vaccines and probiotics are permitted in organic aquaculture (Prein et al., 2012). Organic aquaculture feed is based on a minimal use of off-farm inputs and farmers should not use wild fish as trash fish to supplement protein sources because wild fish are caught domestically and/or imported from abroad (Mente et al., 2011). To use wild fish as fish meal for organic aquaculture would deplete the environment, going against the basic principles of organic production (Mente et al., 2011). Instead, feed should come from certified organic agricultural inputs or from aquatic sources that have been cultured under controlled, organic conditions.

Organic shrimp farming in Bangladesh has a low stocking density (maximum 15 post larvae/m^2). Chemical inputs such as fertilizers, pesticides, and antibiotics are not applied. Farmers do not stock wild caught post larvae because it is not permitted. No artificial feed is used in shrimp ponds in Bangladesh, the shrimp are nourished by food naturally occurring in the ponds. The organic shrimp project supports the preparation of natural compost for regular use in the shrimp pond to support the development of natural food. Farmers exchange water biweekly during high tide which maintains water quality. To ensure traceability the farmers are registered and their activities are documented by WAB Trading International (Asia) Ltd. An internal control system within organic shrimp projects oversees quality management procedures, training, and inspection to ensure compliance with organic regulations and the quality of the products. Harvested shrimp are put into an insulated container with ice and fall into a “sleeping” state at 0–5 degrees Celsius. The sleeping shrimp are brought directly to a collection centre under the supervision of internal inspectors from Trading International (Asia) Ltd. The shrimp are sorted in size, weighed, and placed in ice again at the collection centre. Here, the price is documented with the farmers’ identification number. The shrimp are then transported in a truck directly to the nominated processing plant where they are processed and stored below 18 degrees Celsius.

This study confirmed that the productivity of organic shrimp in Bangladesh is comparatively higher than conventional and integrated shrimp farming. There are several reasons for this. The most likely reason is that soil and water quality has improved due to organic management practices, and natural feed production has improved. Due to semi-intensive and intensive cultivation patterns, Thailand and China achieve a certified shrimp production higher than that of Bangladesh (Ruangpan, 2007; Biao, 2008). The improved extensive organic shrimp cultivation in Bangladesh is traditional and family based. This farming practice saves on fertilizers, pesticides, supplementary feeds, and antibiotics. The lower input costs increase the farmers’ profits. This study confirmed that due to higher organic shrimp yields, lower production costs, and a price premium for “organic” produce, organic farmers in Bangladesh achieved annually 10–20% higher gross margin compared to conventional farmers. As synthetic fertilizers and pesticides are not used in organic shrimp farming systems, their potential negative effects on the environment do not occur. During focus group discussions with conventional farmers, several farmers indicated an interest in converting their farm to organic practices. WAB Trading International (Asia) Ltd. is not expanding their activities because the market of organic shrimp is not big enough to justify an expansion, however, even if they are not certified organic farmers, conventional farmers can shift their farms from conventional to organic to gain from low production costs and higher yields. If they sell their shrimp to middlemen and/or directly to a depot, they will be paid according to their production. In this study, organic farmers confirmed that they did not yet face any shrimp diseases. Focus group discussion participants confirmed that the mortality of organic shrimp post larvae is lower than that of conventional farming. This suggests that if all shrimp farmers converted to organic practices, the risk of diseases would be reduced. This is an opportunity for multinational traders and the government of Bangladesh to inspire conventional farmers to shift their farming practices to organic which can ensure rich biodiversity, biological cycles, and environment friendly shrimp production.

This study suggests that the adoption of organic shrimp farming not only improves the organic farmer's economic situation, but also leads to an overall improvement of the quality of life for the farm family. The majority of organic shrimp farmers expressed a positive attitude toward the future. Although a substantial number of organic farmers depend on loans for their cultivation practices, their tensions are considerably reduced due to better yields from organic shrimp (320 kg ha^{-1} yr^{-1}) than from conventional shrimp (226 kg ha^{-1} yr^{-1}). Organic farmers do not handle pesticides, so their health will be improved compared to conventional farmers and expenses for health care should decrease after conversion to organic farming. The improved socioeconomic status of the organic shrimp farmer can influence neighboring farmers to be early adopters. As organic farming is labor intensive, the conversion to organic farming from conventional farming will initially increase the farmer's workload, but the workload will decrease over time. Family labor can decrease the workload of the principal farmer; women can be involved in looking after the pond and in preparing compost. Organic shrimp farming thus can serve as a vehicle to empower women. Focus group discussion participants revealed that adoption of organic farming reduced input costs, improved water and soil quality, and enabled the farmer to obtain a premium price for the harvest. Focus group discussion with organic farmers felt satisfied that they could pass on fertile ponds to their children. Moreover, organic shrimp farming is group–based in that knowledge and techniques can be shared, and this process can unite farmers.

Due to climatic risks and price fluctuations, revenues from organic shrimp are insecure. Organic shrimp farmers are encouraged to replant mangroves, conserve mangroves, and plant in-pond dikes for greening to cope better with climatic risks and thus reduce the household's vulnerability. As organic farming involves lower production costs, and especially lower input costs, the financial loss in case of production failure or price depression will be lower than in conventional farming. This study found out that exchange of water is a major challenge for organic shrimp production, because both organic and conventional farmers exchange water during high tide from the same river. If diseases occur in a conventional farm, it can easily spread to other farms during water exchange. Mangrove plants purify the water that is discharged from the shrimp farms and reduce pollution. Mangrove plants produce oxygen and absorb toxic substances. Organic shrimp farmers in Bangladesh fully depend on WAB Trading International to sell their produce, there is no alternative buyer. The price of organic shrimp is based on the world market but organic farming initiatives can reduce the farmers' vulnerability by guaranteeing a minimum price and fixing the organic premium in absolute terms. Adopting organic farming not only improves the household's overall income, but also it improves socioeconomic status on experience, occupation, and education in the village in the long term. Higher incomes enabled the organic farmers to invest in strengthening their livelihood base. They invested their profits by buying more land for shrimp farming or paying for a longer or a larger lease. Organic shrimp farmers can reduce their debt burden and thus their dependency on credit institutions.

Organic shrimp farming is moving from small to large (with respect to operational gher land) farmers in Bangladesh. Large farmers are in a better position to bear temporary losses, as they have the necessary resources to bridge the income gap and can rely on multiple income sources. As their basic livelihood is secured, they are more prepared to take the risk of adopting organic shrimp farming, a new innovation for which the outcome is uncertain. Large farmers consider organic shrimp farming to be a business opportunity to get higher production but small and medium farmers consider organic farming to be a strategy to improve livelihood. The small farmers' poverty was manifested in this research through their meagre holdings of financial and physical capital. We found that large farmers do not consume their produced shrimp very often and that small and medium farmers consume only defected shrimp that cannot be sold in the collection centre. In the gher, a different type of fin fish and smaller shrimp (of species different from the marketed shrimp) are also grown, which are harvested and consumed by the families of the small and medium farmers and are additionally served to guests to maintain hospitality. Small farmers sell their shrimp and buy essential goods such as rice, vegetables, and other staples. Small farmers buy small fish for their diets with the proceeds from selling their shrimp produce. Thus, if production fails, it directly impacts the daily livelihood of the small farmer. Small scale aquaculture can improve livelihoods by improving household food security and supplementing the family income of the poor (New, 2003), and it can contribute indirectly to food security by increasing purchasing power at individual or household levels (Allison, 2011). Thus, organic shrimp farming can provide opportunities for food security and poverty alleviation when implemented by rural famers.

Over the past decade, organic farming has experienced a considerable rise in most industrialized countries (Rigby et al., 2001; Kallas et al., 2010). The number of organic farms has substantially increased, accounting for 5% or more of the farms in some European countries (Willer et al., 2008). Organic shrimp can be found in supermarkets in most European cities (Hensler, 2013), however, organic shrimp is a fully export-oriented good and is not available in local markets in Bangladesh. In Bangladesh, the organic shrimp project by WAB Trading International (Asia) Ltd. has obtained organic certification for the stakeholders. Farmers can be associated with exporting organizations to establish new contacts with buyers in international markets. This research is concerned with sustainable social, economic, and environmental development practices. We see the social-economic objectives to be equity, access to livelihood resources, livelihood security, social capital, and incorporation of local management efforts into broader management plans. Environmental sustainability objectives are addressed through the use of farmers' knowledge of water and land as natural resources that can be ecologically restored and maintained in the practice of organic shrimp aquaculture.

6.2. Conclusion

During this study, I explored the potential of organic shrimp farming to improve livelihoods of farmers in Bangladesh. The results showed that organic shrimp farming can produce higher yields (320 kg ha^{-1} yr^{-1}) than conventional (266 kg ha^{-1} yr^{-1}) and integrated (196 kg ha^{-1} yr^{-1}) farming after completing a transitional period of 2−3 years. The biggest challenge is to maintain food security during conversion from conventional to organic farming. Without a doubt, yields are an important factor in farming. Nevertheless, if the diffusion of organic shrimp farming is really to improve rural livelihoods, the focus needs to shift away from yields to a broader perspective that includes sustainability of the management of the production base, economic viability of the farm operations, and livelihood security. Replacing agrochemicals with natural means and management practices has positive impacts on water, land, the environment, and human health. The practice of organic aquaculture not only decreases production costs but also reduces the risk of farming in a context of uncertain diseases and fluctuating market conditions. The results of this study show that organic farming practices contribute to improved incomes with less risk to the environment.

Organic farming seems to be a particularly suitable option for small scale farmers, who, with careful management, can achieve higher yields than they can expect from conventional farming. Small organic farmers can manage the required capital and production means to cultivate their small piece of pond. They can utilize family labor for taking care of the pond. Once production costs are reduced and income increases, organic farming can even help these farmers to invest in another pond and can open up off-farm income sources. However, conversion to organic farming is more difficult for small and medium farmers than for farmers who run large operations, as yields and incomes usually drop in the initial years, putting the fragile livelihoods of small and medium farmers at risk. Thus the challenge lies in finding solutions for small farmers to overcome the obstacles of the conversion period so that they can benefit in the long term. Appropriate extension approaches that facilitate conversion and the development of mechanisms that bridge the initial income gap are needed.

Successful extension, certification, and marketing requires a group approach which exists in the organic shrimp farming community in Bangladesh. When farmers develop emotional ownership of a group identity, the long term sustainability of the project is more likely. Organic shrimp farming is a holistic approach that relates to the societal dimensions of rural livelihoods, thus, cooperatives can create solidarity among farmers. Such a group can implement joint activities in other fields, e.g., in microcredit, community development, and off-farm income generation.

Although this research has shed some light on crucial points regarding the potential of organic shrimp farming in Bangladesh, it also opened up a range of new questions. In some aspects—such as the impact of shrimp farming, sustainability, water management, aquaculture nutrition, and the interface between farmers and project organizers—I could only touch the surface, leaving more in-depth investigations to other researchers. Thus the findings form a broad base for future investigations in different countries as a lot remains to be done to fully utilize the potential of organic farming.

6.3. Policy implications

With the potential to raise incomes, increase production, decrease input costs, improve livelihood quality, reduce vulnerability, and manage natural resources in a more sustainable manner, organic shrimp farming is in line with the development goals of many national governments and international organizations. The largest future increases in the production volume of shrimp organic aquaculture products are projected to cover a small niche in overall organic aquaculture production (Prein et al., 2012). Nevertheless, organic aquaculture has the potential to improve the livelihoods of thousands shrimp farmers in developing countries like Bangladesh. It is possible for governments, multinational companies, and development agencies to frame policies and programs in ways that better support the organic project organizers and facilitators in using this potential. The following recommendations address the constraints identified in our research and propose measures that we think would increase the success and extension of organic shrimp aquaculture.

Review of aquaculture and development policies

The Department of fisheries in Bangladesh increasingly addresses sustainability issues concerning the use of water, land, and biodiversity (DoF, 2012). But the focus is on facilitating the use of inputs (high stocking density, synthetic fertilizers and pesticides, supplementary feeding) to increase yields (Wahab et al., 2012; Ahmed, 2013). In considering the potential of organic shrimp farming, the first step must be to organize agricultural extension services; for instance, training and advice on managing cattle manure more efficiently and on preparing compost could be provided and farmers could be encouraged to depend on hatchery produced post larvae to avoid catching wild post larvae in estuaries and river channels. Policy makers should explore ways to ameliorate the decrease in shrimp production that occurs during the conversion from conventional to organic aquaculture—providing financial contributions could be one option. This opportunity should be available to individual farmers as well as cooperatives. Developing formal loan or microcredit schemes for conversion to organic farming could be another option. These two options would probably attract farmers who have opportunistic attitudes to organic farming. The agricultural extension services from the Department of Fisheries should promote organic aquaculture projects, that is, they should try to motivate farmers to adopt them.

Aquaculture research and extension

The University in Bangladesh Fisheries Research Institute (FRI), and the Department of Fisheries (DoF) could implement long term pond trials for organic aquaculture to observe the changes in water quality parameters, in inputs and outputs, and in the economic performance during and after the conversion period from conventional to organic farming. A similar study in different locations would allow an analysis of the influence of different conditions on the advantages and disadvantages of organic aquaculture. Different systems of organic farming could be compared with respect to their impact on natural resources and livelihoods. Systematic trials could help the Department of Fisheries to develop extension tools that are adapted to local conditions. The information generated could be distributed through the extension services of national and development agencies such as (BRAC, Proshika, World Fish Centre, CARE, DANIDA, Action Aid, and USAID). In addition, universities and fisheries colleges could consider including organic aquaculture in their curricula.

Market development

Currently in Bangladesh, organic shrimp initiatives can sell their produce with a price premium only to a collection centre established by WAB Trading International. Increasing the market demand for organic shrimp in industrialized countries requires that more consumers are aware of the social, environmental, and health benefits of organic shrimp production. Media coverage on conventional and organic shrimp farming and campaigns by organizations such as Greenpeace, WWF, The Pesticide Action Network, and various development cooperation agencies have contributed to sensitizing consumers to social and environmental issues related to organic aquaculture production. Further efforts are needed to maintain and increase this awareness. Producing organic shrimp can be a viable business option. Development of the organic shrimp business sector will continue to require strong commitment from processors, traders, and importers. Continued lobbying of civil society organizations is important to motivate more buyers to procure organic shrimp and thus to further increase its market volume. The domestic market for organic shrimp can be enlarged by continuous media coverage regarding the environmental and health benefits of organic shrimp aquaculture. The Bangladesh Frozen Food Exporters Association (BFFEA) can work with organic shrimp farmers to establish access to supermarket chains all over the world.

Regulatory frame and certification

The Organic Shrimp Project (OSP) and the Department of Fisheries in Bangladesh should work together to ensure traceability and quality management before shrimp are exported to international markets. A regulatory framework for organic shrimp produce is important to prevent fraudulent use of organic labeling. The Bangladesh government should develop national guidelines and standards for organic aquaculture for shrimp and fish. Certification of organic shrimp in Bangladesh is problematic because national standards for organic aquaculture are absent and farmers have to apply to foreign certification bodies. A well-functioning national guarantee system for organic farming that is in line with international norms would facilitate access to export markets. Fees for international organic certification can be an important cost driver at the project level. The Bangladesh government should consider covering these costs, at least during an initial phase, to support organic aquaculture initiatives. Establishment of local certification bodies in Bangladesh would contribute to reducing certification costs. To develop local certification bodies, the government needs to negotiate bilateral agreements with the main importing nations to acknowledge the equivalency of national organic guarantee systems.

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Appendix – I: Additional Tasks Accomplished During the PhD Study Period

A. Publications

- Paul, B.G. and Vogl, C.R. (2011) Impacts of shrimp farming in Bangladesh: challenges and alternatives. Ocean & Coastal Management 54 (3):201−211.

- Paul, B.G. and Vogl, C.R. (2012) Key performance characteristics of organic shrimp aquaculture in southwest Bangladesh. Sustainability 4(5):995−1012.

- Paul, B.G. and Vogl, C.R. (2013) Organic shrimp aquaculture for sustainable household livelihoods in Bangladesh. Ocean & Coastal Management 71:1−12.

- Paul, B.G. and Vogl, C.R. (2013) A comparison of aquaculture systems: The case of shrimp farming in southwest Bangladesh. Agroecology and Sustainable Food Systems (Under review)

B. Contribution to Conference, Symposium, Congress

- Paul, B.G., Ahmed, N. and Glaser, M. (2009) Capital Assets of Char Dwellers in Bangladesh: Opportunities and Challenges for Sustainable Livelihoods. In: Pröbstl, U. (ed.) *Book of abstract, 15th International Symposium on Society and Resource Management (ISSRM).* Symposium was held on July 5-8, Vienna, Austria, University of Natural Resources and Life Sciences (BOKU), p. 218. Available in online: http://www.nas.boku.ac.at/fileadmin/_/H93/H933/Personen/Paul_Brojo/new_10.12.2010_/ISSRM_2009_Book_of_Abstracts.pdf

- Paul, B. G., Waidbacher, H. and Vogl, C. R. (2009) Challenges and pathways of shrimp aquaculture in Bangladesh towards sustainability. 2nd European Congress of Conservation Biology (ECCB). Congress was held on September 1 - 5, Prague, Czech Republic, ISBN 978-80-213-1961-5. Book of abstract published by the Faculty of Environmental Sciences, Czech University of Life Sciences, p. 200. Available in online: http://www.eccb2009.org/uploads/book_of_abstracts_errata.pdf

- PAUL, B. G. & VOGL, C. R. (2011): Toward organic shrimp aquaculture development: Experiences from Bangladesh. Pre-conference Organic Aquaculture, pp. 371-375. 3rd ISOFAR Scientific Conference in the frame of the 17th IFOAM Organic World Congress "Organic is Life - Knowledge for Tomorrow" –Namyangiu, Republic of Korea, 26 Sep - 1 Oct.

- PAUL, B. G. & VOGL, C. R. (2011): Comparison of shrimp farming systems: Evidence from Bangladesh. In: Becker, M.; Kreye, C.; Ripken, C. and Tielkes, E. (eds.), Development on the margin, p. 358. Tropentag-2011, University of Bonn, Germany, October 5 – 7. ISBN: 978-3-86955-879-0

Appendix – II: Curriculum Vitae (CV)

Brojo Gopal Paul
PhD Candidate
Gregor Mendel Strasse 33,
A-1180, Vienna, Austria.
Phone: +43 (1) 47654 3781
Email: brojo.paul@boku.ac.at, brojogopal@gmail.com,

Personal information

Nationality: Bangladeshi

Date of Birth: January 1, 1975

Academic qualification

2009−2013	Doctoral study, University of Natural Resources and Life Sciences (BOKU), Vienna, Austria, (Supported by International Cooperation in Education and Research (OeAD−GmbH). Tentative date of graduation: December, 2013.
2004−2006	Master of Science (M.Sc.) in International Studies in Aquatic Tropical Ecology (ISATEC), University of Bremen, Germany.
2001−2002	Master of Science (M.Sc.) in Aquaculture, Bangladesh Agricultural University, Bangladesh.
1994−2001	Bachelor of Science in Fisheries (Hons.), Bangladesh Agricultural University, Bangladesh.

Manuscript for M.Sc. Degree

a) Household Livelihoods analysis of char dwellers using the capital asset framework: the case of NRSP area, Jamalpur, Bangladesh.

b) The potential of Fresh water Giant Prawn (Macrobrachium rosenbergii) culture in Muktagacha Upazila using Geographical Information Systems (GIS) as a tool.

Selected Publications

- Paul, B.G. and Vogl, C.R. (2013) Organic shrimp aquaculture for sustainable household livelihoods in Bangladesh. Ocean & Coastal Management 71:1−12.
- Paul, B.G. and Vogl, C.R. (2013) A comparison of aquaculture systems: The case of shrimp farming in southwest Bangladesh. Agroecology and Sustainable Food Systems (Under review)
- Paul, B.G. and Vogl, C.R. (2012) Key performance characteristics of organic shrimp aquaculture in southwest Bangladesh. Sustainability 4(5):995−1012.
- Paul, B.G. and Vogl, C.R. (2011) Impacts of shrimp farming in Bangladesh: challenges and alternatives. Ocean & Coastal Management 54 (3): 201-211.

- Salam M. A., Paul, B. G. and Khatun, N. A. (2007) Delineating prawn farming sites in Muktagacha Upazilla through GIS modeling techniques. Bangladesh Journal of Agricultural Sciences 34 (2): 99-107.

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- Paul, B.G., Ahmed, N. and Glaser, M. (2009) Capital Assets of Char Dwellers in Bangladesh: Opportunities and Challenges for Sustainable Livelihoods. In: Pröbstl, U. (ed.) *Book of abstract, 15th International Symposium on Society and Resource Management (ISSRM)*. Symposium was held on July 5-8, Vienna, Austria, University of Natural Resources and Life Sciences (BOKU), p. 218. Available in online: http://www.nas.boku.ac.at/fileadmin/_/H93/H933/Personen/Paul_Brojo/new_10.12.2010_/ISSRM_2009_Book_of_Abstracts.pdf

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- PAUL, B. G. & VOGL, C. R. (2011): Toward organic shrimp aquaculture development: Experiences from Bangladesh. Pre-conference Organic Aquaculture, pp. 371-375. 3rd ISOFAR Scientific Conference in the frame of the 17th IFOAM Organic World Congress "Organic is Life - Knowledge for Tomorrow" –Namyangiu, Republic of Korea, 26 Sep - 1 Oct.

- PAUL, B. G. & VOGL, C. R. (2011): Comparison of shrimp farming systems: Evidence from Bangladesh. In: Becker, M.; Kreye, C.; Ripken, C. and Tielkes, E. (eds.), Development on the margin, p. 358. Tropentag-2011, University of Bonn, Germany, October 5 – 7. ISBN: 978-3-86955-879-0

Report Preparation

1. A report on Baseline Survey with second batch participants of the FoSHoL project of Action Aid Bangladesh.
2. A report on Participatory Baseline with second batch participants of the FoSHoL project of Action Aid Bangladesh
3. A report on Participatory Monitoring of **Amon** season with first batch and second batch participants of the FoSHoL project of Action Aid Bangladesh.
4. A report on Participatory Monitoring of **Boro** season with first batch and second batch participants of the FoSHoL project of Action Aid Bangladesh.
5. A report on Institutionalization of Peoples Organization with the FoSHoL project of Action Aid Bangladesh.

Computer Familiarity

Proficient in Microsoft Office package, Access database, SPSS for windows ver 15.0, IDRISI for Windows ver 2.0, T-Soft DIGI-EDIT for Windows ver 1.5, Paint Shop Pro 5, Adobe Photoshop, Adobe Illustrator, Arc View Software, internet and web-based management.

Notable Awards / Scholarships

- **OeAD** (Österreichischer Austauschdienst) Scholarship to pursue PhD study (October, 2008 to December, 2011 & October, 2013 to December, 2013),
- **OeFG** (Oesterreichische Forschungsgemeinschaft) grant to participate in different conferences
- **DAAD** (German Academic Exchange Service) for M. Sc. Study in Germany**,** (October, 2004 to September, 2006).

Involvement of Professional Societies/Institutions

1. Society for Conservation Biology (SCB)
2. Agricultural Institution Bangladesh- General Member

Language Proficiency

English (Good), Bengali (Native) and Deutsch/German (Satisfactory)

Employment Records

Position	**Employer/Institution**	**Project/Program Focus**	**Period**
Consultant	Food Security for Sustainable Household Livelihoods (FoSHoL) Project / Action Aid Bangladesh	Qualitative and quantitative monitoring, baseline survey, data entry template design, data management, statistical analysis, report preparation, by-laws develop for farmers organization, accounts and record keeping system develop, training	February, 2007 to September, 2008
Internship for M Sc field research	Natural Resource System Project (NRSP) / Practical Action / ITDG	Livelihoods, questionnaire, field survey, FGD, social and resource mapping, Venn diagram, mobility chart, seasonal activity calendar and wealth ranking.	October, 2005 to March, 2006
Training Officer	Patuakhali Barguna Aquaculture Extension Project (PBAEP) / Community Development Centre(CODEC) / DANIDA	Training, extension, capacity development, livelihoods, staff supervision, financial management, reporting, coordination, project management, fisheries & aquaculture	October, 2003 to May, 2004
Project Manager	Mymensingh Aquaculture Extension Project (MAEP) / Unnayan Sangha (US) / DANIDA	Capacity development, aquaculture, training, PME, extension, livelihoods, coordination, staff supervision, credit and financial management, reporting	August, 2002 to October, 2003

Professional Training/Workshop (As Participants)

Course Title	Organized by
Training on infomediary capacity building and mobilization	UNDP Bangladesh and Bangladesh Telecentre Network (BTN)
Corruption a worldwide phenomenon (Causes-Backgrounds- Impacts)	STUBE Nord, East and DAAD Bonn Germany
Cross cultural understanding-Learning about what we have in common- and the differences	STUBE/DAAD (Germany)
Basic training on Technology Transfer of rice prawn and catfish culture	PBAEP/DANIDA
Training of Trainers (ToT) on fish production in pond of NGO and DTA staffs	MAEP/DANIDA
Land reform and asset mobilize with social mobilization for poverty alleviation	Intermediate Technology Development Group (ITDG)
The use of Geographical Information System (GIS) in Fisheries Monitoring and Management	Environment and Geographical Information System (EGIS)
Administration, Office Management and Communication	GTI, BAU, Mymensingh
Training of Trainers (ToT)	GTI, BAU, Mymensingh

Professional Training/Workshop (As Facilitator)

- Organized and facilitated workshop on baseline data collection, by-laws development, executive committee formation, accounts and records keeping process for farmer’s organization.
- Facilitated workshop on strategy development of phase-out organizations.
- Facilitated workshop on experience sharing on handover ceremony of 1st cycle organization development and develop participatory action plan for 1st batch organizations to form alliance.
- Facilitated workshop on inter organization coordination meetings and inter organizations subcommittee meetings to build potential linkages and networks for better understandings.
- Facilitated workshop on role of DANIDA-MAEP in socio-economic development and poverty reduction through micro credit and aquaculture activities.
- Organized and facilitated training on transfer of technology of rice prawn, catfish culture and fin fish aquaculture development and extension