4 Evolution of Shrimp Aquaculture Systems in the Coastal Zones of Bangladesh and Vietnam: a Comparison

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Abstract

Based on on-farm surveys implemented in the Ganges Delta in Bangladesh and the Mekong Delta in Vietnam, the dynamics of shrimp aquaculture in salinity-influenced coastal areas were analysed. Qualitative data were collected through interviewing both individual and group farmers in 2005 and 2006, as well as key informants and value chain stakeholders, to obtain an overview of the dynamics of salinity-influenced aquaculture in these two deltas. The first phase of the coastal area's agroeconomic evolution is related to the policy and infrastructure in the course of agroeconomic transformation. A second phase is characterized by the spread of shrimp aquaculture (in successive levels of technology), causing these coastal zones to become areas of strategic export product generation. Different factors such as government policy, demography and international market demand drove this evolution in both deltas. In a third phase, the risk associated with shrimp farming because of shrimp virus outbreaks led farmers to diversify or intensify the aquaculture farming system. The evolution of shrimp farming systems in both deltas has been toward greater diversification of aquaculture technologies and is dependent on both natural environmental factors such as saltwater period duration and soil quality, technical factors such as access to drainage and socio-economic factors such as investment capacity and market demand. Comparing the coastal area of Bangladesh and the Mekong Delta in Vietnam, the key factors identified were land ownership, access to knowledge for the improvement of shrimp culture technology and diversification of aquaculture production. The alternating rice–shrimp system (i.e. rice in the rainy season, followed by shrimp in the dry season) and diversified brackishwater polyculture show more stable economic returns in comparison to extensive and intensive shrimp monoculture in both areas. In Bangladesh, water management infrastructure, access to information and the development of information networks were highlighted as key factors necessary for the improvement of brackishwater aquaculture. In Vietnam, the higher level of technology used in coastal aquaculture underlined the need for the development of better management practices to reduce the environmental burden and to evolve towards sustainable production systems.

Introduction

Coastal areas include flood plains, mangroves, marshes, swamps, tidal flats and many large and small rivers, canals and creeks. These areas act as a buffer zone between land and sea, with a seasonally affected and variable environment. Coastal areas are under constant change, following different driving forces such as demography,

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national and international market demands or government planning.

In the Vietnamese Mekong Delta, 1.7–2 million ha are affected annually by salt water, whereas about 1 million ha are affected along the coast of Bangladesh. The land use and colonization of the Mekong Delta and the Ganges Delta evolved differently during the 19th and 20th centuries: from wasteland to rice-based agriculture and subsequently to today's widespread adoption of shrimp farming. Since the last two decades of the 20th century, coastal areas have undergone major changes with the development of shrimp culture. The development of the shrimp industry has transformed the economy of the coastal areas dramatically, as well as the foreign exchange earnings of both Bangladesh and Vietnam. However, since the late 1980s, the spread of disease outbreaks in many of the producing countries in Asia has affected shrimp production and the survival of operations seriously, with a high turnover of ownership and a high risk for all stakeholders in the value chain. Hence, the question arises: what are the actual dynamics of aquaculture production systems in these areas and how do farmers cope with outbreaks of shrimp diseases and environmental changes such as saltwater intrusion?

Given the widespread adoption of shrimp farming in the coastal rice and non-rice cropping areas of South-east Asia in general, and in numerous river deltas in particular, the purpose of this study is to compare and contrast the developments in the Ganges and Mekong deltas. These two cases of salinity-influenced areas were studied to highlight the main factors that fuelled their dynamics and the evolution of human intervention, and to understand how farmers coped with various constraints (e.g. soil quality, variability in salinity, diseases, market forces, infrastructure investment, knowledge availability, access to capital and social conflict). The chapter presents an analysis of the evolution of aquaculture and agriculture production systems in salinity-influenced areas in each delta, and the different options for farmers to develop and evolve these production systems in such variable and diversified environments.

Study Sites and Methodology

Study sites

The climate in Bac Lieu Province located on the Ca Mau peninsula of the Mekong Delta is tropically monsoonal, with a distinct dry season from mid-November to April and a rainy season from May to mid-November. Acid sulfate soils characterize the western part of the province and occupy 60% of the area, mostly in the lowlands (Breemen and van Pons, 1978). In the eastern part, alluvial and saline soils are dominant (Ve, 1988). Bac Lieu Province is part of the saline protected area in the coastal area. A series of sluice gates along the main canals regulate saline intrusion in the dry season and create a gradient of salinity from the eastern to the western part of the province. The different survey sites were chosen in consideration of the duration of the freshwater period (more than 6 months, less than 6 months and no freshwater period) and soil quality (saline soil and acid sulfate soil).

In Bangladesh, Paikgacha Subdistrict is located in Khulna District, in the south-western coastal area of Bangladesh. Two main seasons divide the cropping calendar: a dry season from December to mid-March and a wet season from April to November. Salinity intrusion occurs from January to June, limiting the main season for shrimp farming to 5 or 6 months.

Qualitative semi-structured interviews were conducted with farmer groups on a farmer's personal situation, on household socio-economics, farm management, production costs and yields, historical aspects, constraints and access to the means of production and to knowledge. The surveys were conducted over 3 weeks in each region between November 2005 and February 2006. We used a randomized survey of 95 shrimp farms in Vietnam (n = 74, Bac Lieu Province) and Bangladesh (n = 21, Khulna District, Paikgacha Subdistrict). The number of shrimp farms surveyed in Vietnam was higher because of the more diversified agroecological environments and the more diversified salinity-influenced aquaculture systems than in Bangladesh. In both study sites, part of the shrimp industry value chain was investigated by interviewing different stakeholders in the value chain, such as shrimp postlarvae nurseries, shrimp traders and middlemen, shrimp buyers, input suppliers and shop owners. The entire value chain was not investigated because of the absence of nursery and processing factories in the survey site in Paikgacha Subdistrict or the non-access to private hatcheries and processing factories in Bac Lieu Province. We focused only on stakeholders directly connected with producers. The participatory approach used in this study was related to that described by Bammann (2007), with key informant interviews and focus group discussions. This value chain analysis focused on the institutional arrangements that linked producers, input retailers and traders. The present study covers the value chain up to the production stage, excluding later steps such as processing and value-addition industries.

The economic net return of the farms was calculated by using the farm's gross return minus farm operating costs. The operating costs included the different inputs, shrimp 'seed' and labour. Investment costs included pond modification and the equipment required (lift pump, nets, feeding trays, etc.).

Coastal Area Development

From wasteland to rice culture

Development in both deltas underwent contrasting evolutionary steps, facilitated by different driving factors such as government policy or national and international market demand. Government policy, although following different respective frameworks, promoted the colonization of the land in the Mekong and Ganges deltas. In Bangladesh, the colonial government policy created an institutional basis for land clearance, peace, order and guaranteed ownership, which encouraged settlement in the 19th century (Richards and Flint, 1990). Whereas in Vietnam, the progression of settlements and the development of rice-based aquaculture followed the dredging of canal networks that were started under the Nguyen dynasty in the 19th century and were continued by the French administration (Catling, 1992; Biggs, 2004). The demand for goods and services by cities such as Calcutta (now called Kolkata) in the Gangetic delta or Saigon (now called Ho Chi Minh city) in South Vietnam developed a market for food grains, timber and fuelwood. From the subsistence agriculture of the first pioneers, deltas rapidly became an export product-generating area (Richards and Flint, 1990; Biggs, 2004). The development of agriculture was not spatially homogeneous in either of these regions. Previously unused marginal wasteland was available and farmers who wanted to develop rice-based agriculture sought the most suitable areas, protected against floods and saltwater intrusion (Russier and Brenier, 1911; Eaton, 1990). Population density and rice culture development was vastly different in the Mekong Delta in comparison to other areas of Vietnam. At the beginning of the 20th century, rice fields covered 60–80% of the total area in the eastern part of the delta in provinces not affected by saltwater intrusion, whereas they covered only 10% in the western part, namely in the Ca Mau (including actual Ca Mau, Kien Giang, Soc Trang and Bac Lieu Provinces) and Ha Tien Provinces, as these areas were affected by saline intrusion (Russier and Brenier, 1911). This dissimilarity of livelihood activity and corresponding population density was still present in the 1980s, with an average of 450 people/km^2 (or 0.22 ha/capita) across the whole delta, whereas Ca Mau and Kien Giang Provinces, under the influence of saline intrusion, had lower densities with less than 200 people/km^2 (or 0.5 ha/capita available land) (Xuan and Matsui, 1998).

In Bangladesh, the delimitation of a protected area for the Sundarbans forest had restricted the space available for colonization and new settlement since 1920 (Richards and Flint, 1990). With the closure of the Sundarbans settlement frontier, agricultural expansion could no longer rely on seemingly limitless wastelands to transform. From 1880 to 1980, the available land per capita dropped from 0.22 to 0.08 ha (Richards and Flint, 1990), equivalent to an increase in population density from 450 to 1250 people/km^2 for the total land area.

After 1940, the main policy of Bangladesh's central government was to increase rice production, even on marginal lands. A new process of agricultural intensification began because of demographic pressure and technical innovation with the introduction of high-yielding rice varieties (HYV) and irrigation (Pingali *et al*., 1997). In the coastal areas, rice intensification was constrained by salinity intrusion during the dry season. The traditional farming system was a rainfed rice crop in the rainy season followed by a traditional brackishwater aquaculture crop in the dry season, in which wild fish juveniles and crustacean larvae were trapped in ponds and were reared without feeding. In Bangladesh, oil crops (mainly sesame) were also grown during the dry season. In both Bangladesh and Vietnam, the governments planned to increase rice culture to two crops per year by protecting rice land against saltwater intrusion and closing off parts of the delta. In Bangladesh, the coastal embankment project started in 1968, which created 123 polders to enhance crop agriculture productivity in the coastal zone by preventing saline intrusion (PDO-ICZMP, 2005). Between 1990 and 2000, the Vietnamese government planned and constructed new water control infrastructures (sluice gates, embankments) in the saline intrusion area in order to intensify rice cropping (Hoanh *et al*., 2003). In the case of Bac Lieu Province, the salinity control infrastructure induced land use and livelihood change from 1994 until 2000 (Hossain *et al*., 2006).

For both countries, the purpose of the infrastructure investments in these areas was to intensify rice culture in order to increase food security (notably rice). Central governments considered brackish water as a constraint and the improvement of traditional brackishwater aquaculture at that time was not regarded as an alternative for the development of the coastal area, although the expansion of the traditional shrimp farming practice under the farmers' own initiative continued. In Bangladesh, private investors from the cities also strongly influenced the development of shrimp aquaculture in coastal areas.

From rice culture to shrimp culture

The spread of shrimp farming occurred in Bangladesh in the early 1980s, followed later by the Mekong Delta in the late 1980s. The development of shrimp culture was driven by an attractive market price and high international demand. The supply of shrimp larvae was, at the beginning, supported mainly by wild catch carried out by coastal communities (mainly children and women) (PDO-ICZMP, 2003a). Hatchery technology for growing giant tiger shrimp (*Penaeus monodon*), which grew considerably larger than the wild species of shrimp, as well as specific feeds and other inputs became available. In a few years, shrimp culture developed exponentially. In Bangladesh, the area dedicated to shrimp farming spread from 51,812 ha in 1983–1984 (DoF, 1986) to 203,071 ha in 2003–2004 (DoF, 2005), with the number of shrimp farms reported by Deb (1998) and Nuruzzaman and Maniruzzaman (2003) increasing from 7578 to 40,000 from 1989 to 2003.

The shrimp culture area in the Mekong Delta grew from 89,605 ha in 1991 to 429,114 ha in 2003 and contributed to 83% of the total exported shrimp value of the country (Vo, 2003). From rice-oriented agriculture, the coastal area of the Mekong Delta became the largest area of saltwater aquaculture in Vietnam.

In these deltas, extensive shrimp farming and rice–shrimp systems were the most common practices. Hatchery reared *P. monodon* postlarvae progressively replaced the traditional system that was based on wild shrimp larvae of a variety of smaller species being trapped when filling ponds or caught with specific netting techniques. In the Mekong Delta, semi-intensive and intensive systems appeared, loaded with technology and financed by private investors (Table 4.1). These intensive monoculture systems remain controversial because of the level of investment and knowledge required. However, much of the growth in production can be attributed to area expansion rather than intensification. In the case of Bac Lieu Province, the shrimp farming area increased from 45,748 ha to 116,428 ha from 2000 to 2005 (source: Department of Agriculture and Rural Development of Bac Lieu), of which 9% accounted for semi-intensive and intensive shrimp farms. Extensive systems in shrimp monoculture, alternating with rice cropping, or integrated concurrent culture of shrimp in mangroves, were adaptations of the traditional systems, characterized by low-input technology, but also low yield. Farmers used fertilizers

Table 4.1. Characteristics of the different shrimp production systems in the Ganges and Mekong deltas before the spread of viral diseases.

Farming pattern	Monoculture			Alternate culture	Integrated culture[a]
System type	Extensive	Semi-intensive	Intensive	Rice–shrimp	Mangrove–shrimp
Pond size (ha)	1–40	1–2	< 1	1–5	1.1–16
Mean stocking rate (ind/m^2)	1–3	5–15	15–40	1–3	0.1–2.9
Input use	Lime, fertilizer	Feed pellets, water treatment	Feed pellets, water treatment	Lime, fertilizer	–
Mean yield (kg/ha)	200–300	100–2000	> 2000	200–300	146–686
Location	Mekong and Ganges	Mekong	Mekong	Mekong and Ganges	Mekong

[a]From Binh *et al.* (1997).

and limestone to improve plankton growth that served as natural food for shrimp and constituted the main portion of the shrimp's diet, supplemented with homemade feed and trash fish to improve the yield (Brennan *et al.*, 2000; Hossain *et al.*, 2004).

The rapid and high profits earned from shrimp farming resulted in a high demand for land in the salinity-affected area. Thus, in a short time period, the transformation of the land use pattern and wide diffusion of shrimp farming driven by an attractive market had several side effects. In Bangladesh, widespread land tenure conflicts appeared with the development of large extensive shrimp farms. Large-scale but absentee farmers coerced small farmers to lease their rice land to culture shrimp (Gupta, 1997; Alauddin and Tisdell, 1998; Karim and Stellwagen, 1998). Through land reform in Vietnam, farmers were issued a land certificate, but this did not permit the development of shrimp farms. Instead, shrimp farm settlement took place in the mangrove areas. The spread of shrimp culture induced a new surge of mangrove clearing in the Mekong Delta (Luttrell, 2006). The area of mangrove forest in the Mekong Delta declined from 117,745 ha in 1983 to 51,492 ha in 1995 (Hong and San, 1993; Phuong and Hai, 1998, in Johnston *et al.*, 2000). Integrated mangrove–shrimp farming systems were established in the form of state forestry–fishery enterprises to reduce deforestation. The status of the Sundarbans mangrove forest in the Ganges Delta protected the forest from massive clearing for shrimp farm settlement, so that integrated mangrove–shrimp farming systems were not developed (Hoq, 2006).

From an initial agricultural constraint to rice-based production, salinity became the enabling factor for shrimp production and the relatively prosperous development of these regions. The attractive business of shrimp culture induced further private investment and new settlement in the mangrove forest areas and on fallow lands (lowland, acid sulfate soil areas) where agriculture was not suitable. Coastal areas, previously the less developed areas in deltas with low rice yield and slow progress in technological development of salinity tolerant HYV, became the most productive areas in terms of income to farmers and revenue to the government, amounting to US$319 millions and US$199 millions for Vietnam and Bangladesh, respectively, in 2000 (FAO, 2003), because of shrimp farming.

Comparison of Different Production Systems

Since the middle of the 1990s, different viral disease outbreaks in shrimp occurred and spread around coastal areas throughout South-east

Asia, causing the shrimp culture business to suffer considerable losses (Flegel, 2006).

In the Mekong Delta, for the period of 1994–1999, only 20–30% of the farms were successful in shrimp farming (Vo, 2003). In the 1994/95 culture season, a disease outbreak in the southern province affected 85,000 ha of shrimp, equivalent to a loss of 294 billion Vietnamese Dong (VND) (MOFI, 1996).

In 1996, shrimp viruses affected 90% of the shrimp farms in the south-western coastal area of Bangladesh, reducing national shrimp production by 20% (Chowdhury and Muniruzzaman, 2003). In the 1997/98 culture season, the total amount of shrimp exported dropped from 25,742 t to 18,630 t after a white spot disease outbreak. Then in 1999–2000, shrimp exportation increased to 28,514 t after a year without severe disease outbreak (DoF, 2002). In 2001, shrimp production fell by 25% compared to the previous years because of white spot disease associated with other viral and bacterial pathogens (Alam *et al.*, 2007a).

Farmers developed different strategies to reduce the economic risk of virus outbreaks, dependent on several factors such as duration of the saltwater period, investment capacity and socio-economic factors (access to knowledge, access to markets or access to production resources such as land, equipment, inputs, etc.).

Stocking strategy

After several crop losses, farmers reduced the level of inputs and changed their shrimp stocking techniques to stocking earlier in the year (before the dry season) to benefit from lower prices of shrimp postlarvae (PL) for the stocking of ponds before the peak stocking period. In addition, instead of stocking every 3 months, farmers switched to a multiple stocking strategy (stocking every month), in which the stocking density varied from 1.5 to 3 PL/m^2, with an average yield of 242 kg/ha/season in Bangladesh and 172 kg/ha/season in the Mekong Delta. In Bangladesh, this evolution is specific to the large shrimp farms (> 6 ha) often run by entrepreneurial farm operators employing several seasonal workers.

Intensification strategy

An intensification strategy was adopted by farmers who specialized in aquaculture production. This involved a higher level of inputs, equipment and knowledge. However, semi-intensive and intensive shrimp farming depends on access to knowledge, to salt water and to investment capacity (Table 4.2). Intensive and semi-intensive shrimp farming require direct access to salt water and to drainage facilities. These techniques also require access to market for inputs and a high level of knowledge and competence on the side of the operators to manage the shrimp ponds successfully. Labour costs are higher for maintenance and guarding of ponds, and also require hired workers on a year-round basis. In addition, management, aeration and water quality monitoring require more equipment. In the Mekong Delta, 83% of the farmers interviewed using semi-intensive (6) and intensive techniques (6) claimed that intensification of their production was facilitated by the presence of a well-developed value chain, thus improving access to inputs and knowledge.

In the south-western coastal area of Bangladesh, intensification of shrimp production has not yet taken place on a large or even medium scale, with only a few farmers stocking postlarvae at a relatively high density (20 PL/m^2). Farmers' lack of access to loans, the lack of advanced technical knowledge, together with an underdeveloped value chain for access to inputs (shrimp feed, water treatment, etc.) act as a constraint on the sector's progress.

With the development of national and international fish markets, farmers tried to diversify their production with the monoculture of high-value fish in semi-intensive or intensive culture in the Mekong Delta. Elongated goby (*Pseudapocryptes elongatus*), sea bass (*Lates calcarifer*) and lately the 'marble goby', also named sand goby or marbled sleeper (*Oxyeleotris marmorata*), are being raised in homestead ponds (0.1–0.2 ha) at various densities (from 0.2 to 15 individuals/m^2) and fed with trash fish or commercial pellets. Recently, attractive prices have resulted in a surge towards the development of fish monocultures in partial replacement of shrimp culture. National market prices are around US$2.6/kg for sea bass and

Table 4.2. Characteristics of the evolution of shrimp farming from extensive over semi-intensive to intensive aquaculture systems in the Ganges and Mekong deltas (found in this survey, 2005/2006).

Item	Extensive shrimp (*n* = 16)	Semi-intensive shrimp (*n* = 8)	Intensive shrimp (*n* = 6)
Labour (man-day/ ha/year)	28–180 *x* = 73	170–291 *x* = 213	327–466 *x* = 402
Level of equipment required	Low	Moderate	High
Saline water duration required	6 months	6 months	6 months
Drainage infrastructure and direct access to water	Preferable	Needed	Essential
Pond area requirement (ha)	Medium to large (2–10 ha)	Small (1–2 ha)	Small (< 1 ha)
Direct access to input markets	Not necessary	Necessary	Essential
Stocking density (ind/m^2)	1.5–3.0 *x* = 2.1	5.0–15 *x* = 9.7	15–40 *x* = 28.3
Yield (kg/ha)	VN: 60–400 *x* = 172 (*n* = 10) BD: 10–380 *x* = 242 (*n* = 6)	VN: 200–2299 *x* = 1245 (*n* = 5) BD: 49–2067) *x* = 1058 (*n* = 2)	VN: 300–8000 *x* = 5460 (*n* = 5) BD: n.a.
Knowledge requirement	Low	Moderate to high	Very high
Location	Mekong and Ganges	Mekong and Ganges	Mekong

Values are range, *x*, mean; BD, Bangladesh; VN, Vietnam; n.a., not applicable. Yield range and mean were computed using results from farms without massive mortality due to disease outbreak.

US$3.0/kg for elongated goby, whereas in international markets accessed through export, the price of marble goby has reached US$23.3/kg. However, results were not satisfactory for the farmers because of a longer growth period for sea bass to reach market size (10 months) or high mortality for elongated goby. In the case of marble goby, the introduction of this culture technology in saline-affected areas is too recent to permit any conclusion. However, the emergence and rapid spread of such systems is representative of a dynamic and vibrant aquaculture production environment in which farmers are now seeking niche markets and experimenting with new techniques and species.

Diversification strategy

Diversification of the production system is defined here as the number of different kinds of enterprises on the farm, which include both agriculture (rice) and aquaculture products (shrimp, fish and mud crab). There are different options for diversification of aquaculture production (Table 4.3) in the form of either brackishwater polyculture or alternating rice–shrimp systems. The choice between these two main kinds of production system depends on the duration of freshwater availability during and after the rainy season.

When the freshwater period exceeds 6 months, farmers located on higher land with access to drainage can implement the alternating rice–shrimp system. The level of shrimp yield ranges between 73 kg/ha and 294 kg/ha, with a shorter shrimp culture period (only in the dry season) than in the extensive system. The next evolutionary step of this system is the integration of the aquaculture component during the rice crop in the form of a concurrent rice–fish system. Fish species such as Nile tilapia (*Oreochromis niloticus*), carps (various species) or crustaceans such as the giant freshwater prawn (*Macrobrachium rosenbergii*) stocked at

Table 4.3. Characteristics of evolution of shrimp farming from extensive shrimp farming to rice–fish–freshwater prawn/brackishwater shrimp culture in the Ganges and Mekong deltas (found in this survey, 2005/2006).

Rainy season / Dry season	Extensive shrimp (year-round) (*n* = 16)	Extensive shrimp and extensive mud crabs (year-round) (*n* = 26)	Extensive shrimp and extensive mud crabs and fish[a] (*n* = 10)	Rice / shrimp (*n* = 21)	Rice + aquaculture[b] / shrimp[c] (*n* = 8)
Labour (man-day/ ha/year)	28–180 *x* = 73	28–58 *x* = 43	28–60 *x* = 43	35–152 *x* = 98	35–152 *x* = 113
Level of equipment required	Low	Low	Low	Low	Low
Saline water duration required	6 months	6 months	6 months	Salinity < 4 ppt during 6 months	Salinity < 4 ppt during 6 months
Drainage infrastructure and direct access to water	Preferable	Preferable	Preferable	Preferable	Needed
Pond area requirement (ha)	Medium (> 2 ha)	Medium (> 2 ha)	Medium (> 2 ha)	Small to medium (1–2 ha)	Small to medium (1–2 ha)
Access to markets	–	–	Preferable for fish output		Preferable for prawn seeds and fish output
Stocking density (ind/m^2)	1.5–3	Shrimp: 0.50–2.90 *x* = 1.87 Mcrab: 0.01–0.05 *x* = 37	Gcarp: 0.05–0.60 *x* = 0.17 Sbass: 0.003–0. 03 *x* = 0.02 Egoby: 0.26–1.92 *x* = 0.61 Scat: 0.07–0.25 *x* = 17	Shrimp: 0.80–4. 81 *x* = 2.47	Tilapia: 0.10–0. 16 *x* = 0.13 Prawn: 0.15–0.50 *x* = 0.33 Ccarp: 0.09– 0.2 *x* = 0.15
Yield (kg/ha)	VN: 60–400 *x* = 172 BD: 10–380 *x* = 242	Shrimp 126–444 *x* = 271 (*n* = 21)[d] Mcrab: 25–83 *x* = 53 (*n* = 18)[d]	Gcarp: 219–222 *x* = 220 Sbass: 40–125 *x* = 82 Egoby: 12–106 *x* = 65 Scat: 50–150 *x* = 102	VN: 130–294 *x* = 205 BD: 73–268 *x* = 160	VN: Prawn: 45–60 *x* = 52 Tilapia: 88–112 *x* = 99 BD: Tilapia: 200–285 *x* = 232 Prawn: 50–60 *x* = 54 Ccarp: 300–369 *x* = 334

Continued

Table 4.3. Continued.

Rainy season / Dry season	Extensive shrimp (year-round) (*n* = 16)	Extensive shrimp and extensive mud crabs (year-round) (*n* = 26)	Extensive shrimp and extensive mud crabs and fish[a] (*n* = 10)	Rice / shrimp (*n* = 21)	Rice + aquaculture[b] / shrimp[c] (*n* = 8)
Knowledge requirement	Low	Low	Moderate	Moderate	Moderate
Location	Mekong and Ganges	Mekong	Mekong	Mekong and Ganges	Mekong and Ganges

[a]Yield and stocking density data for shrimp and mud crab are similar to extensive shrimp + extensive mud crab system, Gcarp and Egoby only in rainy season, other fish mentioned are raised all year round; [b]aquaculture = in rainy season, concurrent culture of paddy rice with various fish and crustacean species; [c]yield and stocking density data for shrimp are similar as alternate rice/brackishwater shrimp system; [d]yield range and mean were computed using results from farms without massive mortality due to disease outbreak or mortality. Abbreviations: BD, Bangladesh; VN, Vietnam; Shrimp, giant black tiger shrimp (*Penaeus monodon*); Mcrab, mud crab (*Scylla* spp.); Egoby, elongated goby (*Pseudapocryptes elongatus*); Scat, spotted scat (*Scatophagus argus*); Prawn, giant freshwater prawn (*Macrobrachium rosenbergii*); Tilapia, Nile tilapia (*Oreochromis niloticus*); Sbass, sea bass (*Lates calcarifer*); Ccarp, common carp (*Cyprinus carpio*); Gcarp, grass carp (*Ctenopharyngodon idella*).

low density in irrigated or flood-controlled rice fields (Table 4.3) produce average yields ranging from 88 kg/ha to 369 kg/ha, depending on the species and the stocking density. In the case of the giant freshwater prawn, the adoption of this species depends mainly on knowledge and the availability of postlarvae or juveniles on the market. Freshwater prawn production was recorded at low levels (45–60 kg/ha) both in Bangladesh and Vietnam, because of low stocking density and relatively short growing periods (5–6 months). The abundance of wild fish species (snakehead *Channa* sp., catfish *Clarias* sp., climbing perch *Anabas testudineus*, Mozambique tilapia *Oreochromis mossambicus*, etc.) trapped in relatively small ponds or rice fields together with low market prices for some of these fish, are not enough to convince farmers towards wider adoption of concurrent rice–fish culture in both countries, with average yields of only 60–80 kg/ha of these and other wild fish species. In addition, in Bangladesh, the land tenure system (where leasing contracts for rice fields do not allow the digging of refuges for fish) is also constraining the development of such a farming system.

In the Mekong Delta, in areas with longer periods of saltwater intrusion (more than 6 months) or with severe soil constraints (acid sulfate soils), diversification of production is oriented towards extensive polyculture of *P. monodon*, mud crab (*Scylla* sp.) and fish (sea bass, spotted scat, elongated goby and grass carp). The choice of species for diversification depends on the salinity period, knowledge level of the farmer, availability of postlarvae for stocking and the farmer's investment capacity. In some cases, farmers stock certain fish species at low density (0.003 ind/m^2 to 0.05 ind/m^2) with the intention of serving a sanitary function, namely cleaning the pond bottom (e.g. grass carps – the response of 8% of those interviewed) or to control virus outbreaks by eliminating weak shrimp using predatory fish (e.g. sea bass – the response of 6% of those interviewed). Some Asian shrimp farmers also claim that tilapia markedly inhibit outbreaks of shrimp diseases when stocked together with shrimp in ponds (5% of those interviewed). Most of these statements are the result of the work of the extension services.

Shrimp production (126–444 kg/ha) is within the same range of the extensive system (69–400 kg/ha). Mud crab (25–83 kg/ha) and elongated goby (12–106 kg/ha) production also appear to be highly variable in comparison to other types of fish production, particularly as a result of high mortality.

The different shrimp production systems described in the Mekong and Ganges deltas cover a wide range of economic investment and operational costs (Table 4.4). In terms of start-up investment, semi-intensive and intensive systems can be separated from other systems based on the low level of technology and investment, such as in extensive or rice–shrimp systems. Intensification of shrimp production requires investments that are 6–12 times higher than in extensive systems, principally for pond construction and essential equipment. However, in Bangladesh, the semi-intensive system observed uses a lower level of technology (no paddlewheel aerators, no night lights surrounding the ponds, fewer lift pumps for water management installed per hectare, etc.) than in the Mekong Delta. In the Ganges Delta, the operational cost of the semi-intensive system is 7.4 times higher than the extensive system. In the Mekong Delta, the operational costs of the semi-intensive and intensive systems are 20 and 41 times higher than the extensive systems, respectively. The allocation of the cost is also different, with feed representing 60–80% of the operational cost respectively in semi-intensive and intensive systems, whereas the main costs of extensive systems are for shrimp postlarvae. However, even loaded with technology, intensive and semi-intensive systems present a high economic risk, with crucial investments (that have to be implemented and then operated correctly, requiring expertise) and also a 20–30% risk of disease outbreak in the intensive system and a 50–60% risk of disease outbreak in the semi-intensive system, as has been recorded in the Mekong Delta. These results reflect the differences between shrimp production systems, in terms of risk (disease outbreak occurrence) and investment, despite the sample size.

Comparing operational costs between extensive farms in the Ganges and Mekong deltas reveals a higher cost for labour and postlarvae in the south-western coast of Bangladesh. *Penaeus monodon* postlarvae cost US$1.30–2.60/1000 PL in the Mekong Delta compared to US$5.30–9.20/1000 PL in the south-western coast of Bangladesh. In addition, the extensive system in Bangladesh employs more hired labour (28 man-days/ha in Vietnam versus 80 man-days/ha in Bangladesh), including farm operators and several workers.

In addition, these extensive farms rely on larvae of wild shrimp species trapped in the ponds during initial filling and top-up of salt water at high tides (Islam *et al*., 2005; Alam *et al*., 2007a). However, this low-cost sourcing of shrimp larvae (which are often already carriers of pathogens) comes with the associated

Table 4.4. Investment and operational cost of the different shrimp production systems in the Mekong and Ganges deltas from surveys in 2005–2006, in US$/ha (mean and standard deviation of the mean).

Item	Investment (US$/ha)	Operational cost (US$/ha)
Extensive shrimp		
Ganges Delta (*n* = 6)	338 ± 94	562 ± 131
Mekong Delta (*n* = 10)	279 ± 116	287 ± 206
Semi-intensive shrimp		
Ganges Delta (*n* = 2)	581 ± 97	4154
Mekong Delta (*n* = 6)	1834 ± 1174	5339 ± 2838
Intensive shrimp		
Mekong Delta (*n* = 6)	3564 ± 1267	11,880 ± 8324
Shrimp–mud crab		
Mekong Delta (*n* = 26)	289 ± 108	429 ± 264
Shrimp–mud crab–fish		
Mekong Delta (*n* = 10)	289 ± 72	528 ± 132
Rice–Shrimp		
Ganges Delta (*n* = 9)	338 ± 74	623 ± 169
Mekong Delta (*n* = 12)	334 ± 44	485 ± 158
Rice–aquaculture/shrimp		
Ganges Delta (*n* = 4)	462 ± 31	930 ± 472
Mekong Delta (*n* = 4)	384 ± 61	528 ± 231

high level of disease outbreaks and low survival rate of *P. monodon* (Milstein *et al.*, 2005; Alam *et al.*, 2007a). Other extensive systems with brackishwater polyculture do not improve the stability of the farm economy, where 66–75% of the farms record at least one disease outbreak during the shrimp crop. In addition, culture operations of mud crab and high-value fish such as elongated goby are considered to be risky activities, with several cases of mass mortality.

The most economically stable production systems in both study sites were the systems based on the alternating rice–shrimp farming system. In some cases, these incorporated the additional integration of an aquaculture activity (e.g. freshwater prawn, Nile tilapia or various carp species) during the rice crop in the rainy season. The otherwise high risk of disease outbreak in shrimp production was reduced to 28% by seasonal rotation of rice and aquaculture production in the Mekong Delta. The integration of an aquaculture component in the rice field required a higher cost in Bangladesh, with necessary modification of the field, such as the raising of bunds and the excavation of refuges for fish or crustaceans, whereas in Vietnam farmers had already transformed their fields when they initially started shrimp cultivation. This difference explains the higher investment required in Bangladesh for the rice–shrimp farming system.

The production results of all the systems based on shrimp farming vary widely because of disease outbreaks. We have seen that intensification of production increases the risk of bankruptcy because of considerable levels of required investments when compared to extensive systems. The risks associated with shrimp farming drive farmers to secure farm incomes by diversifying their production with high-value fish or other crustaceans. In the 2007 survey in Vietnam, we observed that in areas with periods of freshwater lasting longer than 6 months, the rice–shrimp system was more profitable and the occurrence of disease outbreaks seemed to be lower.

Diversification of production can be progressive and species stocked in ponds evolve according to market demands. These production systems are less restrictive than intensification processes, with lower investment cost, lower labour cost and less knowledge requirement.

Factors affecting the evolution of shrimp production systems

The evolution of coastal aquaculture depends on different socio-economic and environmental factors. The Mekong and Ganges deltas have followed different pathways in adopting shrimp farming. Besides the technical aspects, several keys factors influence the evolution of coastal aquaculture in these two specific areas.

Development of the shrimp value chain

The survey included not only study grow-out ponds but also a part of the shrimp value chain, with interviews of postlarvae nursery operators, shrimp buyers and traders and input retailers (Table 4.5). It revealed the notable differences of *P. monodon* postlarvae supply markets, which were US$1.30–2.60/1000 PL in the Mekong Delta compared to US$5.30–9.20/1000 PL in the Ganges Delta. The higher price of postlarvae in Bangladesh could be explained by several factors such as transport and less competitive larvae supply markets. The south-western coast of Bangladesh can be considered as a ‘grow out’ area, with almost all the postlarvae produced in hatcheries located along the south-eastern coast and these have to be transported to the south-western coast, where 70% of the Bangladesh grow-out shrimp farms are located and 77% of the Bangladesh shrimp production occurs (Alauddin and Tisdell, 1998; PDO-ICZMP, 2003b). The south-western coastal area can be considered only as a value-adding area, importing 2.1 billion PL (at a value of US$9.5 million) and exporting 23,000 t shrimp (valued at US$187 million) (Alauddin and Tisdell, 1998; PDO-ICZMP, 2003b).

In Vietnam, only 48 hatcheries were present in the Mekong Delta in 1999, producing 5.4% of the country’s total shrimp PL production. In 2005, 38.8% of the *P. monodon* PL production came from the 1261 hatcheries in the Mekong Delta. A survey implemented in

Table 4.5. Shrimp value chain stakeholders investigated in this study and main outcomes in the Mekong Delta, Vietnam (VN) and the south-western coast of Bangladesh (BD).

Stage of value chain	Study sites	Indicators	Outcomes
Nursery operators	VN/BD	PL price, PL origin	Difference of PL price between VN and BD
Postlarvae traders	VN/BD	PL price, PL origin	Difference of PL price between VN and BD
Input retailers	VN	Diversity of products sold	Importance of input retailers as source of knowledge and wide spread of technique. Role of retailers in informal loans for access to manufactured feeding pellets
Shrimp producers	VN/BD	Yield, operational cost, stocking density, etc.	Process of intensification or diversification of aquaculture production systems
Shrimp buyers	VN/BD	Kind of contract, origin and destination of products	Absence or presence of verbal contract with producers
Shrimp traders	VN/BD	Kind of contract, origin and destination of products	Absence or presence of verbal contract with buyers

Bac Lieu Province in 1997/98 (Brennan *et al.*, 2000) highlighted the shortage of PL during the peak stocking period, and a price of US$10–15/1000 PL compared to US$1.30–2.60/1000 PL in 2006. The distinctly increased availability of PL on the market during the peak season and the subsequent lowering of the PL price enabled the evolution of the shrimp production system, with far less reliance on wild-caught larvae of shrimp and fish.

The PL price and quality in Bangladesh were highlighted during the survey as constraints for farmers who needed to engage in contractual loans (at 30–50% interest rate) with nursery operators and PL traders. Together with other factors such as access to land, loans and knowledge, the higher cost of PL in Bangladesh reduces the investment capacity of farmers to modify their production system.

In the Mekong Delta, the widespread diffusion of technologies was supported by the development of a dense network of input retailers. In comparison to Bangladesh where access to chemicals, probiotics or even manufactured feed pellets is difficult, in Vietnam several input retailers are located in each village, thus allowing widespread accessibility of diverse products. Although farmers can benefit from competition between input retailers, a recent development is the provision of informal loans to farmers, notably in semi-intensive and intensive shrimp production areas. These loans are mainly for manufactured feed pellets. Even when severe losses occur as a result of disease outbreaks, loans are contracted by input retailers only after 60–80 days of grow-out, in order to limit the risk for the input retailer. Input retailers also play a crucial role in access to knowledge, as they organize training courses for farmers.

In both study sites, the number of shrimp buyers and shrimp traders was important, with several layers and intermediaries between the farm and the processing factories. Rules and agreements between the different stakeholders in the value chain are diverse, where sometimes contracts are established between buyers and producers, or between buyers and traders in the two study sites. A common aspect was found in the form of verbal contracts between buyers and traders, or sometimes between producers and buyers or traders, for exclusive sale of the harvest. In the latter case, the moneylender defines the selling price. These contracts are the collateral of a loan for start-up investment in the case of shrimp buyers, or to cover the operational costs in the case of shrimp producers.

It appears that links and institutional arrangements between the different components of the value chain connected to the shrimp producer are diverse, complex and cannot be generalized. In addition, oral contracts and informal loans are extremely variable and depend on several factors, such as the personal relationship between the two contractors or the economic results of the farm in previous years. Larger sample sizes in both countries would be needed for a more detailed analysis of the value chain.

Water management and land ownership

Access to water is also one of the main factors that differ between these two case study sites. In Vietnam, the development of an elaborate canal network in the Mekong Delta since the 19th century has enabled private access to water for each pond. In Bangladesh, the absence of such canal network severely constrains farmers who do not have direct access to rivers for filling their pond with water and must do so by taking in water via neighbouring intermittent pond(s), thereby increasing considerably the potential of viruses spreading and restricting water exchange (Masudur Rahman, 1999).

The variations in access to water between the Ganges Delta and the Mekong Delta reflect the consequences not only of two different water management development plans but also of differences in land tenure. In Vietnam, ownership of the land allows farmers to modify their pond according to the needs of the production systems (inlet and outlet canals, higher dykes and refuges for shrimp and fish in the rice field). In contrast, in Bangladesh, large numbers of farmers are leasing land on a contractual basis of 3 years, as found in a socioeconomic survey in Paikgacha Subdistrict with 63% of the 60 shrimp farms (Joffre *et al.*, 2007). Therefore, modification of the pond is almost impossible, as the landowners would not permit this to be undertaken. This situation does not enable improvement of the water management infrastructure, and consequently the evolution of the production systems.

Sources of knowledge

Vietnamese aquaculture in the coastal area appears to be more diversified and dynamic than in the south-western coast of Bangladesh, with the frequent emergence and rapid spread of technical innovations and development of new production systems such as high-value fish culture or extensive mud crab farming. In addition, most Vietnamese farmers have some knowledge of water quality management and monitoring. For example, in the acid sulfate soil area, pH monitoring using pH paper or even a pH meter is common.

In Paikgacha Subdistrict, only farmers located near the town are able to join training courses from extension services and engage in the integrated rice–aquaculture system or in semi-intensive shrimp culture. The average number of different sources of new technical knowledge was only 0.8 in Paikgacha Subdistrict but was 2.1 in Bac Lieu Province. In Vietnam, aside from the government extension services, television and radio broadcasts regularly present aquaculture technologies, and even the private sector is engaged in training courses for farmers, leading to diversified accessibility to knowledge for the farmers.

Information networks are more developed and diversified in the Mekong Delta compared to the Ganges Delta, where information flows from farmers and government agencies only. This situation can explain the difference in terms of evolution and the numbers of different farming systems between the two study areas and the rapid spread of new technology and new production systems in the Mekong Delta.

Conclusions

The development of shrimp culture has modified drastically the development and economy of the coastal areas. However, the Mekong and Ganges deltas present major differences. In Vietnam, development of the shrimp industry, with hatcheries, processing plants and feed factories, has occurred within the production areas. In contrast, in Bangladesh, the major production area is geographically separated from other components of the shrimp industry. This difference, with other factors such as land tenure, credit availability and/or water management infrastructure, leads to two distinct dynamics. Compared to the south-western coast of Bangladesh, the Mekong Delta in Vietnam has a more diversified shrimp value chain, with lower costs of postlarvae and more diversified sources of knowledge for farmers. In this delta, the wide spread of shrimp viral diseases has led to diversification of the brackishwater aquaculture systems, with the development of market-oriented brackishwater polyculture or alternate culture of rice and shrimp, to secure and diversify farm incomes. This most recent evolutionary step within the coastal area highlights their potential use, characterized by the seasonal variation of the environment and the possibility to alternate freshwater and brackishwater production.

In Bangladesh, land tenure, water management infrastructure, lack of knowledge and the high price of postlarvae are the major constraints for such evolution. In Vietnam, the development of the shrimp industry with more access to advanced technology has enabled, but also driven, a process of intensification. This evolution towards intensification may lead to important environmental change and may jeopardize the sustainability of the economic growth of these areas. It seems important for policy makers and development agencies to regulate and steer such farming system evolution through the development of alternative production systems with more benign environmental and social characteristics for adoption by farmers. For example, in areas where the freshwater period exceeds 6 months, rice–shrimp farming achieves more sustainable results than shrimp monoculture, with a lower percentage of disease outbreak. In this system, a rice crop is considered as a ‘sanitary’ crop between two shrimp crops. In Bangladesh, the results of the experiments of Project No 10 of the CGIAR Challenge Program on Water and Food (CPWF) in the south-western coastal area achieved promising results with rice–freshwater prawn and Nile tilapia (GIFT strain), followed by a shrimp crop. When freshwater prawn PL were stocked at the end of the dry season, the net returns of the rice-integrated aquaculture system were 330–422% higher than the locally practised rice monoculture (Alam *et al.*, 2007b).

In areas where rice culture is impeded by saltwater intrusion, diversified brackishwater aquaculture can improve the farm economy without important environmental cost. Moreover, these systems do not require a significant investment and have potential for wider adoption. However, the development of such production systems will be effective only with the involvement of national and local agencies. In Bangladesh, water management infrastructures at the pond polder level have to be improved for better water management (for both rice and shrimp culture) and to reduce the exchange of water between ponds.

In Vietnam, intensive and semi-intensive practices have to be standardized to reduce the environmental burden of intensive shrimp farming, for example, with the development of good management practice (GMP). Coordination among state agencies should be reinforced to elaborate well-accepted land use planning, thus reducing conflict between rice–shrimp and semi-intensive and intensive shrimp farmers for water resources. In addition, as in Bac Lieu Province, intensive shrimp farming should be restricted by local government to areas with suitable environmental characteristics (water flows, water salinity, soil structure, etc.) for shrimp farming, to reduce the risk of crop failure and environmental degradation of the surrounding environment.

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