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Changes of shrimp farming in southwest coastal Bangladesh

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Abstract Shrimp (*Penaeus monodon*) farming is a traditional aquaculture in southwest coastal Bangladesh. Changes in both the farming practice and yield of shrimp since the advent of commercial production in this area are evident in scientific studies. We assessed the historical perspective of shrimp farming indicating the major phase changes and present situation of the shrimp farming practice including recent changes in yield and cost-benefit. A systematic random sampling method was employed to conduct a total of 240 questionnaire surveys, 24 focused group discussions, and 60 key informant interviews in six sub-districts (upazila) from southwest coastal Bangladesh. We identified four major phase changes in the history of shrimp farming in southwest coastal Bangladesh and found that shrimp mixed culture is the most preferable form of extensive cultivation at present. Shrimp farmers' perceptions about changes in shrimp yield and changes in availability of ecosystem services represent declining trends over the last two decades. For 2015, shrimp yield was not significantly different with respect to salinity levels. The net benefit from shrimp mixed culture in

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2015 was 121,000 taka/ha, which is 2.35 times higher compared to the net benefit from only shrimp (51,500 taka/ha). In this context, promoting shrimp mixed cultivation could be a management solution for sustainable development of shrimp farming in southwest coastal Bangladesh. The National Shrimp Policy of the government also emphasized on promoting environment-friendly shrimp mixed cultivation for sustainable development of shrimp farming. However, more institutional support such as training, extension support, technical assistance, and credit facility is required to implement the policy.

Keywords Brackishwater shrimp · Shrimp farming · Yield · Mixed cultivation · Coastal Bangladesh

Introduction

The coastal areas of Bangladesh favor brackishwater shrimp (*Penaeus monodon*, locally known as *Bagda*) farming due to its geographic features (Islam 2008; Ahmed 2013). Bangladesh had 216,468 ha of brackishwater shrimp farms producing 75,274 MT of shrimp in the statistical year 2014–2015 with a mean annual yield of 348 kg/ha. Shrimp is one of the major export items of Bangladesh, and this industry employs about 0.833 million people (Debnath et al. 2015). In the year 2014–2015, 32,500 MT of shrimp was exported, which was equivalent to 28.39 billion taka[1] (61% of total earning from fisheries export) (FRSS 2016). Therefore, shrimp farming has a great contribution in the socio-economic development of Bangladesh.

Shrimp farming within the levees and river channels along the coast was a traditional practice in southwest Bangladesh (Deb 1998; Islam et al. 2005; Nandy et al. 2007; Datta et al. 2010). It started to grow slowly in a commercial mode of aquaculture in the middle of the 1970s (Tutu 2006) due to higher demand in the international market, higher economic return from small investments, and favorable government policies (Alauddin and Tisdel 1998). Thus, the southwest coastal region of Bangladesh turned into the "shrimp zone" of the country as the major share of brackishwater shrimp produced in Bangladesh comes from this region (Datta et al. 2010). In the statistical year 2014–2015, Khulna, Bagerhat, and Satkhira districts of the southwest coastal area of Bangladesh had 166,800 ha land under brackishwater shrimp cultivation and produced about 79% of the total shrimp produced in Bangladesh (FRSS 2016).

Although shrimp framing was very profitable initially, farmers are experiencing decreased profitability and increased environmental consequences over the last 12–15 years (Kabir et al. 2016a). Shrimp farming is associated with greater environmental consequences, such as sedimentation, salinization, pollution, disease outbreak, mangrove destruction, and loss of biodiversity (Landon 1991; Beverage and Phillips 1993; Douglas 1994; Deb 1998; Shang et al. 1998; Flaherty et al. 1999; Ali 2006; Sohel and Ullah 2012; Hossain et al. 2013; Kabir et al. 2016a). Prolonged saline water logging in shrimp ponds accelerates leaching of base minerals and increases salinity and acidity of soil (Landon 1991; Douglas 1994; Flaherty et al. 1999; Ali 2006), which may affect the productivity of adjacent rice fields. Therefore, shrimp farming has been a reason for major land use conflict in this area (Hossain et al. 2013). Outbreak of disease in shrimp farms was also a major concern for shrimp farmers (Alam et al. 2007). In 1996, about 90% of the extensive shrimp farms incurred a 20% loss of yield due to disease outbreak (Chowdhury and Muniruzzaman 2003; Datta et al. 2010). In recent years, with the progress of

[1] taka = Bangladeshi currency; 1 USD = 78 taka

environmental impacts, a declining trend in ecosystem services (Hossain et al. 2016) and shrimp yield (Kabir et al. 2016a; FRSS 2016) is observed in the coastal area of Bangladesh. An alternate rice–shrimp system, which is considered as an ecologically sustainable approach (Brennan et al. 2002), has gained popularity in this region over the last decade as a response to changing environmental condition (Datta et al. 2010; Ahmed 2013). However, the integration of rice in traditional brackishwater shrimp farming here is not well developed (Alam et al. 2010). The National Shrimp Policy 2014 of the Government of Bangladesh emphasized on management activities on environment-friendly mixed shrimp cultivation and crop diversification (MoFL 2014).

In this context, there is a research need to understand the way shrimp farming is changing over time in the southwest coastal Bangladesh. This issue is not adequately addressed in existing literature. Recent studies have assessed the impacts of brackishwater shrimp farming (Ali 2006; Azad et al. 2009; Paul and Vogl 2011; Sohel and Ullah 2012; Afroz and Alam 2013; Hossain et al. 2013; Paul and Røskaft 2013); sustainability of integrated shrimp fish/rice farming (Ahmed and Garnett 2010); shrimp farming as a successful adaptation to salinity intrusion (Johnson et al. 2016); evaluation of existing regulatory and institutional framework regarding shrimp farming (Afroz and Alam 2013); linkage between prawn/shrimp farming and green economy (Ahmed 2013); profitability, risks, and sustainability of a rice/shrimp cropping system (Kabir et al. 2016a); and impacts of climate change on shrimp farming (Ahmed and Diana 2015). None of the studies particularly focused on the way shrimp farming practice is evolving in southwest coastal Bangladesh over the years.

This study aims to understand changes of shrimp farming in southwest coastal Bangladesh since the advent of commercial mode of this aquaculture in this region. To achieve this aim, we assessed the historical perspective of shrimp farming indicating the major phase changes and present situation of the shrimp farming practice including recent changes in yield and cost-benefit. Therefore, this study is expected to give better insights to promote sustainable shrimp farming in southwest coastal Bangladesh.

Materials and methods

Study area

The study was conducted in the southwest coastal area of Bangladesh, which includes Satkhira, Khulna, and Bagerhat districts (Fig. 1). This area is bounded between 21° 37′ 22.8″ to 23° 0′ 22.76″ N and 88° 53′ 54″ to 89° 58′ 20.44″ E. It covers 12,048 km^2 and holds a population of about six million (BBS 2014). This low-lying coastal plain is heavily intersected by tidal rivers, has elevation lower than 10 m (Kabir et al. 2016b), and is gently slopped toward the Bay of Bengal on the south. The southern fringe is fully covered by *Sundarbans*, the largest single tract of mangrove forest in the world. This land is also heavily intervened by the construction of polders (Dewan et al. 2015). Water salinity ranges between 0 and 30 ppt (CEGIS 2006).

Data collection method

The study selected two sub-districts from each of the three districts, considering the spatial distribution of salinity. We discussed with experienced fisheries officers from the three districts to identify the sub-districts which better represent brackishwater shrimp farming in the area.

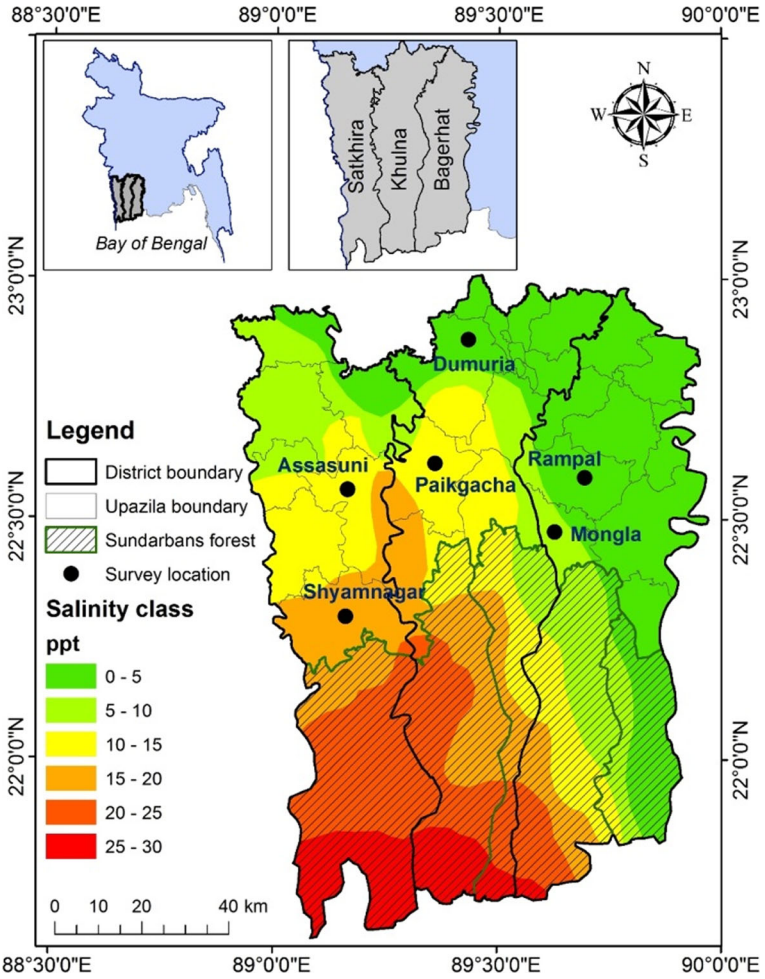

Fig. 1 Map of the study area (salinity profile is extracted from CEGIS 2006)

We also classified the study area into six salinity classes by dividing its salinity range (0–20 ppt) in equal intervals of 5 ppt. The area under 20–30 ppt salinity was excluded since it mostly covers the Sundarbans Reserve Forest. Then, we arbitrarily chose six sub-districts among the previously identified sub-districts to select at least one sub-district from each salinity class. In the case of a sub-district boundary extending over different salinity zones, the salinity class under majority of its area was considered as the representing salinity zone.

Extensive shrimp farming requires tidal water exchange with the adjacent river or canal, which largely depends upon the location of the shrimp pond with respect to the waterway. During the baseline survey, it was realized that the local famers consider tidal water exchange capacity as the main source of ecosystem services (ES) for the extensive shrimp farming. Therefore, to understand the impact of availability of ES on shrimp yield, the respondents from each of the sub-districts were divided into two groups: (i) good ES—farms with better opportunity to exchange water and (ii) poor ES—farms without good opportunity to exchange water. We identified the locations with good and poor water exchange capacity with the help of

upazila fisheries officers and community leaders of the respective sub-districts, and made a list of farmers (i) having shrimp farming as the primary occupation for at least the last 20 years and (ii) with ages within 40–50 years. Among the listed shrimp farmers, we randomly selected 20 of them under each of the good ES and poor ES groups for questionnaire survey. Thus, a purposive sampling method was followed to choose 40 respondents from each sub-district. The questionnaire was pre-tested and revised before the final survey. Focus group discussions (FGD) were conducted in four randomly selected villages from each of the sub-districts. A group of 10 farmers who have more than 20 years of involvement were randomly chosen from a selected village as per the suggestion of the village head. The purpose of FGD was to understand the historical development of shrimp farming in this region. A key informant interview (KII) was conducted to validate the information obtained from the questionnaire survey and to obtain better clarification of the relevant aspects. Senior upazila fisheries officers, experienced shrimp farmers, and school teachers were considered for the KIIs. Thus, a total of 240 questionnaire surveys, 24 FGDs, and 60 KIIs were done.

Shrimp farmers' perceptions on past yields (for 1995–2015, at a 5-year interval) were recorded in the questionnaire survey to understand the relative differences in shrimp yield over time. Since they reported from their memory, the perceptions of yield for a harvesting period (locally known as *gon* which is related to the lunar phase) were recorded and then multiplied by the number of harvesting periods per year to calculate annual yield per hectare. Cases with extreme values were eliminated in calculating mean annual yield. Alongside perceptions about changes of ecosystem service, total cost and benefit over the last 20 years were estimated. Tidal water exchange capacity of a farm was classified as very low, low, moderate, and high, compared to the farmer's desired capacity of water exchange for a good yield. Total costs of shrimp production were calculated by summing up the expenditure on the inputs (e.g., shrimp fry, pond preparation, feed, land rent) used during a farming period. Benefit was calculated by subtracting the total cost from the gross value (unit price times quantity produced).

Before conducting the final data collection, a daylong workshop was organized including senior shrimp farmers, upazila fisheries officers, district fisheries officers, and university teachers to incorporate expert opinions on the research design. The questionnaire surveys, FGDs, and KIIs were conducted by trained enumerators. All the data were collected for a period of 6 months from July to December 2015.

Data analysis

Both qualitative and quantitative statistical techniques were considered for data analysis and interpretation of results. The history of shrimp farming in the southwest coastal area of Bangladesh was developed based on the statements of the farmers from the FGD sessions. The statements were organized in chronological order to identify the phase changes of shrimp production in this region and also compared with the available literature to keep the validity of the information. Since the data on shrimp yield failed to meet the assumption of normal distribution, non-parametric tests were used. The Wilcoxon signed-rank *t* test was used to compare shrimp yield between good and poor ES. To compare shrimp yield of areas with different salinity ranges, the Kruskal-Wallis test was used. Results regarding the perception of ecosystem services, cost, and benefit were analyzed by descriptive statistics. Statistical analyses were conducted using Statistical Package for Social Science (SPSS) version 16.0.

Results

The history of shrimp farming in southwest Bangladesh

The beginning of shrimp farming in southwest Bangladesh is not clearly known, but it could be estimated apparently following the history of fish aquaculture in this region. Livelihood associated with polyculture of finfish along with various freshwater and brackishwater shrimp was existent here for centuries (Das 1931; Hora 1948; Rahman et al. 2006; Bagchi and Jha 2011; Pokrant 2014). Kesteven and Ling (1951) mentioned in a report of FAO that farmers in the Khulna area practice "brackishwater trapping pond operations" (ponds alone or as part of rice cultivation) in which the main catch are mullet, *bhetki* (Barramundi), *chanda* (pomfret), and shrimp. This type of cultivation was locally known as *bheri* culture since the earthen enclose made to entrap water is called *bheri* in Bengali, and the ponds prepared in this way were known as *gher*. Thus, shrimp was cultivated from January to July when salinity remains favorable for shrimp, and transplanted rice (Aman) was cultivated from August to December when salinity declines due to monsoon rainfall. Most of these fish and shrimp were consumed by locals, except for small amounts directed to regional trade.

The southwest coast of Bangladesh became the center for wild shrimp processing since the 1960s when fish canning plants were established in Khulna District (Rahman et al. 2006; Pokrant 2014). However, the commercial mode of this aquaculture started growing slowly in the middle of the 1970s, when catches from non-commercial or open water fisheries proved insufficient to meet the requirements of those processing plants to export frozen shrimp to the international market (Tutu 2006). Shrimp farming during this time was mostly extensive cultivation based. Shrimp farmers used to make earthen encloses (*bheri*) to entrap wild fry or fingerlings from tidal water exchange and added little or no additional inputs. These kinds of farm usually took 20–200 ha area and were generally located near the river or canal to get easy access to tidal water.

In the late 1970s and beginning of the 1980s, shrimp farming expanded rapidly in the southwest coastal area of Bangladesh along with the advent of shrimp export. The government also supported many initiatives to improve cultured shrimp production through its "five years plan (1980–1985)." The number of shrimp farmers grew rapidly due to higher economic return from shrimp farming and favorable government policy. Influential entrepreneurs in this sector started using their economic and political power to emphatically convert the land of local rice farmers and public lands to shrimp farms. Relatively small actors of this business community used to take lease of land from local rice farmers to make shrimp farms. In this period, small farm sizes of 10–20 ha area became usual. Gradually, many of the local rice farmers were interested on converting their land into a shrimp farm, partly because of higher profitability and partly because of external effects of saline water intrusion in adjacent lands. Numerous events of conflicts regarding land conversion are well known in this region (Rahman et al. 2006; Pokrant 2014). There were also cooperative shrimp farms made by a group of local rice farmers contributing their land in a shrimp farm.

As more actors were getting involved in shrimp farming, farm size started to further be reduced with increased farm density. Around the middle of the 1980s, the farm size was approximately 2–3 ha area with almost no opportunity to exchange tidal water, which is often mentioned as "pocket gher." Gradually, shrimp farmers became dependent on collected fry and supplied feed. Therefore, the extensive shrimp farming was replaced by an improved extensive farming method, where the farmers apply some control against entry of other species and

regular feeding and fertilization. Meanwhile, shrimp yield also increased. Demand for shrimp fry and feed also grew faster with the increased number of shrimp farms. Shrimp farmers used to buy both wild-caught and hatchery-reared shrimp fry from fry traders, who in turn relied on wild shrimp fry collectors operating along the coast, estuaries, and rivers, and shrimp hatcheries mainly located in Cox's Bazar. Increased demand for wild shrimp fry created a wage-earning employment opportunity, especially for women from poor peasant households (Ito 2002; Jalais 2010; Pokrant 2014). Although women involved in fry collection had to face strenuous problems including poor wage, unsafe working condition, and socially demeaning situation, this income opportunity transformed their social role in the rural community as their participation in productive economic activities increased (Jalais 2010; Pokrant 2014). However, in the late 1980s, the price of shrimp fry became higher and more hatcheries developed.

In the early 1990s, shrimp farming kept its pace of expanding and increasing yield. The number of small ponds (less than 1 ha) also increased, and there was a growing tendency among shrimp farmers to invest more in this sector. Sometimes, they used to overstock and apply more feed and fertilizer aiming for a better yield. Unavailability of tidal water exchange capacity became prominent because of increased farm density and absence of cooperation among the farmers in sharing water. Around the middle of the 1990s, increased frequency of disease, lack of ecosystem services (mainly tidal water exchange), and unavailability of healthy shrimp fry became the major threats to the shrimp farmers. Yield of shrimp started to decline by the end of the 1990s. Meanwhile, most of the land with potential for shrimp cultivation has been converted to shrimp ponds. Some of the farmers started shrimp mixed cultivation (shrimp along with giant freshwater prawn (*Macrobrachium rosenbergii*, locally known as *golda*) and different types of finfishes) to reduce the uncertainty of emerging threats of disease outbreaks. The Shrimp Culture Tax Act, 1992, was enacted by the Government of Bangladesh in 1992 for revenue collection.

One of the major crises in the shrimp farming history of southwest Bangladesh is the ban on exports to the European Union in 1997, imposed due to the lack of health and safety initiatives of the processing plants (Alam and Pokrant 2009). Although it was withdrawn after 6 months by maintaining the inspection standards and other provisions, it provoked improved regulations and monitoring of the processing plants and depots. In the National Fisheries Policy 1998, the government of Bangladesh encouraged the private sector commercial production of shrimp post larvae (PL). In 2000, the government of Bangladesh imposed a ban on wild PL collection, to prevent the adverse effect of high-level by-catch from indiscriminate wild PL collection. However, it was not successfully implemented due to the lack of alternative livelihood for this poor community (Ahamed et al. 2012). Moreover, farmers had to mostly depend on wild-caught PL since there was inadequate supply of hatchery-reared PL. The Hatchery Act 2010 was enacted by the Government of Bangladesh for the establishment and proper management of fish and shrimp hatcheries to produce good-quality seeds (Paul and Vogl 2011). The government also formulated a National Shrimp Policy 2014, which emphasized on promoting alternative livelihood for PL collectors to stop wild PL collection. This policy mentioned about introducing and enforcing a Shrimp Seed Certification system to ensure the supply of specific pathogen-free (SPF) PL.

After 2000, the frequency of diseases of shrimp further increased resulting in a decline in yield. In this situation, shrimp mixed cultivation started gaining popularity as it was a good adaptation to the uncertainty of lower yield from sudden disease outbreaks in shrimp farms (Ahmed 2013). Farmers used to cultivate shrimp along with different types of carps, tilapia (*Oreochromis mossambicus*), *horina* (brown shrimp, *Metapenaeus monoceros*), *golda* (giant freshwater prawn, *M. rosenbergii*), and *chaka* (Indian white shrimp, *Fenneropenaeus indicus*), followed by

transplanted rice (*Aman*) cultivation in the monsoon. Some farmers also added vegetables along the earthen dyke during winter. Adding crab in shrimp mixed cultivation is also gaining popularity. After 2009, there was a sudden fall in yields, which could be anecdotally attributed to the shock of the cyclone Aila. It affected the entire southwest Bangladesh, and the shrimp farms were hugely damaged. Shrimp yields did not improve much in the years following Aila. Together with this, an increasing trend of disease (Paul and Vogl 2011; Hossain et al. 2013) and extreme weather events (Shameem et al. 2015) were observed. Adverse impacts of climatic stressors on shrimp farming in southwest coastal Bangladesh were also reported in recent studies (Ahmed 2013; Ahmed and Diana 2015; Shameem et al. 2015). Besides, unavailability of healthy PL exists in the market. Given these conditions, the shrimp industry of southwest Bangladesh is under full uncertainty. Four major phases since the advent of commercial shrimp farming were identified from the history, and their characteristics are presented in Table 1.

Changes in shrimp yield over time

Farmers' perception on shrimp yield over the last two decades (1995–2015) obtained from questionnaire surveys and district-level shrimp yield data of the Department of Fisheries (DoF) for 2002–2015 (data before 2002 is not available) (FRSS 2016) are depicted in Fig. 2. Both datasets represent gradual decline in shrimp yield.

Changes in cost and benefit of shrimp farming

The mean annual cost of producing shrimp increased gradually in the last two decades (Fig. 3). The net benefit was relatively stable in between the years 1995 and 2005. However, benefit

Table 1 Phases of shrimp farming in southwest coastal Bangladesh

Phase	Characteristics
1976–1983	- Emergence of commercially producing extensive shrimp farming - Good market price and profit - Favorable government policy initiative - Large shrimp farms developed by external entrepreneurs and local elites - Conflicts regarding land conversion
1984–1995	- Increase in number and spatial distribution of small-scale farms - Emergence of improved extensive shrimp farming - Use of hatchery-reared PL along with wild-caught PL - Decline in tidal water exchange capacity and conflicts on water sharing
1996–2009	- Emergence of disease of shrimp - Ban on exports to the European Union - Increase in cost of production due to higher price of shrimp fry and land rent - Government-imposed ban on PL collection - Decline in shrimp yield - Emergence of mixed culture - Serious physical damages of shrimp farms by cyclone Aila
2010–present	- Increased frequency of disease of shrimp - Reduction of ecosystem services, especially tidal water exchange capacity - Further decline in yield of shrimp - Lower market price and higher production cost - Expansion of mixed culture - Increased frequency of extreme weather events in recent years - National Shrimp Policy 2014

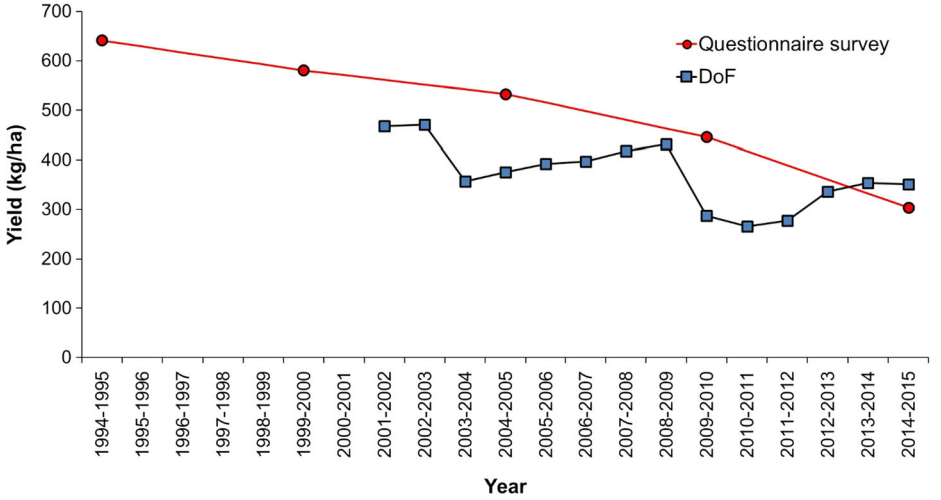

Fig. 2 Temporal changes of shrimp yield in southwest coastal Bangladesh

suddenly decreased after 2005, and continued to decline until 2015. At the end of this decade, the benefit became almost one fifth of that of the previous decade. In 2005, only 2% of the farmers reported net loss in producing shrimp, which increased by 10 and 39% in 2010 and 2015, respectively.

The changes of the major heads of expenditure over the last two decades (Fig. 4) give more insights into the increase in costs. In 1995, the major head of expenditure was shrimp fry alone. Although it gradually increased over the time, its percent share in total expenditure decreased. Expenditure for pond preparation also increased gradually. Shrimp farmers expended only 130 taka/ha for feed in 1995, which increased very rapidly over the last two decades and reached 3300 taka/ha by 2015. The most dramatic change occurred in land rent, especially

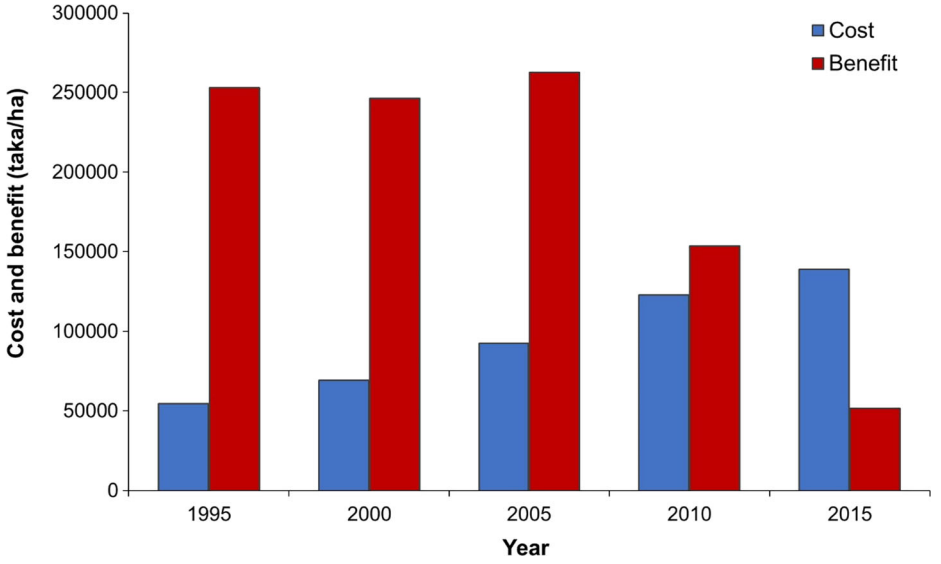

Fig. 3 Changes of cost and benefit of shrimp aquaculture

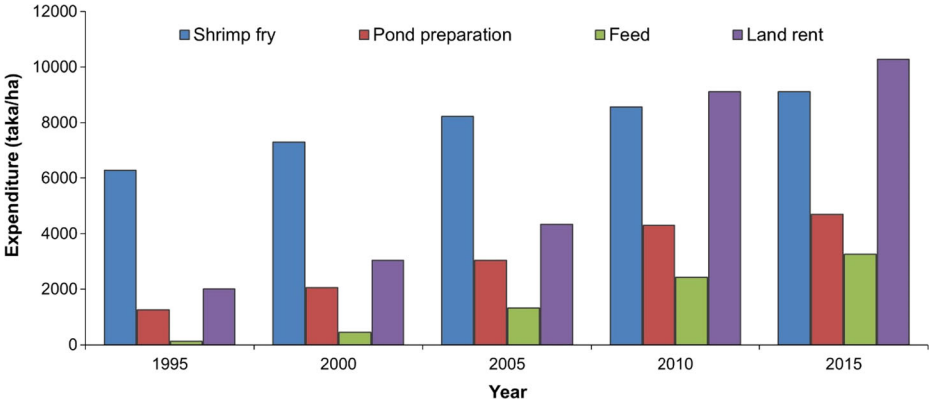

Fig. 4 Changes in heads of expenditure of shrimp farming

after 2005. Within 2005 to 2010, annual expenditure for land rent hiked more than double. It further increased slightly in 2015 and became the major head of expenditure (10,300 taka/ha, equivalent to 38% of total expenditure).

Impact of tidal water exchange on shrimp yield

More than 60% of the farms experienced better water exchange capacity before the year 2000, which declined to about half of that in 2015 (Fig. 5). Meanwhile, the percentage of farms with very low water exchange capacity increased. However, in 2015, shrimp farms with either good or poor water exchange capacity resulted in similar yields in all the sub-districts (no statistical significant yield differences, $p = 0.16$). We also did not find significant differences in yield based on salinity ($p = 0.35$) (Fig. 6).

Shrimp mixed cultivation

Shrimp mixed cultivation has become the most popular extensive shrimp farming practice here in recent years. In this method, shrimp is cultivated along with other finfishes and crops. We found

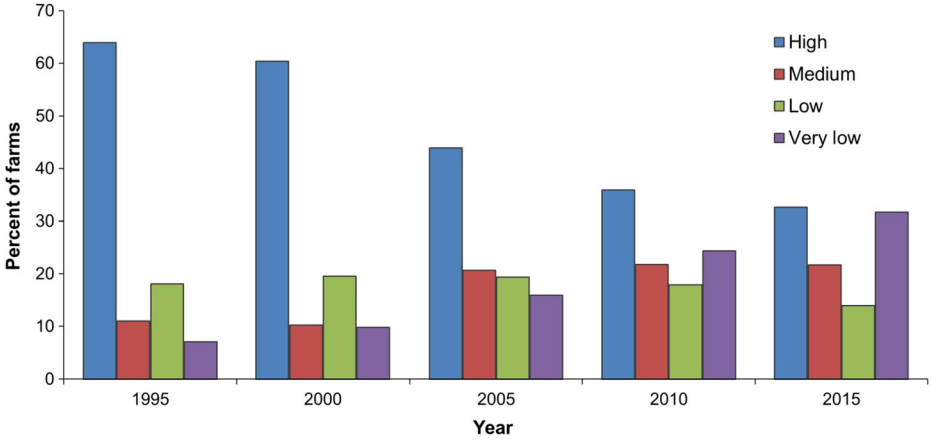

Fig. 5 Changes in tidal water exchange capacity of the shrimp farms

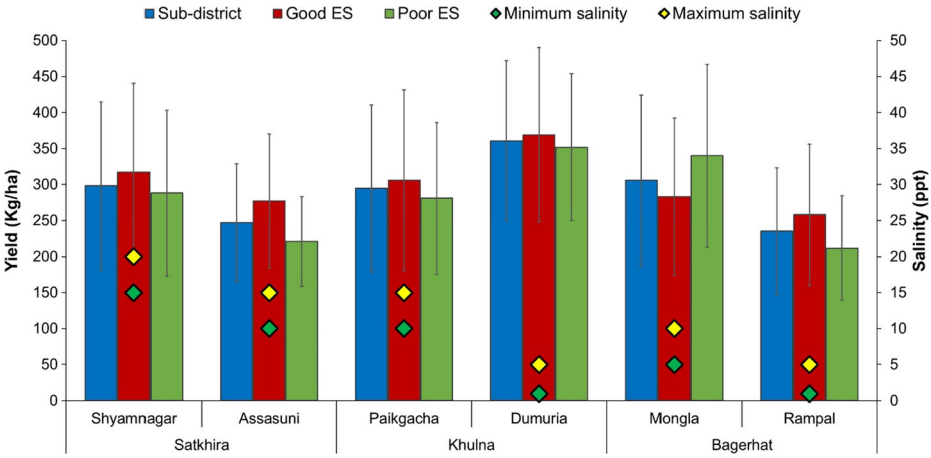

Fig. 6 Shrimp yield in good and poor ES groups compared to the sub-districts and salinity classes. The *bars* represent shrimp yield, and the *dots* represent salinity. The *middle lines* in the *bars* represent standard deviations

that the majority (60%) of the farmers cultivate brackishwater shrimp (*bagda*) along with finfishes (carps, tilapia, barramundi (*bhetki*), etc.) (Table 2). About 13% of the farmers cultivate rice (transplanted rice) along with shrimp and finfishes. About 12% of the farmers cultivate shrimp alone. There is also a growing combination that includes crab along with shrimp and other variety of prawn. Few of the farmers also use to cultivate vegetables along the dikes for a short period. We calculated 121,000 taka/ha mean annual benefit from various combinations of shrimp mixed cultivation, which was 2.35 times higher than the benefit of only shrimp (51,500 taka/ha).

Shrimp is cultivated almost all the year round (Fig. 7). Shrimp fry is released in January–February and harvested starting from March to April (2 months after the first release of shrimp fry). Usually, shrimp farmers harvest two times in a month depending on the lunar phase (locally known as *gon*). Shrimp fry is released every month until September–October and harvested until October–November. Finfishes are released within June–July to September–October and harvested in November–December. Transplanted rice is sown in July–August and harvested in December. Vegetables are cultivated in July–September.

Discussion

The history of shrimp farming in southwest coastal Bangladesh indicates that it started to emerge as an industry in the 1980s, although shrimp processing started even before the 1960s.

Table 2 Shrimp and shrimp mixed culture in the study area (n = 240)

Farming type	Frequency	Percent
Shrimp and finfish	143	60
Shrimp, finfish, and rice	31	13
Shrimp	29	12
Shrimp, prawn, and crab	23	9
Shrimp, crab, rice, and vegetable	6	2
Shrimp and rice	4	2
Shrimp, prawn, crab, and rice	4	2

Crops	January	February	March	April	May	June	July	August	September	October	November	December
Shrimp	↓	↓	↓↑	↓↑	↓↑	↓↑	↓↑	↓↑	↓↑	↑	↑	
Finfishes						↓	↓	↓	↓	↓	↑	↑
Rice							↓	↓				↑
Vegetable							↓	↑	↑			

Cultivation period Fry releasing / planting ↓ Harvesting ↑

Fig. 7 Crop calendar for shrimp mixed culture

Rapid expansion of shrimp farms at the beginning of shrimp commercial production accelerated environmental consequences and lowered the yield. According to Kautsky et al. (2000), high pond densities facilitate the spread of pathogens between ponds. Shortage of clean water supply and insufficient waste removal lead to overloading of metabolites, environmental degradation, and shrimp becoming stressed by bad water quality, which ultimately makes shrimps more prone to disease.

The perception of shrimp farmers regarding shrimp yield shows almost a similar trend compared to the district level data of DoF (Fig. 2). The deviation in mean annual yield obtained from our questionnaire survey is not surprising since our sample selection criteria were different than those of the DoF. According to Islam et al. (2005), shrimp yield may vary depending on farm size and management practice. The authors also suggest that small farms (1–5 ha) are expected to have better yield due to higher survival rate. Moreover, it is also not surprising to have highly variable shrimp yield among the farms in the same area as the conventional shrimp production is subject to myriad uncertainties (Alam et al. 2007). Two studies conducted in Satkhira (Alam et al. 2007) and Khulna (Islam et al. 2005) districts after major outbreak of diseases in 2001 obtained 146 and 148 kg/ha of mean annual shrimp yield, respectively, which were even less than half of the yield recorded by DoF (Fig. 2). The yield data of DoF also shows a sudden decline in 2009–2010, which can be attributed to the effect of the cyclone Aila in 2009, which heavily damaged the farm structure in this region.

Our results revealed a continuous increase in all the heads of expenditure over the last two decades (Fig. 3) with the decline in ecosystem services availability (Fig. 4). Islam and Bhuiyan (2016) found that the tidal water exchange capacity of farms in this region has declined gradually and deteriorated water quality with the increase in shrimp farming area and farm density. Anecdotally, this implies incurring higher cost due to additional input requirements for shrimp farming. Our results also indicated that shrimp farms with either good or poor water exchange capacity resulted in similar yields. However, the key informants advocated that better water exchange facility may help increase the yield and may lower the production costs. They also approved that better cultivation practice (i.e., pond preparation, nursing of shrimp fry before recruitment, avoiding over stocking, and providing sufficient food supply) is highly important for a better yield.

In the present context, shrimp mixed cultivation is popular in this region (Table 2) and it generates higher profit in an extensive cultivation system. Key informants mentioned that mixed cultivation helps lower the economic uncertainties from a sudden outbreak of disease in shrimp. According to Kautsky et al. (2000), the risk of disease in shrimp farming often increases with

culture intensity, and when polyculture is replaced by monoculture. Conversion of paddy fields into shrimp ponds also reduces the opportunities for other traditional dry season activities, such as grazing cattle and homestead gardening (Alam et al. 2005; Islam and Bhuiyan 2016). These problems could be effectively solved by extensive and balanced polyculture of shrimp including other finfishes in a more balanced ecosystem approach (Frankic and Hershner 2003). Besides, having multiple crops from the same land can also help shrimp farmers meet their subsistence needs such as rice, vegetable, and other fish. Therefore, shrimp mixed cultivation could be a better solution to cope up with the present context of shrimp farming in southwest coastal Bangladesh.

We observed that shrimp mixed cultivation is practiced in various combinations (Table 2) of other crops. Most of the farmers add finfishes with shrimp. It only requires fry and some supplemental food as additional input. In some cases, farmers also cultivate salinity-tolerant transplanted rice in one season, but this is very limited to those areas where salinity is relatively low and farmers can use groundwater irrigation. Low-saline areas also offer opportunities to include prawn in a mixed cultivation system. However, crab cultivation (case cultivation) along with shrimp is gaining popularity in this area since crabs have higher survival rate. Therefore, shrimp mixed cultivation offers an ecosystem-friendly shrimp cultivation system.

Shrimp farming is one of the few options for economic development of the coastal region of Bangladesh (Islam and Bhuiyan 2016). Besides substantial foreign exchange, it offers employment opportunity for various stakeholders related to this industry (Swapan and Gavin 2011). Extensive cultivation of shrimp is more likely to keep ecosystem harmony with dynamic balance by recycling and feedback mechanisms (Kautsky et al. 2000). Although extensive cultivation is less productive, it seems to be less sensitive and usually have a much longer lifespan than intensive cultivation (Gujja and Finger-Stich 1996). Therefore, shrimp farming is also being considered as a potential adaptation option to increased salinity in this region (Johnson et al. 2016). The government of Bangladesh has also identified the promotion of shrimp and other saline-tolerant fish species as a necessary climate change adaptation option in its national climate policy (MoEF 2005; MoEF 2009). However, there is still a lack of well-structured adaptation strategy to promote sustainability of shrimp farming in southwest coastal Bangladesh (Rahman and Islam 2013; Pokrant 2014).

Sustainable development of shrimp farming demands both well-structured policy and institutional support. The National Shrimp Policy 2014 is directed toward achieving poverty alleviation and increasing export earnings by promoting environment-friendly and sustainable production of shrimp. In this regard, the policy indicated the requirements of institutional development, enforcement of technical and administrative management, innovation of sustainable technologies, and extension support. It emphasized on promotion of shrimp mixed cultivation and crop diversification. The National Fisheries Policy 1998 has also emphasized on promotion of shrimp mixed cultivation in the coastal region of Bangladesh. Both of these policies identified the requirement of "Land Zoning" for shrimp cultivation. The National Shrimp Policy 2014 mentioned about taking necessary action for the socio-economic betterment of small-scale shrimp farmers. This issue requires more emphasis since the shrimp sector of Bangladesh includes about 15 million people (MoFL 2014) and majority of the shrimp farmers are small-scale farmers. However, the government is yet to establish well-structured institutional support (such as training, extension support, technical assistance, and credit facility) to implement the National Shrimp Policy to promote sustainable development of shrimp farming in southwest coastal Bangladesh. Research efforts should be invested toward best practices for sustainable cultivation, training needs of the farmers, and adaptation measures for climate change.

This study had limitations in data collection process and design. The statistics of government agency (DoF) only had district-level data of shrimp yield since 2001–2002. Consequently, there was no alternative than constructing the shrimp yield data from the memory of the shrimp farmers to get the impression of yield for a longer time span. Although we tried to distribute the samples in various salinity levels, we did not consider other biophysical differences and differences in cultivation practice in the study area. Moreover, there are differences in the extension services and training facility through the study area, which we did not consider in the study design.

Conclusions

Shrimp farming has a great importance for the economy of Bangladesh. Although it was traditional aquaculture practice in the southwest coastal area of this country, commercial-scale production started here in the 1970s. A rapid expansion of shrimp farming took place at the advent of commercial shrimp farming due to higher economic returns. However, we observed a decline in yield over the last two decades. Shrimp mixed cultivation gained popularity to local farmers as it provides opportunity to produce multiple corps, brings higher profit than monoculture of shrimp, and lowers uncertainty of economic damage due to disease outbreak. It can be a potential adaptation option for the increasing salinity and other environmental stresses (such as extreme weather events, increased frequency of disasters). Shrimp mixed cultivation is also prioritized in government policy. It is essential to improve cultivation practice for the sustainability of this aquaculture, and consequently demands more research efforts and technical assistance. Providing training and extension facility to the small-scale shrimp farmers along with credit support with low interest is vital to strengthen marginal economies by increasing employment opportunities. Therefore, improvement of institutional support is necessary to implement the National Shrimp Policy of the government and achieve sustainable development of shrimp farming in southwest coastal Bangladesh. Shrimp policies need to be adapted to consider more than technical and financial feasibility of shrimp and should be directed toward the interest of small-scale shrimp farmers.

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